



The ecological impacts of recreational trails in a tropical protected area

MALANDI, Wilter Azwal

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THE ECOLOGICAL IMPACTS OF RECREATIONAL TRAILS IN A TROPICAL PROTECTED AREA

Wilter Azwal Malandi

A thesis submitted in partial fulfilment of the requirements of
Sheffield Hallam University
for the degree of Doctor of Philosophy

February 2025

Candidate Declaration

I hereby declare that:

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2. None of the material contained in the thesis has been used in any other submission for an academic award.
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Wilter Azwal Malandi

THE ECOLOGICAL IMPACTS OF RECREATIONAL TRAILS IN A TROPICAL PROTECTED AREA

Abstract

This thesis investigates the ecological impact of natural area tourism on vegetation, soil, and wildlife in the Tropical Borneo Rainforest Protected Area in Maliau Basin Conservation Area (MBCA), Sabah Malaysia. Despite it being classified as a highly protected area in 1997, visitor and recreation activities continue to rise due to ecological attractions. The research explores impacts on trails through comparing data on ecological indicators which include vegetation, soil, wildlife and light intensity measured across five trails of varying visitation intensity through sampling points and trail proximity along transect lines. Results showed differences in number of individual plants, species and of families found in every trail. Biodiversity indexes showed little differences among trails, suggesting a linearity between the amount of use and impact: no obvious difference was found between proximity and distal plots, while significant differences were registered in trails areas. Moreover, the results also showed a similar trend for soil Compaction, SOM, and SMC. For wildlife, less visited trail indicated highest frequency of animal encounter. The key findings of this study indicated that while the level of trampling impact recorded might still be under the threshold of diminishing species diversity, human trampling in natural areas over long periods can have devastating impacts on the condition of the ecology.

Keywords: Recreation Impact, Biodiversity, Species richness, Soil, and wildlife

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LIST OF ABBREVIATIONS

MBCA	Maliau Basin Conservation Area
DVFC	Danum Valley Field Centre
ICCA	Imbak Canyon Conservation Area
ICSB	Inoprise Corporation Sdn Bhd
IUCN	World Conservation Union
UNESCO	The United Nations Educational, Scientific and Cultural Organization
UNDP-GEF	United Nations Development Programme – Global Environment Facility
WWF	Worldwide Fund for Nature
WWFNM	World Wide Fund for Nature Malaysia
UNEP	United Nations Environment Programme
WCMC	World Conservation Monitoring Centre
WCPA	World Commission on Protected Areas
WTO	World Tourism Organization
UNWTO	United Nations World Tourism Organization
DANCED	Danish Cooperation for Environment and Development
DANIDA	Danish International Department Assistance
FAO	The Food and Agriculture Organization of the United Nations
TIES	The International Ecotourism Society
DWNP	Department of Wildlife and National Parks
MOCAT	Ministry of Culture, Arts and Tourism
EPU	Economic Planning Unit. Prime Minister's Department, Malaysia
INIKEA	Innoprise-IKEA Tropical Forest Rehabilitation Project
CBD	Convention on Biological Diversity

HoB	Heart of Borneo
LAC	The Landscape Archaeology Conference
EE	Environmental Education
SOM	Soil Organic Matter
SMC	Soil Moisture Content
DDT	dichloro-diphenyl-trichloroethane - first of the modern synthetic insecticides in the 1940s
U.S.	United State
SAS	Statistical Analysis System
SPSS	Statistical Package for Social Science
ASL	Above Sea Level
NGO	Non-Government Organizations
EIA	Environmental Impact Assessment
NERC	the Natural Environment Research Council (NERC)
ESRC	the Economic and Social Research Council (ESRC)
WCS	The World Conservation Strategy
IDH	Intermediate Disturbance Hypothesis

THESIS STRUCTURE

Chapter 1 (Introduction)	Covers the background and context of the research, identifying the knowledge gap that it introduces the aims, objectives and methodological approach of this study.
Chapter 2 (Literature Review)	Consists of a critical literature review, covering aspects of nature tourism in general, recreation activities in nature tourism, ecosystem characteristic, the threats of recreation in nature tourism and recreation impact, visitor participation and previous studies on recreation ecology
Chapter 3 (Case-Study Area: MBCA)	Presents background and details of the Maliau Basin Conservation Area (MBCA), include geological and physical features, biodiversity, recreation activities, and tourism facilities and ecological impacts as observed, reported, or published.
Chapter 4 (Methodology)	Consists of a comprehensive discussion of the research methodology of the study, including collection of: 1) secondary data; 2) physical data on vegetation, soil compaction, soil organic matter, light intensity, and wildlife density; 3) visitor perception toward recreation ecology.
Chapter 5 (Ecological Impact of Recreation in the MBCA)	Presents Ecological results and analysis of the in relation to its objectives, mapping out the information and interpretation of each research objective and hypothesis.

Chapter 6 (Visitor Perceptions of Natural Area Recreation in the MBCA)	Presents Perception results and analysis of the in relation to its objectives, mapping out the information and interpretation of each research objective and hypothesis.
Chapter 7 (Discussion)	Discusses the findings of the study, presenting further explanations of the results are presented in the context of the data and other findings and of relevant prior research and theory, with reference to the stated aims and objectives of the research.
Chapter 8 (Conclusion)	Consists of the conclusions and recommendations of the research. In this chapter, several conclusions are reached by drawing together results and information from literature. This chapter also identifies gaps in current research and suggests several potential areas for further research.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND AND CONTEXT

The significance of nature in various cultures is undeniable, often being seen as essential to human existence and the foundation of civilization (Kaplan 1992; Kellert, 1997). Throughout history, the resources provided by nature have played a crucial role in supporting human activities, even in our modern, technologically advanced society (Williams 2005). Humans in the past were greatly influenced by the natural world and were at the mercy of its forces (Rotherham 2017; Fitzsimmons 1989; Franklin 2002). As a result of progress in technology and science, there has been a negative impact on the environment, leading to a decrease in human connection and appreciation for the natural world. Despite the growing disconnection from the natural world, there is a significant number of individuals who still prioritise spending their vacations in untouched wilderness. This preference has contributed to the flourishing ecotourism sector (Page and Dowling 2002). Natural area tourism, also referred to as nature-based tourism, encompasses this concept.

The environmental movement was influenced by the Industrial Revolution in nineteenth-century Europe (Blanning 2011). During the Romantic Movement, Wordsworth (1835) encouraged the British to embrace the beauty of the natural landscapes in North England (Rosen 1995). The inaugural global environmental conference took place in Rio de Janeiro, Brazil, in 1992, resulting in the adoption of Agenda 21 and the Convention on Biological Diversity (CBD) with a focus on

"sustainable development". The current count of Parties listed by CBD is 196 (CBD 2024).

The Industrial Revolution, hailed as a remarkable era of progress and prosperity, was a significant milestone in 19th-century history (Vries 1994). This marked the end of the Malthusian perspective on restricted agricultural and industrial production, and the potential for humanity's growth became boundless (Aligica 2009). The roots of environmental conservation can be traced back to influential figures like John Muir, whose advocacy led to the establishment of the first National Parks in the United States, such as Yosemite and Yellowstone in the late 19th and early 20th centuries (Turner 2019). Muir's efforts laid the foundation for the broader conservation movement, which soon extended beyond the U.S. to influence the development of game reserves and protected areas in Africa and other regions globally (Carruthers 2019). This movement was driven by both ecological concerns and colonial interests in wildlife preservation.

The global trend towards prioritizing environmental conservation gained momentum as nations made commitments to safeguard the natural world (Rotherham 2014). By the late 20th century, UNESCO recognized certain natural areas as World Heritage Sites, viewing nature not only as an ecological resource but as part of cultural heritage with intrinsic value for humanity (UNESCO 2019). As a result, numerous new nature parks and reserves have been established, both in addition to and alongside those that existed before the 1992 Rio Summit. Therefore, extensive regions of conserved or preserved "wildernesses" are currently accessible for nature tourism (Newsome et al. 2002, Figure 1.1). With the conservation and management

of more areas, there has been a noticeable rise in tourism to natural areas, with the world's protected sites receiving approximately 8 billion visits annually (pre-Covid) and generating significant economic benefits (UNEP-WCMC 2019).

Some individuals have recognised the spiritual void caused by a society that prioritises materialism and excessive consumerism. As a result, they have turned to the natural world in search of profound experiences that can help them discover the deeper purpose of life on our planet and within the vast expanse of the universe (Limerove 2005). Beyond spiritual enrichment, forests and natural landscapes provide a range of ecosystem services that are crucial to human well-being, including climate regulation, carbon sequestration, water purification and biodiversity conservation. Recent ecosystem service models highlight the multifaceted benefit of forests, demonstrating their role not only in cultural and spiritual fulfilment but also in supporting ecological stability and human livelihood (Zhou et al., 2024). In recent years, several countries have increasingly relied on their conserved natural wonders for economic development. For instance, over 90 percent of UNESCO's listed natural sites create jobs and provide income from tourism and recreation, underscoring the global economic importance of preserving natural wonders (UNESCO 2025).

The World Conservation Strategy (1980) defines conservation as the responsible management of human activities in the biosphere, ensuring that it provides the maximum sustainable benefits for current generations while preserving its capacity to meet the needs and aspirations of future generations. It emphasises the importance of preserving, maintaining, and enhancing the natural environment in a

sustainable manner (World Conservation Strategy, 1980). This definition covers a wide range of conservation practices implemented in various countries. In this context, this thesis examines the ecological impacts of natural area tourism on flora, fauna, and environmental parameters, through the lens of a detailed case study in tropical Malaysia. The above definition guides this thesis's goals and methods.

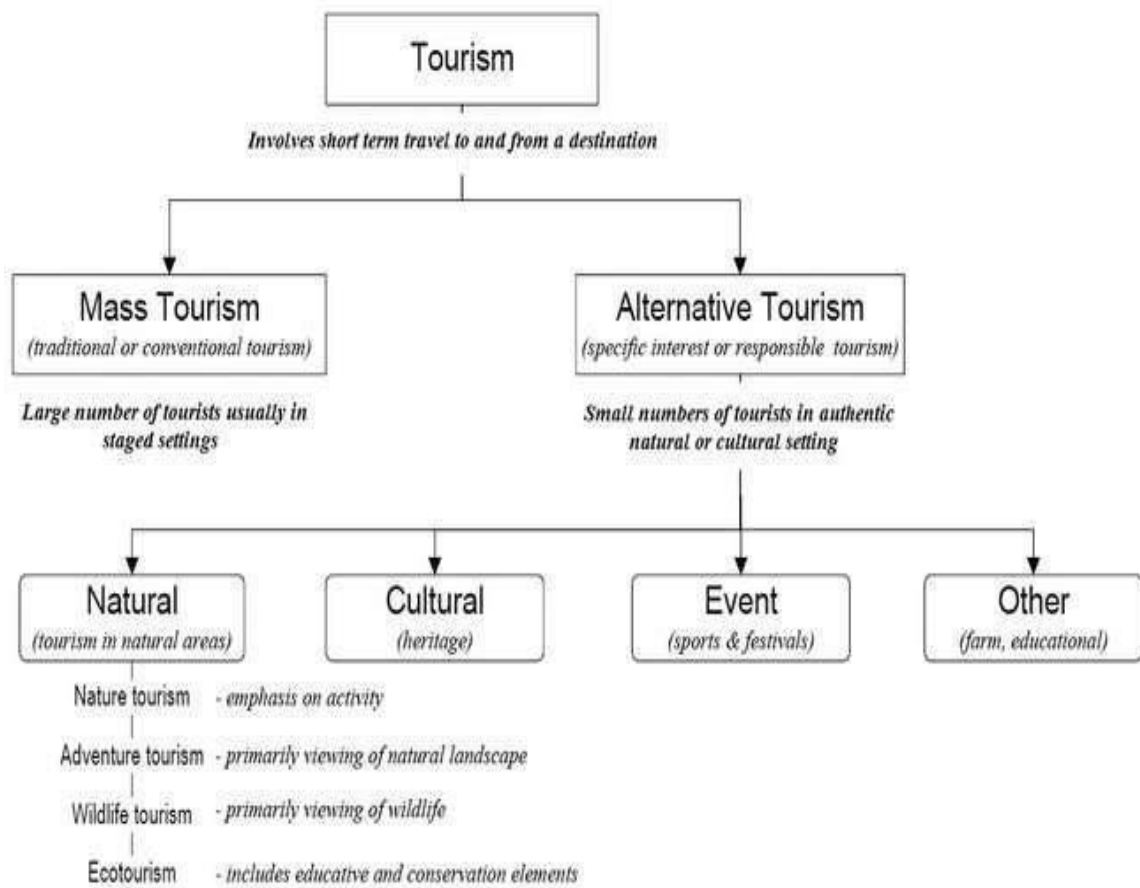


Figure 1.1: Classification of tourism according to Newsome *et al.* (2002)

1.1.1 Nature Based Tourism

Newsome *et al.* (2002) classified tourism into specific categories and types (Figure 1.1). In this classification, tourism is broadly categorized into two subcategories, i.e. (a) mass tourism, and (b) alternative tourism. Mass tourism is also referred to as

traditional tourism or conventional tourism. On the other hand, there is what is known as “alternative tourism” which is defined as a type of tourism that incorporates specific interest or responsibility as part of the tourism program or itinerary (de Kadt 1990).

As seen from Figure 1.1, alternative tourism can be further categorized in four areas of tourism, namely (a) natural, (b) cultural, (c) event, and (d) other (Newsome *et al.* 2002). This thesis mainly focuses on natural area tourism, which is further classified into four types, namely:

1. Nature-based tourism – Responsible travel for the purpose of enjoying undeveloped natural areas or wildlife.

(Note: not to be confused with natural area tourism; the other most commonly used term is “nature tourism” – these terms are used thoroughly in this thesis, but the meanings depend on context)

2. Adventure tourism - involving activities with a certain degree of risk, and which may require special skills and physical exertion.
3. Wildlife tourism - the observation and interaction with local animal and plant life in their natural habitats.
4. Ecotourism - Responsible travel to natural areas which conserves the environment and improves the welfare of local people.

Under the above classification, each category or type of tourism is defined by its own unique “spatial” aspect, meaning that each activity needs its own settings and

surroundings. The type of activity may differ from one form of tourism to another, and this may involve recreation, educational, festivals, and other activities. Thus natural-based tourism is associated with a tourism program which incorporates aspects of nature interpretation that would involve, say, trekking (e.g., jungle trekking), while adventure tourism, which generally involves travel to remote, exotic and hostile areas, (Harris,2009), incorporates activities such as mountain climbing, sky bridging, and water rafting and so on.

Cebbalos-Lascurin (1996) broadly defines “nature-tourism” as “all tourism activities directly dependent on the use of natural resources in relatively undeveloped state including scenery, topography, water features, vegetation, and wildlife”. In short, any tourism activity conducted and experienced within the natural surroundings can be considered as a form of nature tourism (Rotherham 2014; Wan Sabri and Sam Shor 1994; Newsome *et al.* 2002; Fennel 2003). Due to the rather specific definitions of the various categories and types of natural area tourism (i.e., as defined by Newsome *et al.* 2002), such types often not be properly understood by the general public and it is therefore not uncommon for the terms “nature tourism” be used interchangeably with “ecotourism” (Rotherham 2014).

1.1.2 Natural Area Tourism Recreational Impacts on Natural Ecology

In the context of recreational activity within natural area tourism, the so-called “recreational environment” or “recreation setting” may comprise of the natural resources or landscapes, ranging from forest areas, national parks, protected areas, rivers, beaches, islands, and highlands (McNeely 1990; Douglass 2000). In order to fulfil the needs and requirements of each natural area tourism activity and to engage

with the suggested recreational activities available while appreciating these natural resources, visitors have to physically move closer to the exact location of the specific resources (i.e., the natural area tourism destination). The increased number of visitors will bring about the parallel increase in recreational activities, e.g. sight-seeing, hiking or trekking, whereby the increased visitors' pressure may bring about adverse negative impacts on the environment and the natural resources (Hassan *et al.* 2017).

The recreational use of natural areas for natural area tourism has increased in recent decades. In the United States, for example, Cole and Laudres (1996) reported a ten-fold increase in the past 40 years for such use of natural areas, while Cordell *et al.* (1995) highlighted that recreational activities associated with trail use are growing most quickly in the many natural areas in those spots or routes where opportunities for outdoor recreation along trails are conveniently provided. There are many reports, such as Wilson and Seney (1994), Green (1998), Sun and Walsh (1998), that indicate the inevitable ecological impacts due to natural area tourism in many regions, including the tropics. In this context, it should be noted that the tropical rainforests are among the most popular natural area tourism destinations.

Outdoor recreation is becoming increasingly popular worldwide and as such that it has inevitably resulted in greater and wider spread of ecological impacts on the natural ecosystems. With the increased volume of visitors to popular natural spots all over the world, nature trails have to withstand heavy visitor pressure especially along the trails (Cole 1983; Forman 1995; Barros 2013; Korkance 2014). The increased intensity of trail use, in addition to efforts to develop the trails to

accommodate the growing number of visitors, there cause inevitable changes in the affected natural areas. Trail impacts, including physical, ecological, and aesthetic effects due to construction works and intensive trail use are considered the most prominent impacts of recreational use in natural areas (Leung and Marion 1996; Symmonds *et al.* 2000).

The most common forms of recreational use impacts on trails include soil erosion, and its combination with 'muddiness', trail extension and widening, vegetation damage, and litter (Hendee *et al.* 1990; Marion *et al.* 1998; Leung and Marion 2000). Furthermore, Jordan (2000) emphasizes that recreational use has a negative impact on ecosystems, particularly flora and fauna important in tropical forests, due to trampling, soil erosion, and pollution. There is also disturbance caused by noise and human movement within natural areas.

Trails are a means of accessing natural areas, and their routes are typically designed to meet favourable criteria that will have the greatest impact on visitors in terms of expectations and satisfaction. (Liddle 1975; Bhuju and Ohsawa 1998). Trails normally pass through accessible areas which are generally safe to visitors, although some recreational activities such as sports and adventures may involve trails of a different category to fit the requirements of such activities (Miller and Hobbs 2000). Often, trails also bring about other indirect impacts such as forest fragmentation and edge effects on the affected vegetation, which in turn may affect particular plant or animal species (Hickman 1990).

1.2 PROBLEM STATEMENT

Natural area tourism, and ecotourism in particular, is of great economic importance to many communities and contributes to livelihoods and awareness of conservation (Buckley, 2019). However, the growing interest in ecotourism can result in what is known as overtourism, that is, too many visitors can have negative impacts on natural spaces (Newsome & Hughes, 2020). This tension leads to the Wilderness Paradox: the challenge of balancing the preservation of wild areas in their natural state with the need to accommodate human recreational use, which inevitably leaves environmental footprints (Cole, 2021). Protected areas managed for tourist Trail usage can unwittingly foster disturbed ecologies that undermine conservation objectives and threaten biodiversity (Monz et al., 2020).

This problem is especially pronounced in developing nations, where many protected area managers simply do not have the resources and capacity to consider visitor management as a priority (Gallo et al., 2019). Due to competing concerns - including poaching, illegal encroachment, and limited enforcement staff - addressing recreational impacts often comes second (Baral et al., 2020). In many tropical contexts, however, there is a critical lack of information on the relationship between visitor activities and ecological degradation (Pickering et al., 2021). The lack of baseline data on recreation ecology makes it challenging to establish effective management strategies that reduce environmental impacts while promoting sustainable tourism.

Visitor impacts like trampling, soil erosion, vegetation loss, and habitat disturbance are localized to ecologically vulnerable areas including trails and campsites (Barros

et al., 2020). These are detrimental towards the ecological integrity of protected areas and equally the sustainability of ecotourism in the long term (Leung et al., 2019). However, there is still a considerable lack of knowledge about how specific recreational activities impact ecosystems, particularly with respect to factors such as slope, elevation, topography and distance from watercourses (Marion et al., 2020). For example, the risk of soil compaction and erosion may differ substantially between trails located near water bodies and those on higher ground, but such nuances are poorly understood (Pickering & Rossi, 2021).

1.3 JUSTIFICATION FOR THE STUDY

This study aims to address these problems by obtaining baseline information comparative to recreation ecology in a tropical protected area in Malaysia, assessing the effects of visitors' use along heavily used trails. Because of this, the research looks at the ecological effects of tourism in this context with the objective of providing information on management strategies that balance conservation priorities with sustainable recreational use (Newsome et al., 2021). Ultimately, this work will help build on the understanding of the Wilderness Paradox and inform the emergence of practices that protect natural spaces while allowing the economic and social benefits of ecotourism (Buckley & Brough, 2020).

Despite the growing global interest in recreation ecology, there has been comparative lack of research on recreation ecology in the tropical region (Pickering & Barros 2024). Early studies, such as Boucher *et al.* (1991) in Costa Rica and Talbot *et al.* (2003) provided foundational insight yet systematic investigations in tropical rainforests have been limited. Recent global reviews of outdoor recreation

impacts and recreation ecology highlights the persistent lack of studies from tropical ecosystems despite of their ecological significance (Pickering & Barros, 2024; Cardona et al. 2024). There remains a critical need for more localised investigations to understand and mitigate the ecological consequences of recreational activities in ecologically rich but understudied areas (Cardona et al., 2024).

1.4 AIM AND OBJECTIVES

The overall aim of this study is to obtain a comprehensive understanding of the effects of recreational disturbance along recreation trails in a tropical rainforest area, and correlate these with visitor perceptions of ecological richness and preferences in relation to access and trail infrastructure. The geographical focus of this study is the Maliau Basin Conservation Area (MBCA) in Sabah state, Malaysia. However, the research addresses broader questions regarding the ecological impacts of natural area tourism in tropical rainforest areas contributes to a more comprehensive understanding of this relatively under-researched issue.

This study focuses on specific aspects of the impacts that occur in the MBCA rainforest and aims to enhance understanding of the effects of recreational activities on forest ecology when a protected natural area is open to public for tourism. In particular this research aims to address the following questions:

- (1) What impact does recreational disturbance have along tropical forest trails?
- (2) What effects do recreational disturbance impacts along tropical forest trails have on visitor perceptions, expectations, and satisfaction with their visit?

The objectives of the research will be to:

1. Gather and critically appraise published literature related to conservation, tourism, and recreational ecology.
2. Develop appropriate methods for impacts assessment on fauna, flora, and soils in the tropical case study environment.
3. Use and apply the developed methods to evaluate recreation impacts and visitor experience.
4. Evaluate the applicability and effectiveness of established impact assessment methods in tropical forest ecosystems, identifying necessary modifications for reliable assessments.

1.5 SUMMARY

This chapter has provided a background for the study by discussing the interdependence of humans and their environment, the romanticism of nature, and the growing focus on nature conservation and natural area tourism by the travel industry. After introducing the issue, the gap in knowledge was presented together with an overview of the justification for the work and its focus on the MBCA case study. The overarching goals and foci of this research have been laid out in order to address the concerns and questions raised.

CHAPTER 2

LITERATURE REVIEW

The chapter addresses the ecological effects of recreational trails in tropical protected areas. It provides an overview of relevant literature on the natural area tourism, recreation ecology, and their implications for ecosystems, especially in tropical environments. This chapter, therefore, aims to set out the research context by synthesizing existing knowledge, pointing out gaps and weaknesses, and informing the methodological and conceptual designs of the study.

2.1 PHILOSOPHY OF NATURAL AREA TOURISM

2.1.1 Socioeconomic vs. Environmental Considerations in Tourism

At the national (or state) level, the primary focus for tourism development is typically socioeconomic. However, the foundation for natural area tourism is the actual existence of the natural environment itself, which becomes an asset for such development. Kumar et al. (2023) emphasized that the philosophical underpinnings of ecotourism require the examination of its role within broader ecological, social, and cultural contexts. These philosophical considerations highlight a complex balance between utilizing natural areas for tourism and preserving their intrinsic ecological values.

Tourism's reliance on natural environments necessitates rigorous sustainability measures. Newsome et al. (2022) suggested that natural area tourism must incorporate environmental stewardship into development plans to mitigate ecological degradation. The challenge lies in addressing the socioeconomic

demands of stakeholders while maintaining the integrity of natural ecosystems. This balance is particularly critical in tropical protected areas, where biodiversity hotspots are under increasing pressure from human activities.

2.1.2 Human Values and Attitudes Toward Natural Areas

Natural area tourism is very much reliant upon human values and attitudes. Riper et al. (2019) suggested that natural landscapes and people form a cultural landscape which is mediated through social values. Part of the evolution in attitudes of modern-day societies is reflected in environmental campaigns by groups such as the World-Wide Fund for Nature (WWF) and the World Conservation Monitoring Centre (WCMC). Public awareness of the environment has raised over the last few decades, with increased advocacy for the protection of natural landscapes.

This dichotomy reflects this value of nature in and of itself against the perspective of economic returns. Chan et al. (2020) illustrated this dichotomy, noting the need for successful natural area tourism programs to balance conservation objectives with cultural and recreational desires. Such a (biocentric and) human-centric focus allows for a more holistic respect for natural environments, where both ecological factors and human components are important.

2.1.3 Changing Public Attitudes and Environmental Awareness

Attitudes towards nature conservation have undergone substantial evolution, especially since the mid-20th century. Zwieter et al. (2019) noted that generational value shifts have resulted in a heightened focus on environmental ethics and sustainable practices. This transition has been propelled by a confluence of scientific

inquiry, advocacy initiatives, and policy reforms focused on emphasising the significance of biodiversity preservation. Additionally, integrating the concept of ecosystem services into modern economic models provides a comprehensive framework for capturing the wide range of ecological values, ensuring that biodiversity conservation is not only an ethical imperative but also an economically viable strategy (Costanza et al., 2017).

A significant change in public attitudes, which is particularly pertinent to eco-tourism, is an increasing awareness of the relationship between human and the environment health (Irawan et al., 2023). Surveys by the United Nations Environment Programme (UNEP 2022) reveal that people are increasingly perceiving natural areas as relevant for ecological and psychological well-being. This raises some important questions about how conservation strategies can be designed to balance ecological protection and visitor satisfaction, how financial benefits from tourism can be reinvested for long-term sustainability, and how tourism can contribute to both environmental preservation and human well-being without leading to degradation around natural area tourism. Again, the implementation of conservation strategies improves visitor satisfaction bringing in financial benefits allowing for long-term sustainability.

2.1.4 Historical Development of Ecotourism Philosophy

Ecotourism emerged from the broader environmental movement of the 20th century. The term “eco-tourism” comes from Héctor Ceballos-Lascuráin who, in 1983, responded to the growing interest in nature-based tourism that had an emphasis on environmental protection (Stronza et al., 2019). Early supporters of

ecotourism argued that it had the potential to reconcile economic and environmental goals because it could promote low-impact travel and promote environmental education. The concept of ecotourism has changed over time to include more general sustainability objectives. According to Silva et al. (2023), community development and cultural preservation are becoming more and more integrated into the frameworks of modern ecotourism initiatives. This development shows a greater awareness of the various ways that tourism in natural areas can promote conservation and sustain local economies.

2.1.5 Ethical Considerations in Natural Area Tourism

Ethics play an important role in shaping tourism policies and practices associated with natural areas. Ecotourism is an ethical framework that focuses on principles like minimizing environmental disruption and respecting local customs and equitable sharing of profits. As Hall and Page (2021) state, in the case of ethical tourism practices, the rights of indigenous communities must be prioritized, along with the integrity of natural ecosystems.

A serious ethical dilemma in natural area tourism is the need to balance access with conservation and preservation. Although tourism opens doors for environmental education, economic opportunity, and cultural exchange, it also threatens to degrade the resources that intends to be celebrated. As Moi *et al.* (2020) stressed the prospective nature of morality in tourism management that involves the periodic management of the temporal process of balancing visitor satisfaction and ecological sustainability to promote an enhanced awareness of the gates of moral consequence. In addition, equity and inclusion must be addressed in ethical tourism

practices. Indigenous communities, which are often the stewards of natural regions, need to be at the forefront of tourism planning and benefit-sharing. According to Roberts (2019) adopting indigenous knowledge in tourism strategies not only improves cultural authenticity, it also works towards sustainable use goals.

2.2 TOURISM AND ENVIRONMENT

Tourism has a complex and intimate relationship with the environment, especially in natural areas where ecosystems are both the setting and subject of travel activities. The relationship between tourism and the environment is complex and multidimensional, involving economic, ecological, and sociocultural factors. Tourism, however, if not properly managed, can have serious threats to these natural resources. It is necessary to better grasp these dynamics to design and advocate for tourism modalities that align human activity with environmental conservation practices (Hall, 2019, Liburd et al., 2020).

2.2.1 Trends in Natural Area Tourism

WWFNM (1996) and Silva *et. al.* (2023) indicates that nature-based tourism and recreation in protected areas and nature parks has grown worldwide over several decades, including in Malaysia. Several studies show that this type of tourism (i.e., natural area tourism as defined by Newsome et al. 2002 and Žafran, 2023) has grown rapidly. For instance, 40–60% of international tourists were nature tourists (UNWTO Global Report on Adventure Tourism (2014), and out of a total £36 billion spent on tourism and leisure activities in 2017, £22.5 billion was attributable to natural capital, equating to 0.9% of the UK GDP (Fitch 2022). Compared to 1950–1989, annual arrivals grew 7% in the 1990s (Cebbalos-Lascurin (1996), quoting

WTO and UNEP (1992)). Ecotourism accounted for US\$1 trillion of the tourism market in 2012 (Coles *et. al.* 2015). UNWTO (www.unwto.org) reports that 46 of the 49 Least Developed Countries earn foreign exchange from tourism, including nature area tourism.

Between the years of 2020 and 2023, global tourism was drastically hit due to the COVID 19 pandemic. In 2020, international tourist arrivals dropped to 406 million, a far below from the projected number of 1.6 billion by UNWTO's 2011 report (UNWTO 2011). In 2021 the numbers were slightly better as 458 million accessed locations, however, this was still 69% lower than the pre-Covid level (UNWTO, 2022). There was a major improvement by the end of 2022 as arrivals reached 975 million or 66% of the 2019 levels and by the end of 2023 there was an impressive bounce back as levels reached 1.3 billion or 88% of the pre-pandemic levels (RoadGenius, n.d.). This 2023 figure aligns with long-term projections that international tourism is expected to reach 1.9 billion arrivals and \$2 trillion in spending by 2030, as markets shift eastward and new destinations emerge, generating more revenue from emerging economies (Yeoman 2008).

2.2.2 Global Governance on Natural Area Tourism

Natural area tourism was strongly promoted by the United Nations especially after the United Nations Conference on Environment and Development (UNCED) of 1992 (also known as the Rio Earth Summit). The booming natural area tourism industry can be in part attributed to the various efforts by the various international organizations and institutions. IUCN (World Conservation Union) in collaboration with UNEP (United Nation Environment Program), WCMC (World Conservation

Monitoring Centre) and WCPA (World Commission on Protected Areas) established Protected Areas in six major categories (Table 2.1) in all parts of the world under Agenda 21 and Convention on Biological Diversity 1992.

Table 2.1: IUCN categories for Protected Areas (www.iucn.org)

Category Ia	Strict Nature Reserve: Protected areas that are strictly set aside to <i>protect biodiversity</i> and also possibly <i>geological/ geomorphological features</i> , where human Trail usage, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.
Category Ib	Wilderness Area: Category Ib protected areas will generally be larger and less strictly protected from human Trail usage than category Ia: although not usually subject to mass tourism they may be open to limited numbers of people prepared for self-reliant travel such as on foot or by boat, which is not always the case in Ia.
Category II	National Park: Category II protected areas usually combine ecosystem protection with recreation, subject to zoning, on a scale not suitable for category I.
Category III	Natural Monument or Feature: Category III protected areas are generally centred on a particular natural feature, so that the primary focus of management is on maintaining this feature, whereas objectives of Ia are generally aimed at a whole ecosystem and ecosystem processes.
Category IV	Habitat/Species Management Area: Category IV protected areas protect fragments of ecosystems or habitats, which often require continual management intervention to maintain. Category Ia areas on the other hand should be largely self-sustaining and their objectives preclude such management activity or the rate of Trail usage common in category IV. Category IV protected areas are also often established to protect particular species or habitats rather than the specific ecological aims of category Ia.
Category V	Protected Landscape/ Seascape: Category V protected areas are generally cultural landscapes or seascapes that have been altered by humans over hundreds or even thousands of years and that rely on continuing intervention to maintain their qualities including biodiversity. Many categories V protected areas contain permanent human settlements. All the above are incompatible with category Ia.
Category VI	Protected area with sustainable use of natural resources: Category VI protected areas contain natural areas where biodiversity conservation is linked with sustainable use of natural resources, which is incompatible with category Ia. However large category VI protected areas may contain category Ia areas within their boundaries as part of management zoning.

The IUCN identifies and defines seven categories for Protected Areas, ranging from Strict Nature Reserve to Wilderness Areas, National Park, Natural Monument/Feature, Habitat Management Areas to Protected Land/Seascape and Protected area with sustainable use of natural resources (Elleason *et al.*, 2020). The site of this study, the Maliau Basin Conservation Area (MBCA), is listed under Strict Nature Reserve (Category 1a): Protected areas that are strictly set aside to protect biodiversity and also possibly geological/ geomorphological features, where human Trail usage, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring (Zafra-Calvo & Geldmann, 2020). The guideline criteria used for this category are quite specific for [a] for the protection of biodiversity, and [b] protection (possibly) of geological/geomorphological features (more detailed explanations are given in Section 3.1). The categorization is not mutually exclusive since the criteria used for the other categories may also be applied to the same Protected Area which is already categorized in one category.

Natura 2000, a network of nature protection areas in Europe had laid down key concepts for special conservation of natural areas at the various levels from the broader eco-region to smaller functional conservation areas which include both terrestrial and marine protected areas. One of the designations of this network is directly on habitat which is categorised at the landscape and site levels (European Commission, 2003). The Maliau Basin Conservation Area (MBCA) used as the focus of this study covers an entire geomorphological formation of an ancient basin and thus would be categorized under functional landscape. The efforts to conserve

Maliau Basin are at the landscape level, although within MBCA are many functional sites which are included for conservation.

2.2.3 Sustainable Development Goals

The UN World Tourism Organisation (UNWTO) is crucial to aligning global tourism practices with the 2030 SDGs. Sustainable tourism that supports the SDGs' economic, social, and environmental goals is the UNWTO's focus. Tourism can boost economic growth, but the UNWTO advises responsible tourism that protects natural resources and biodiversity, which supports SDGs like Goal 15, which seeks to protect, restore, and promote the sustainable use of terrestrial ecosystems, manage forests sustainably, combat desertification, and stop biodiversity loss (Hall, 2019).

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) supports the UNWTO by providing scientific data and assessments to conserve biodiversity and ecosystem services, which are vital to Natural Area Tourism (Krug et al., 2020). IPBES advocates for integrating diverse knowledge systems, including indigenous knowledge, into tourism and conservation policies to promote biodiversity, ecosystem health, and human well-being. This approach is intended to ensure tourism development is environmentally sustainable (Vadrot et al., 2018). UNWTO and IPBES promote a balanced approach to natural area tourism, where tourism supports the SDGs while preserving these areas' unique natural and cultural heritage (Carius and Job, 2019). Collaboration is necessary to ensure that tourism development supports global sustainability goals without harming natural areas (Liburd et al., 2020).

2.2.4 Ecosystem services

Ecosystem services are the benefits humans obtain from natural ecosystems, this process is fundamental to the tourism sector, where environmental sustainability and economic development have great relevance. The link between tourism and ecosystem services has been addressed in recent literature, acknowledging tourism's contribution to ecosystems as having both a positive and negative effect (Pueyo-Ros, 2018; Zhang et al., 2022).

Pueyo-Ros (2018) highlights the dual role of tourism in the Ecosystem Services Framework (ESF); Although tourism is known as a cultural service that satisfies recreational and aesthetic needs, it is also an economic sector that was a source of consumption of natural resources. This dual aspect emphasizes the importance of the tourism sector to not only understand the importance of the cultural services provided by the ecosystems, but also to recognize and manage its consumption of provisioning services (food, water and energy) towards sustainable practices.

As far as ecotourism is concerned, Tung et al. (2020) conducted a systematic review on ecosystem services within Southeast Asia. In fact, the researchers found that 70% of ASEAN countries have conducted studies on the ecosystem services ecotourism offers, suggesting that its importance is finally being recognized. Such perspectives reflect a sustained submergence of sustainable ecotourism practices in the review, which are crucial for improving ecosystem services while also generating financial resources for the welfare of local communities.

Recent research highlights the intrinsic intersection between tourism and ecosystem services. Although tourism greatly relies on ecosystem services, it is also entities endowed with the sublime responsibility of ensuring that development and operations are not compromising the integrity of natural systems. Finding a sustainable balance between tourism and ecosystem conservation is an important area of continuing research and policy development.

2.2.5 Environmental Benefits

Ecotourism, which can also be known as Natural Area Tourism (NAT), is important in the conservation of biological diversity and resources. Ecotourism facilitates the conservation of natural areas by offering economic incentives to do so in lieu of other forms of more damaging land conversion. As studies (for example, those by Naidoo et al. (2011), have shown that ecotourism can serve as an effective means of conserving biodiversity, especially in areas where alternate pathways for economic development are constrained. Also, it contributes to sustainable practices regarding the ecological preservation with the communities and tourists (Gouvea, 2017).

Ecotourism also contributes to climate change mitigation by supporting low-impact travel and conservation efforts that protect carbon-sequestering ecosystems like forests and wetlands. The protected areas often linked to ecotourism create ecological buffers, which enhance biodiversity conservation and ecological resilience to environmental transformations (Leung et al., 2019). Ecotourism revenue also supports conservation initiatives, which typically emphasize habitat restoration and wildlife protection, thus promoting environmental sustainability. E.g.,

ecotourism programs in African savannahs have aided anti-poaching efforts while wildlife populations have rebounded (Ballantyne et al. 2021).

2.2.6 Cultural and Psychological Benefits

Ecotourism provides important cultural ecosystem services, which are benefits for recreation, aesthetic enjoyment, and spiritual experience obtained from ecosystems in a non-material sense (Saha & Mukul, 2021). These services are vital in areas that are globally important for cultural heritage and biodiversity. In a study on the contribution of urban green spaces to health and well-being, Pinheiro et al. (2021) demonstrate that protected areas provide residents and visitors with aesthetic values, social bonding, emotional and cognitive interaction leading to improved health and well-being and better living environment (Pinheiro et al. 2021). The environment, in the form of natural landscapes, becomes a physical site for social and spiritual traditions rooted in indigenous ways of life contributing to the sense of connection to the environment.

Moreover, Willis (2015) underlined that cultural ecosystem services are central to the tourism-nature-wellbeing nexus, stressing that the natural landscape has a positive impact on mental well-being and tourist satisfaction. Contact with nature via ecotourism has been associated with reduced stress, greater mental health, and improved cognitive restoration. Ghasemi et al. According to Lamas et al. (2023), ecotourism has psychosocial advantages, especially by developing mental reset through nature-based experiences. Similarly, Phelan et al. (2020) concluded that overall health can be greatly improved through nature tourism improving physical and mental health.

Other research shows the education benefits of ecotourism. Zubair et al. (2020) observed reported an increase in localized environmental awareness following eco-tours in Southeast Asia. That educational component reinforces our connection to nature and encourages eco-friendly actions, encouraging a more general environmental awareness

2.2.7 Socioeconomic Benefits

The positive impact on local economies, particularly nurturing and underdeveloped regions is greatly enhanced by ecotourism. It employs people, nurtures local businesses, and creates tax revenue that can be reinvested in development and conservation. Study by Saha and Mukul (2021) found that the economic valuation of the cultural ecosystem services of Lawachara National Park, Bangladesh, resulted in significant financial benefits that are important in sustaining local livelihoods. Moreover, ecotourism promotes eco-entrepreneurship, creating space for opportunities for sustainable business (Iakovoglou & Zaimis, 2018).

The socioeconomic benefits of ecotourism go beyond profits, taking in its contribution to sustainable development. Ecotourism encourages conservation through empowering communities to participate in it, by building local economies and encouraging a sense of belonging. Ecotourism revenues contribute to development of local infrastructure and better access to education and health care, which many communities benefit from. It encourages long-lasting social sustainability and drives a better standard of living for inhabitants.

A study by Kiper et al. (2020) which illustrates how ecotourism developments in Turkey enhanced household incomes and reinforced migration away from rural environments. That is, López-Rodríguez et al. (2022) provided significant economic returns through forest conservation via ecotourism projects in the Amazon basin. These examples highlight the potential of ecotourism to serve as a tool of sustainable development by using economic incentives that align with the preservation of ecology.

Ecotourism has been described not simply in terms of the greater environmental awareness of tourists but also as a contributor to the psychological health of the participants (Brymer & Lacaze, 2013), thus providing further support for ecotourism as a multi-faceted concept. As a community that merges economic gains with environmental preservation, ecotourism offers a path for sustainable development that emphasizes both humanity and the environment.

2.3 VISITOR PERCEPTIONS AND THE WILDERNESS PARADOX

2.3.1 Theories of perception and behaviour

Perception deals with how individuals interpret raw stimuli in order to understand their environment. In a recreation setting, perception guides the user's behaviour, decision-making, and choice of the site. It encompasses both sensory and cognitive aspects, providing a mental model for people to use to create representations based on environmental contexts and stimuli (Sisneros-Kidd et al., 2020). The role of perception in determining these issues is key for understanding how people perceive natural environments and the components influencing their satisfaction and decision-making processes. The perception has become a complex phenomenon

as visitors interpret environmental stimuli based on their personal, cultural and social backgrounds.

The strongest two theoretical frameworks that can explain visitor perceptions and behaviours are the Theory of Reasoned Action (Fishbein & Ajzen, 1975) and the Theory of Responsible Wilderness Behaviour (Hanna, 1995). The Theory of Reasoned Action asserts that the behaviour of an individual is determined by behavioural intentions, which emerges from attitudes and subjective norms. For example, a visitor's perception of environmental damage affects their intention to participate in pro-environmental behaviour. In contrast, the Theory of Responsible Wilderness Behaviour draws upon previously posed behaviour theories and includes components of environmental knowledge, beliefs, and motivations. It implies that environmental attitudes interact with predisposing factors, including past experiences and socio-demographics, to affect behaviour. Thus, through these frameworks, managers can identify ways to improve pro-environmental behaviours of visitors.

2.3.2 Factors influencing visitor perceptions

The perceptions of visitors are influenced by a complex set of factors which are intrinsic and extrinsic. People perceive and respond to environmental impacts differently, depending on demographic variables and prior experiences and motivations, and on knowledge about the environment.

2.3.2.1 Demographic Factors

Environmental attitudes are strongly influenced by demographic factors such as age, gender, and education. Previous studies have shown that younger people are more receptive to environmental education, with the age group of 7 to 16 years old being more likely to develop lasting positive attitudes about nature (Otto et al., 2019). Wells and Lekies (2023) further highlight the significance of childhood experiences in the natural world, stressing the role of early exposure in developing a lasting love for nature. There are also gender differences, with some studies indicating women are more responsive to environmental issues on average owing to emotional and empathetic tendencies (Chan et al., 2019). Yet other studies claim that gender differences may not be as prominent as previously believed: family influence and community practices could matter more (Hutchison et al., 2019).

2.3.2.2 Education

Education, of which the level attained tends to be positively correlated with environmental awareness and negatively correlated with ecological degradation (Rizzolo et al., 2023), is a significant but individual propensity for LEV. Suarlin and Ali (2020) supported this finding by reporting that people who were educated in biology or environmental sciences were more sensitive toward environmental issues than those who were educated in non-environmental fields. Education increases environmental awareness that guides situations and decisions that meet sustainable practices.

2.3.2.3 Prior Experiences

Good outcomes with outdoor activities from the past experience influence perceptions of visitors as well. The visitors with a long experience of recreational have a greater sensitivity to environmental impacts, and it is likely to take part of preservation behaviours. Recent research supports that involvement in non-consumptive outdoor activities facilitates a greater connection with nature that translates into environmental empathy and concern (Barragan-Jason et al., 2022). Likewise, visitors with more outdoor experience generally have greater expectations and do not tolerate apparent environmental degradation. Studies by Moghimehfar et al. (2020) illustrates that greater participation in activities such as hiking and camping is associated with increased awareness of the ecological effects of recreational use.

2.3.2.4 Environmental Knowledge and Motivation

Motivation also has a big impact on how we perceive things. Naturalistic intrinsic values tend to correlate with higher sensitivity towards the environment. Outside factors (like the desire to break out of daily habits) or the search for social interaction can also affect how we perceive our environment, but these stimuli can decrease environmental awareness, according to Schunk & DiBenedetto (2020). Lastly, environmental knowledge helps develop sensitivity to ecological issues and promotes responsible behaviour, gained from formal education or interpretive programmes (Gao et al., 2021).

2.3.3 Contrasting perceptions of visitors and managers

Environmental impacts are frequently perceived differently by visitors and resource managers because their priorities, knowledge, and decision-making frameworks are often fundamentally different. Visitors tend to base impacts on their own experiences and the magnitude of the changes they can see. For example, many visitors will be unaware of ecological change unless it is blatant, such as litter, vandalism, or crowding (White et al., 2001). And even on occasions when impacts are noted, they may not be seen as a problem—such as when the overall recreation experience is not diminished. Visitor tolerance towards environmental impacts is influenced by a range of factors including demographics, personal value systems and the nature of recreational goals (Rigolon et al., 2019). In contrast, managers seek ecological integrity and are often sensitive to gradual or long-term changes in their environment (Table 2.2). This increased sensitivity is due to the professional obligation they have to protect natural resources for future generations. As a result, managers are prone to support stricter impact thresholds and more aggressive actions than visitors may think are warranted.

Table 2.2. Key Differences Between Visitor and Manager Perceptions (Adapted from Zhang et al. 2019)

Aspect	Visitors	Managers
Focus	Recreation and enjoyment	Ecological integrity
Awareness of Impacts	Limited to visible impacts	Sensitive to subtle and long-term impacts
Decision-Making Basis	Personal values and convenience	Scientific knowledge and conservation goals
Threshold for Acceptability	Higher tolerance for minor impacts	Lower tolerance for even minor impacts

Such different perceptions can lead to conflicts in natural area management. For instance, managers may want to implement restrictive measures to protect fragile ecosystems, which visitors might view as excessive or unnecessary. Education and communication programs are capable of bridging the gap between visitor perspectives and management goals that allow for an aligned and shared comprehension of the values of conservation. Zhang et al. (2019), which suggests that by engaging visitors with opportunities for conservation and decision-making, their understanding and support of the management techniques will be greater.

2.3.4 Previous studies on visitor perceptions in tropical regions

Case studies in tropical regions provide important clues about the way visitors view environmental effects, and how these relate to attitudes. Supriadi and Darusman (1992) found that littering was rated by visitors to Gunung Gede Pangrango National Park in Indonesia as the biggest problem, illustrating that they are sensitive to visible impacts. In a similar vein, visitors in Malaysia's Bako National Park ranked biophysical impacts, such levels of litter, vandalism, and vegetation damage as significant concerns and readily visible that negatively affected their recreational experiences (Chin et al., 2000).

Similar patterns were found in comparative studies from western countries. For example, the most negative impacts reported by visitors hiking on Canada's Starkey Hill Interpretive Trail were litter, damage to trees, and signs of campfires, while other forms of less visible damage such as soil erosion were rated as moderate concerns (Wu et al., 2021). These results indicate that a range of cultural and environmental contexts influence visitor perceptions, but that visibility of impacts is a major factor.

In tropical countries, it is important to focus management efforts on visible impacts, as these currently have the greatest and most immediate effect on visitor satisfaction. Educational initiatives can further the visitors' awareness of less visibly apparent ecological changes, providing a more holistic understanding of conservation issues. For example, Oliveira et al. (2020), interpretive programs that make visitors aware of the wider eco-social contexts of their actions foster more sustainable behaviours.

Supriadi and Darusman (1992) suggested the monitoring of visible and less visible impacts, having facilitated an understanding of visitor's perceptions in order to improve the management intervention. Specific strategies - including offering clean bathrooms and waste disposal spots, can help overcome common visitor complaints and increase overall satisfaction. So together with necessary interventions to treat visible degradation, these efforts can better align visitor experiences with sustainable management objectives.

2.3.5 The Wilderness Paradox

The Wilderness Paradox encapsulates the inherent tension between preserving natural areas in their untouched state and facilitating human recreation within these spaces. Recreation ecology emphasizes this paradox in the conflict between protecting wild areas in their natural and free condition and allowing recreational contact with the same area and its access roads, which leaves behind its environmental footprints. For example, Shogan (2013) explores the philosophical assumptions and implications of this paradox, drawing attention to the ethical and moral challenges of managing the wilderness. He claims that wilderness, so

frequently imagined to be the land unmarked by the touch of humankind, in fact requires human intervention because the process of designating and managing for wilderness requires inevitable human management. This paradox complicates the goals of preservation and recreation as management strategies seek to balance keeping areas pristine with accommodating human use (Shogan, 2013).

This dilemma has been further studied in recent research. Baker (2022) notes that while recreational users tend to appreciate landscapes for their perceived wilderness attributes, they simultaneously engage in practices that undermine those same attributes. This duality highlights the complicated relationship with wilderness and the damage users do unintentionally through recreational activities.

The idea of wilderness itself has been criticized for its dualistic understanding, one where humans are viewed as separate from nature. According to Cronon (1995), this view creates the presumption that the true state of nature is remote from human presence, making human beings a threat to any sort of natural purity. Such a perspective makes it difficult to infuse human encounters into the natural environment without degrading ecological integrity. To address these challenges, the emerging field of recreation ecology has focused on the environmental effects of recreational activities in protected natural areas. In using the information, managers must strike a balance between human utilization and ecological preservation, an approach with an underlying understanding that recreation both promotes appreciation of nature and creates risk to environmental health.

The Wilderness Paradox represents a critical dilemma in environmental conservation, where the balance of wilderness preservation and limited human engagement is a delicate one that must be tread carefully in order to mitigate detrimental impacts to ecosystems. To understand this complex interaction between preservation and recreation, further research and adaptive management strategies are needed (Gascón et al., 2016; Hammer et al., 2018).

2.3.6 Challenge of balancing preservation and recreation

Balancing preservation and recreation are especially difficult in tropical ecosystems, some of the most biodiverse but fragile environments on the planet Hammitt et al. (2015). There is a foundation for this work in Marion and Wimpey (1992), who developed a classification and assessment of the types of environmental degradation that resulted from recreational use and the potential effects on wilderness lands. Such as soil erosion and vegetation and fauna disturbances, which have high importance in biodiversity hotspots; Soil erosion, for example, decreases soil fertility and impedes vegetation regrowth; disruptions of wildlife disturb breeding and feeding behaviours, which worsen biodiversity loss.

In a more recent publication (Wolf et al., 2019), Wolf expanded upon this discussion to explore the specific implications of outdoor recreation to global conservation work. The study pointed to the importance of cautious management to reduce the adverse effects while using recreation to generate conservation awareness and sponsorship. For instance, nature-based tourism provides funds for conservation efforts but must be tightly regulated for ecological sustainability. Benítez-López et al. (2019) showed how recreational overhunting leads to extensive defaunation in

tropical forests, representing over 50% of these ecosystems and potentially cascading effects on crucial ecological processes like seed dispersal and predator-prey interactions.

2.3.7 Previous studies of the wilderness paradox in tropical ecosystems

New studies highlight that the wilderness paradox in tropical ecosystems is even worse. França et al. (2020) the combined pressure on biodiversity exerted on tropical forests and coral reefs by the intensification of human recreation coupled with climate change and human disturbances leads to increased biodiversity loss and decreased ecosystem resilience. In heavily human-affected areas, for example, we see substantial drops in mammal populations and altered ecological processes. Coral reefs, which are critical for marine biodiversity, endure physical destruction from snorkelling and boating, and pollution from chemicals in the sunscreen.

In tropical areas, these pressures are further exacerbated by the constraints of financial and institutional resources (Rodríguez et al. (2022), which encourage global collaboration and resource mobilization for conservation efforts. Many small island countries with rich biodiversity do not receive enough funding for proper ecological regulation and conservation management.

Roberts (2019) called for the integration of Indigenous knowledge into considerations of wilderness management. Many Indigenous communities have developed deep ecological knowledge and sustainable practices nurtured over generations. This attack on the no-humans perspective on wilderness points out that the division of nature and culture is neither intrinsic nor natural, and that Indigenous

practices healing the land in even short periods of connectivity can serve as healing practices that promote ecologically sustainable land-use and cultural sustainability. Similarly, Liu et al. (2023) emphasized the importance of cultural ecosystem services, showing that certain services such as leisure, recreation and cultural identity are critical for local communities living near tropical nature reserves and can promote conservation efforts. One example is how community-led ecotourism ventures in tropical regions have successfully aligned conservation interests with economic rewards for local communities.

2.3.8 Strategies for managing the Wilderness Paradox

Management that addresses the Wilderness Paradox will have to be effective on tropical ecosystems. Perino et al. (2019) suggesting rewilding proposes to restore ecosystems in depleted landscapes through species reintroductions and natural processes. In regions that are high in biodiversity where ecosystem recovery is possible, this approach is relevant. These perspectives might include reintroducing apex predators in tropical ecosystems, or planting native vegetation to restore natural habitats.

In addition, Rodríguez et al. highlighted barriers and the need for institutional and financial support, especially in tropical areas under high recreational pressure (Rodríguez et al., 2022). Incentives for conservation, such as payment-for-ecosystem-services programs, can be adopted by those in a local community. Such programs have the power to marry ecology to economic well-being and sustainability.

Another strategy is the incorporation of cultural and Indigenous practices. Roberts (2019) and Liu et al. (2023) call for integrating Indigenous knowledge and cultural ecosystem services into conservation planning. Incorporating local perspectives and respecting Indigenous rights to manage ancestral lands can foster a sense of ownership in these communities, leading to more sustainable conservation practices. Educating multi-day tourists about the damaging ecological impacts of their recreation can also be an effective way to reduce pressures on wilderness areas by simply getting these tourists to adopt more environmentally-friendly behaviours.

As a whole, these strategies are a holistic management strategy to resolve the conflicting interest of human use versus ecosystem preservation in tropical landscapes. To lessen the damage recreation does, scientific studies must combine with community efforts and creative conservation practices to make sure these biodiverse, fragile places remain for years to come.

2.4 RECREATION AND DISTURBANCE ECOLOGY

2.4.1 Definitions and scope

Recreation ecology is a systematic and scientific discipline focused on examining, assessing, and monitoring the impacts of visitor activities in wilderness, natural, and other protected areas (Sumanapala & Wolf, 2019). It seeks to understand the types, amounts, and rates of ecological changes caused by recreational use, as well as the environmental and use-related factors that influence these changes (Cole, 2004; Sumanapala & Wolf, 2019). Additionally, the discipline informs resource managers about the extent of resource changes, models the impact process and its influencing

factors, and provides insights for the development and evaluation of effective management interventions (Marion, 2023).

A fundamental concept within recreation ecology is disturbance ecology, which highlights the significance of disturbances, whether natural or anthropogenic, in shaping ecosystems (Newman, 2019). The study of how visitor activities affect natural environments through the perspective of disturbance ecology has gained increasing importance within recreation ecology. Traditionally, visitor-induced disturbance was viewed negatively, often associated with environmental degradation and biodiversity loss (Orihuela-Torres et al., 2023). However, advancements in ecological knowledge, particularly the Intermediate Disturbance Hypothesis (IDH), have contributed to a more nuanced understanding that acknowledges potential benefits of moderate disturbances (Moi et al., 2020).

This section of the literature review explores the evolution of perspectives regarding visitor disturbances in natural ecosystems, examines the role of disturbance in maintaining ecological processes, and discusses the implications of human recreation as a form of ecological disturbance. Understanding these dynamics is essential for informing sustainable management strategies that balance conservation efforts with recreational use in protected areas.

2.4.2 Historical perspectives

Research in recreation ecology began in the early 20th century, motivated by concerns over the environmental impacts of increasing recreational use in natural areas. The earliest documented study was conducted by Meinecke (1928), which

examined the ecological impacts of tourism on recreation resources. This was followed by Bates (1935) investigation into the effects of trampling on vegetation in the United Kingdom. At the same time, the dominant ecological perspective was rooted in the equilibrium paradigm, which viewed ecosystems as advancing towards a stable and peak state. Disturbances, particularly those caused by human activities such as tourism and recreation, were perceived as threats to this equilibrium. Conservation efforts were primarily focused on minimizing human impacts, operating under the assumption that any disruption would lead to ecological degradation and biodiversity loss (Okie & Storch, 2023).

The field of recreation ecology gained momentum in the late 1960s with growing concerns about ecological impacts due to the rise of ecotourism and increased Trail usage to natural areas. Seminal research during this period examined recreational carrying capacity (Wagar, 1964) and campsite impacts (Frissell & Duncan, 1965). By the 1970s, research evolved into long-term studies, with Bayfield (1973) and Liddle (1975) monitoring the effects of human activities on vegetation and soil in the United Kingdom. This period also saw the establishment of the Recreation Ecology Research Group in Great Britain, facilitating the exchange of research findings across Europe.

By the 1980s, recreation ecology research had expanded significantly in the United States, focusing on ecological impacts in national parks and wilderness areas. Notable contributions included the development of impact monitoring protocols (Cole, 1989; Marion, 1991), the Limits of Acceptable Change (LAC) planning framework (Stankey et al., 1985), and studies on curvilinear relationships between

use intensity and impact (Cole, 1985, 1987). The belief that visitor activities were inherently detrimental to ecosystem health remained prevalent, with studies documenting negative effects such as soil compaction, vegetation damage, and wildlife disturbances (Liddle, 1997). The publication of the first recreation ecology textbook by Hammitt and Cole in 1987 marked a significant milestone, consolidating the field's knowledge and methodologies.

Throughout its historical development, recreation ecology has been shaped by broader ecological perspectives on disturbance. Initially, disturbances were viewed primarily as harmful disruptions to ecosystem stability. However, as research progressed, a more nuanced understanding emerged, recognizing that ecosystems are dynamic and that some levels of disturbance can play a role in maintaining ecological processes. This shift has influenced contemporary management approaches, moving beyond strict preservationist models towards adaptive frameworks that balance conservation with sustainable recreation.

2.4.3 Intermediate Disturbance Hypothesis (IDH)

A significant shift in the understanding of ecological disturbances began with the introduction of the Intermediate Disturbance Hypothesis (IDH) by Connell in 1978. The IDH posits that species diversity is highest at intermediate levels of disturbance, where competitive exclusion by dominant species is reduced, and yet the mortality rate of species is not so high as to result in local extinctions. This hypothesis challenged the traditional view by suggesting that disturbances could, under certain conditions, enhance biodiversity rather than diminish it (Connell, 1978).

The IDH has since been widely applied in various ecological contexts, including recreation ecology. It provided a theoretical foundation for re-evaluating the impacts of human activities in natural environments, leading to the recognition that moderate levels of visitor disturbance might actually contribute to ecological diversity and resilience. Recent studies have supported this view, showing that controlled recreational activities can create habitat heterogeneity and promote species diversity (Battista et al., 2019).

2.4.4 Role of disturbance in maintaining ecology

In recreation ecology, disturbances as disruptions to ecosystems caused by recreational activities are recognized as significant factors influencing ecological dynamics. These disturbances can lead to soil compaction, vegetation loss, and wildlife displacement, thereby altering nutrient cycling and successional pathways. The frequency, intensity, and spatial extent of recreational disturbances are critical in determining their ecological impact. For instance, high-frequency disturbances such as repeated trampling can hinder plant regeneration, while less frequent disturbances might allow ecosystems to recover more effectively (Monz et al., 2019). The variability in disturbance regimes necessitates context-specific management strategies to mitigate negative ecological effects.

Recent studies have highlighted the complex relationships between recreational disturbances and biodiversity. While moderate levels of disturbance can sometimes enhance species diversity by creating a mosaic of habitats, excessive or poorly managed recreational activities often lead to habitat degradation and a decline in biodiversity. For example, research has shown that areas with high recreational use

exhibit reduced plant cover and increased soil erosion, negatively affecting plant and animal communities (Sumanapala & Wolf, 2019). Understanding these dynamics is essential for developing sustainable recreation practices that balance human use with ecological integrity.

2.4.5 Disturbance in tropical ecosystems

In tropical ecosystems, which are among the most biodiverse regions on the planet, disturbances are particularly important (Schmitt et al., 2020). Tropical forests, for example, are dynamic systems where disturbances such as tree falls, fires, and storms create gaps in the canopy. These gaps are essential for the regeneration of certain plant species, allowing light to reach the forest floor and enabling a diverse range of plants to thrive. Without these disturbances, tropical forests would likely experience reduced biodiversity, as dominant species would outcompete others for resources (Mirabel et al., 2020).

Research by Battista et al. (2019) highlights the importance of understanding the temporal scales of disturbance and recovery in these ecosystems. The study emphasizes that disturbances, while sometimes appearing destructive in the short term, are critical for long-term ecological balance and diversity in tropical environments (Battista et al., 2019).

2.4.6 Human recreation as a mimic of natural disturbances

Human recreational activities, particularly in natural areas, often mimic the disturbances caused by fauna, especially large mammals. Activities such as hiking, camping, and off-road driving can lead to soil compaction, trampling of vegetation,

and the creation of trails, similar to the effects caused by the movement of large herbivores. These human-induced disturbances can create new habitats, influence species composition, and even enhance biodiversity in ways similar to natural disturbances (Erfanian et al., 2021).

For instance, Gutwiller et al. (2017) found that in some cases, moderate recreational use of natural areas can enhance habitat heterogeneity and support diverse plant and animal communities. However, the study also noted that the benefits of such disturbances depend on the intensity and frequency of the activities, with excessive recreation leading to negative impacts such as soil erosion and habitat fragmentation (Gutwiller et al., 2017).

Thom et al. (2022) further expanded on this by exploring how different types of recreational activities impact ecosystems in various ways. Their research suggests that while some activities may mimic natural disturbances beneficially, others may exceed natural disturbance levels, leading to degradation rather than enhancement of ecosystem functions (Thom et al., 2022).

2.5 ECOLOGICAL IMPACTS OF RECREATION IN TROPICAL ECOSYSTEMS

When viewed through the lens of disturbance ecology, recreation can have both positive and negative impacts on ecosystems. The key lies in the management of recreational activities to ensure that they remain within levels that mimic natural disturbances rather than exceed them. Davidson et al. (2021) emphasized the need for adaptive management strategies that incorporate the principles of disturbance ecology. Their research highlighted that while low to moderate levels of human

disturbance can enhance biodiversity and ecosystem resilience, higher levels can lead to ecological degradation. They argue for a management approach that balances human use with the preservation of ecological integrity, using disturbance ecology as a guiding framework (Davidson et al., 2021).

Newman (2019) also contributes to this discussion by exploring the role of disturbance ecology in the Anthropocene, where human activities are the dominant force shaping ecosystems. Newman argues that understanding the interactions between human disturbances and natural processes is critical for developing sustainable management practices in an era of rapid environmental change (Newman, 2019).

2.5.1 Impacts of recreational in tropical ecosystem

Recreational activities such as hiking, wildlife watching, and camping have significant effects on tropical ecosystems, influencing both physical and biological components. These impacts range from direct physical damage to more subtle shifts in ecosystem functions. Research has demonstrated that trampling is a key stressor in various environments, with studies such as Liddle and Scorgie (1980) highlighting the detrimental effects on freshwater ecosystems, where trampling disrupts plant and animal life. Similarly, Bessa et al. (2017) observed that even casual disturbances on tropical beaches can alter faunal behaviour and destabilize ecosystem functions.

In terrestrial environments, recreation-related activities contribute to habitat degradation and biodiversity loss. For instance, Steven et al. (2011) found that avian

species experience reduced reproductive success and behavioural disruptions due to hiking and camping activities, ultimately leading to population declines. Furthermore, human-induced pressures, coupled with climate change, exacerbate the degradation of ecosystem services (Hernández-Delgado, 2015). These services, which include coastal protection and biodiversity maintenance, are essential to both ecological balance and local economies.

Recreational activities also pose significant challenges to ecosystem services and biodiversity. While nature-based tourism offers economic benefits, these must be carefully balanced against the ecological costs. Over-tourism, in particular, has been identified as a major challenge, necessitating the implementation of sustainable tourism practices (Ahmad, 2013). Studies indicate that community-based tourism programs, such as those suggested by Hamdi et al. (2019) and Matthew et al. (2022), can provide a framework for conservation efforts while simultaneously benefiting local populations.

Coastal and marine ecosystems are especially vulnerable to recreational pressures. Freshwater environments have experienced fish biodiversity loss due to tourism-related activities (Damen et al., 2018), while coral reefs and mangrove ecosystems face degradation from unchecked visitor impact (Ahmad, 2013; Mahmud et al., 2015). These pressures threaten not only biodiversity but also critical ecosystem services, including coastal protection and fisheries sustainability.

Addressing the impacts of recreation in tropical ecosystems requires integrated management strategies that consider both ecological and social dimensions.

Scientific research and community engagement play a pivotal role in developing effective conservation measures. Implementing sustainable tourism practices that align economic interests with environmental stewardship is essential for preserving Malaysia's natural resources and other tropical regions. Moreover, fostering education and awareness among tourists and local stakeholders is vital for minimizing recreational impacts and ensuring the long-term protection of biodiversity and ecosystem services (Selamat, 2016; Sidi et al., 2022).

2.5.2 Curvilinear Model

In recreation ecology, the pattern of impacts shows a curvilinear pattern (Marion 1998) (Figure 2.1). Much of the subject has been described by Marion (1998) which is explained here. One important implication of the curvilinear use-impact relationship is that nearly all use must be eliminated to achieve significant reductions in most forms of recreational impact. Level of use is an inherent determinant of recreational impacts, but research has demonstrated the importance of many other factors (Deacon, 2015). Three categories of influential factors and their potential for manipulation by Conservation managers are described:

- (i) Use-related,
- (ii) Environmental, and
- (iii) Managerial factors.

These factors illustrate the diversity of options available to managers in their efforts to reduce visitor impacts. However, such efforts incur costs in terms of their implementation, as well as costs in terms of visitor experience associated with alternative actions (Arredondo et al. 2020).

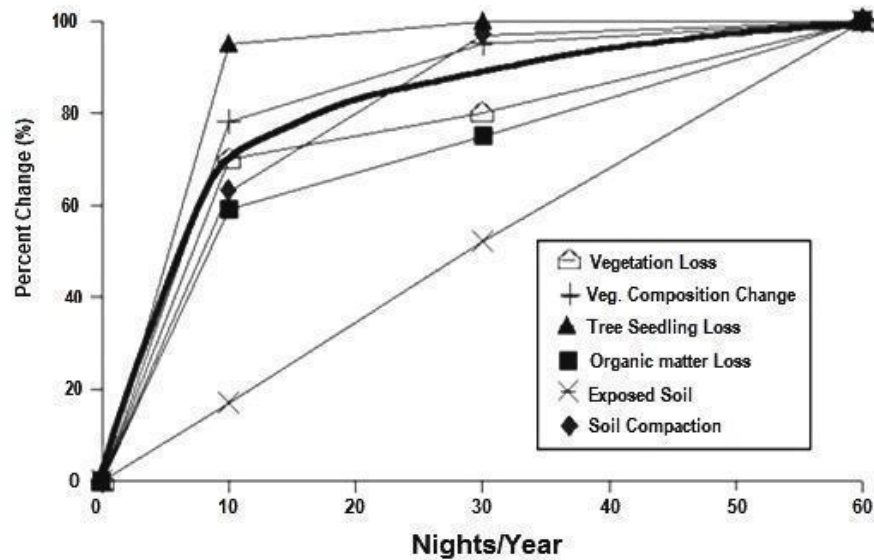


Figure 2.1: Changes of ecology parameters over time recreation activities occurred. The generalized curvilinear use-impact relationship is depicted by the thicker black line (Marion 1998).

2.5.3 Trail and Campsites

Ecological impacts of recreational activities in natural area are mostly concentrated along nature trails and campsites as suggested by Bookhari et al. (2020). These two foci of recreational activities are said to provide appropriate indication for level of impacts in the affected natural area. Arredondo *et al.* (2020) also pointed out that this factor should be the *raison d'être* for selecting trails and campsites as a research focus that could be used to identify the suitable physical impact indicators at the mountain trails in Malaysia.

Cole & Hall (2015) stated that the trails and campsite spots are the favourite locations that are visited regularly by the wilderness users. Most popular recreational activities such as hiking, camping and jungle trekking have a close connection to the trails (Ke, 2018). In remote mountainous regions, mountaineering activities also

need the trails to ensure the climbers can ascend in the right direction to reach the top of the mountains.

Basically, trails are where recreational activities are performed (Ballantyne & Pickering, 2015). Consequently, recreational impacts on vegetation, soil, and wildlife are most likely to occur in or along trails, especially those that are unsurfaced (Salesa & Cerdà, 2020). The study on recreational use of trails and its impacts mostly focuses on those factors affecting trail degradation such as trail widening, trail erosion and soil compaction in relation to use (Evju et al., 2020). Attempts to conduct studies on the subject should give more attention on vegetation loss in and alongside the trails because trampling is likely to be most concentrated along frequently used trails.

Nature trails are the most common mode of accessing and connecting routes within natural areas. Geographically, most of nature tourism attractions in Malaysia are located in remote areas (or “primitive core zone”) and placed within the boundary of national parks, protected areas and forest reserves (Nazaruddin 2016; Aihara *et al.*, 2016). These areas are usually surrounded by various natural attractions and feature uniqueness such as mountain complexes, multi-stepped waterfalls, hidden valleys and wilderness forests. Therefore, to reach these areas, nature trails are the most practical access, and function as a link to those destinations. Furthermore, trails are considered as the best option for enhanced recreation opportunities and experiences (Marion, 2023). For these reasons, it is plausible that the number of trail users is much higher than at other recreation places.

2.5.4 Nature Trails in Tropical Forest

Many previous studies have documented changes to vegetation, seedling recruitment, mortality, and soil properties along trails; however, these studies focused predominantly on recreational trails in the temperate regions (Ballantyne et al., 2016; Lenevych, 2021). Research on the recreational impacts of trails in tropical rainforests is limited, with few studies addressing this issue comprehensively. For instance, a review by Ballantyne and Pickering (2015) highlights that most research on trail impacts is concentrated in temperate and alpine regions, with tropical ecosystems being underrepresented or almost none (*sic*) in the literature except perhaps that of Boucher *et al.* (1991). Additionally, Gueratto et al. (2019) note that studies specifically focusing on trail impacts in tropical forests, such as their effects on butterfly communities, are relatively rare (Gueratto et al., 2019). In the subtropics, there have been several studies of this nature e.g., Liddle and Thyer (1986) who among earliest studied in the subtropical forest in Australia, and Jim (1987) who initiated such a study in Hong Kong.

The awareness of the lack of study and information on recreation impact use of trails has begun in the past four decades ago and this retarding the manager's ability to control the severe impacts on ecology although eco-tourism is increasing substantially in the tropical rain-forest area (Cole 1987). Up to recently, review by Ballantyne and Pickering (2015) highlights significant gaps in research on trail impacts in tropical and temperate ecosystems. This concern is significant because most of the tropical rain forest species combine several of the properties predicted by Kuss (1986) to be associated with sensitivity to damage (Cole 1987). The complex rainforest ecosystem, characterized by being green all year round, with high

biodiversity and moisture content, and easily compacted soil, exhibits significant variations in sensitivity to trampling between different kinds of plants and vegetation types (Ballantyne and Pickering 2015). A study by Zakaria et al. (2016) emphasizes that tropical rainforests, due to their high species diversity and complex structure, are particularly vulnerable to disturbances, including trampling, which can lead to soil compaction and loss of vegetation cover (Zakaria et al., 2016). Additionally, Marsandi et al. (2017) note that the diversity of plant species in tropical rainforests is closely related to soil conditions, which are highly sensitive to physical disturbances, such as trampling, leading to significant impacts on vegetation and soil health (Marsandi et al., 2017).

2.5.5 Ecological impact indicators

The increasing number of people in wilderness areas will lead to crowding, visitor conflict, and threats to wilderness values. Such incidents can be easily noticed, particularly in high concentration recreation areas such as recreation trails (Marion, 2023). Impact tends to become more prevalent along the trail. Therefore, recognition of the impact effort needs to be taken by the recreation resources manager. This managerial effort can only be done effectively with suitable indicators to balance public access with biodiversity management (Lei *et al.* 2022).

Globally, the request on the importance of indicators as a tool of sustainable resource management has long been agreed upon, as stated in Agenda 21 (UNCED, 1992). Presently, many indicators are commonly used to guide decision-making. In the field of tourism and recreation, ecological indicators enable the recreation manager to establish a standard (future action) of acceptability to guide

decision-making at the ground level (e.g., trail closures, use limit and activity zoning) (Meadema *et al.*, 2020).

Basically, indicators are needed to prove the type and severity of recreation impacts. In the long-term, impact indicators will help recreation resource administrators in the development of recreation impact monitoring systems. It also helps the administrators to protect both natural environments, and provide opportunities which would enhance visitor satisfaction, while promoting conservation and ecological sustainability at the recreation site (Barros *et al.*, 2015). Hammit and Cole (1987) defined resource impact or *ecological* impact as the disturbance to natural areas resulting from recreational use, where undesirable change to the resource base mean degradation to four elements, namely, soil, vegetation, wildlife, and water resources. (Marion *et al.*, 2016) described these elements in detail including the direct and the derivative effects.

2.5.6 Effects of trampling

Figure 2.2 below shows the overall impacts on the ecosystem due to recreational activities within a natural area. This figure shows the impacts of trampling on vegetation and soil. As recreational activities take place in natural areas, they can impact all resources in a wilderness ecosystem. Soil, vegetation, wildlife, and water are four primary components affected by recreational use (Marion *et al.*, 2016).

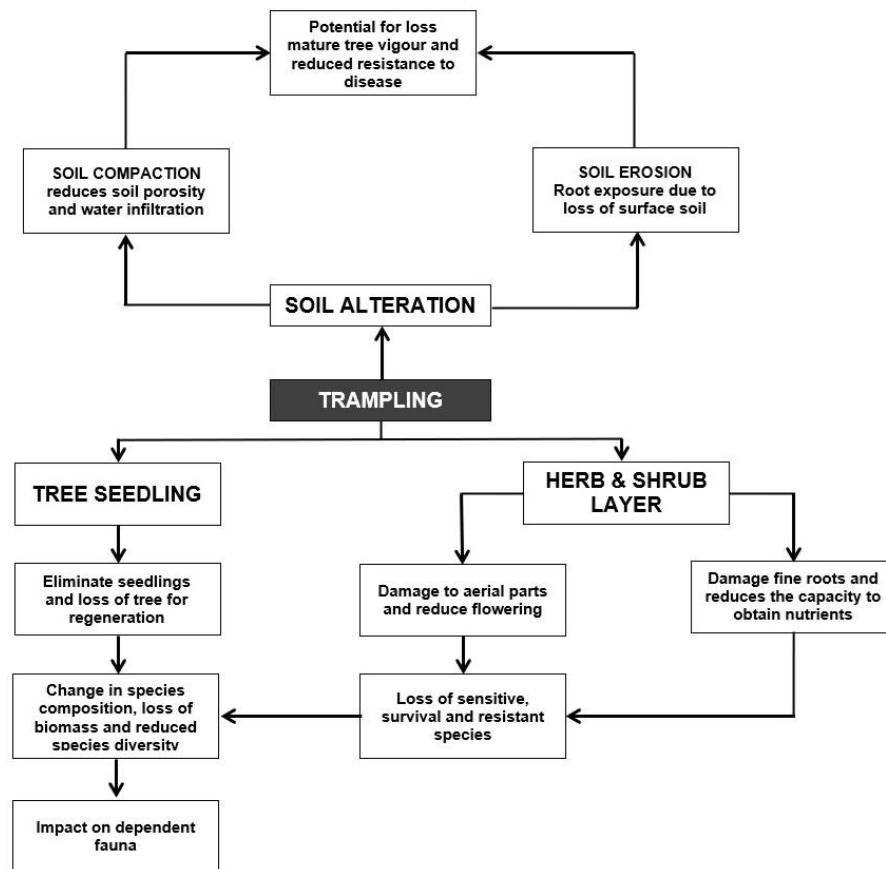


Figure 2.2: Effects of trampling on soil and vegetation (Newsome *et al.* 2002)

Among these four components, soil and vegetation attributes have been the focus of many studies (Ballantyne & Pickering 2015; Gathoni *et al.*, 2022). These attributes have been examined in the context of four different types of studies: trampling experiments, trail impacts, campsite impacts, and impact indicators. Trampling studies are directed at the relationship between amount of use and intensity of impact and the different susceptibilities of plant species or vegetation types (Apollo & Andreychouk, 2020). Impacts from recreational trampling in natural environments typically follow a natural progression. Initial and very light trampling may only damage particularly fragile vegetation. However, at low levels of trampling the majority of vegetation cover is lost and surface organic litter (e.g., leaves and twigs) are pulverized. At moderate trampling intensities all but the most resistant plant

species are lost, and mineral soils are exposed as organic soil layers are eroded. High trampling intensities expose mineral soils to compaction and erosion, which in turn expose the roots of trees.

Cole (1986; 1987) and Sumanapala & Wolf (2019) have described some generalized concepts about recreation impacts on trails particularly trampling, where the relation between amount of impact and damage is generally strongly curvilinear as indicated in Figure 2.1. The figure shows those sites with only 12 nights of campsite use per year caused substantial biophysical changes, while further increases in use could cause little additional change for most forms of impact. A few impact parameters, such as loss of tree seedlings, are highly affected by very low levels of site use. In contrast, the exposure of mineral soil occurs later in the progression of impacts and is related to use intensity in a more linear fashion. Thus, about 70% of the vegetation loss on sites receiving more than sixty (60) nights per year has already occurred on sites receiving ten (10).

2.5.7 Impacts on vegetation and soil

2.5.7.1 Vegetation/ Flora

Studies on recreational impact on vegetation cover plant density, biodiversity, and tree vandalism. Specifically, they involve reduced height and vigour, loss of vegetation cover, loss of fragile species, loss of trees and shrubs, tree trunk damage, introduction of exotic species, composition change, and altered microclimate (Kuznetsov et al., 2019). In most cases, deteriorations were observed (Chappell *et al.* 1971; Burden and Randerson 1972; Dale and Weaver 1974; Liddle and Greig-Smith 1975; Cole 1983; Cole 1986; Cole and

Hall 1992; Leung and Marion 2000; Ballantyne *et al.*, 2016; Erfanian *et al.*, 2021). (Gauj et al., 2019) also reported on similar trends i.e., the effect of recreation is greater on plants than that of logging, due to the regenerative capability of logged over-forest as compared to constant disturbance from recreational activities. Examination of any area of natural or semi-natural environment that is used for recreation will show signs of impact, usually by looking at differences in the size and quantity of plants in the used area. This effect may range from a minor pathway across a pasture, which can only be detected by a slight lowering in height of the grass and other plants, to the partial or complete clearance of trees and the rest of the ground cover in a forested area, camping area, trail, and other recreational areas.

Research by Marion et al. (2016) found that amount of impact is influenced by the amount of use, vegetation fragility, vegetation density and the type and distribution of the recreation activity. In all cases one simple way of measuring the degree of change is to record the weight of biomass, percentage cover of height of the undisturbed vegetation and to compare the results with the biomass, percentage cover of height of the plants in the disturbed area (Liddle 1997). Trampling can crush, bruise, shear off and uproot vegetation. In trampled places, plants may have reduced height, stem length, leaf area, flower and seed production, and carbohydrate reserves. Such changes adversely affect plant vigour and reproductive success and can lead to death. Consequently, the vegetation of trampled places generally has reduced biomass, sparser cover, reduced stature and a different species composition than undisturbed places (Mason et al., 2015).

Study by (Barros & Pickering, 2015) indicated that reduction in plant cover that occurred as a result of wear by hikers or vehicles has a curvilinear relationship with the number of hikers or vehicles walking or driving on the vegetation. Figure 2.3 (after Marion 1998) below illustrated the impact curve on trampling intensity where the terms "dispersal" and "containment" are frequently used to refer to the movement and control of trampling impacts in natural areas or recreational settings. Earliest research on recreation impacts on vegetation in Costa Rica rainforest area was conducted by Boucher *et al.* (1991). The study also found that impact on vegetation alongside trails give curvilinear response, suggesting that a similar response may be found in most habitat types. The exception to the curvilinear relationship between cover and wear appears to occur when the same plot is measured sequentially, rather than when a series of plots with different levels of wear and are measured at one time (Bayfield 1971, 1979; Holmes and Dobson 1976).

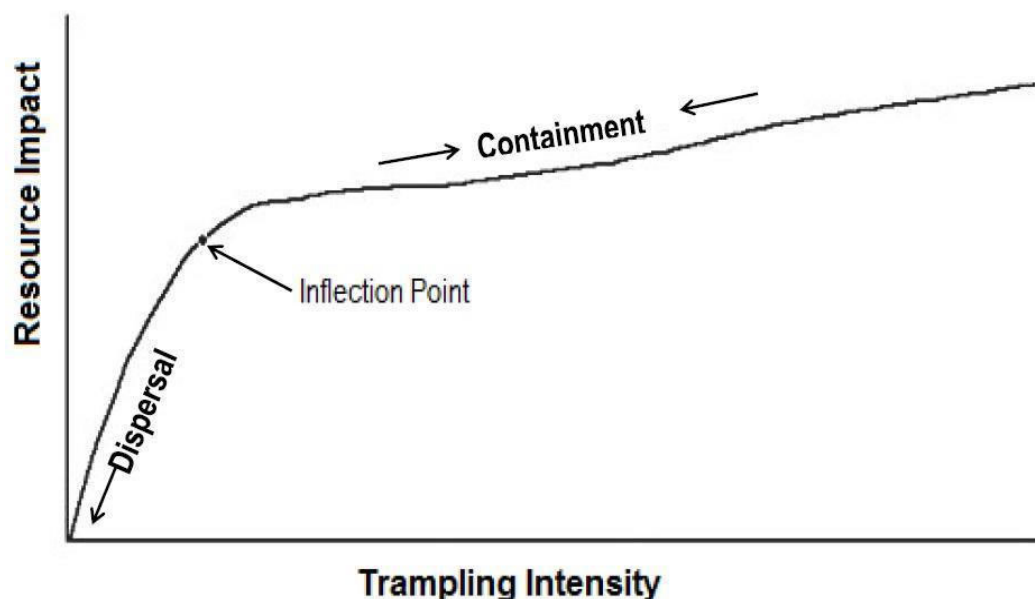


Figure 2.3: Recreation impact on resources with trampling intensity (Marion 1998).

Findings by Cole (1992) commented that in campsite area “the curvilinear relationship between amount of use and amount of impact can be explained by the tendency for activities to become increasingly concentrated as amount of use increases”. Furthermore, Liddle (1997) stated that although differences in height are often the first visual of wear taking place, it has not often been measured in wear experiments. However, height is important when the processes of damage are considered, especially with respect to the response of separate species.

One of the early studies by Klecka (1937) in Czechoslovakia provided a representative figure of a transect cutting across a path or trail that illustrates the effects of trampling on the height and composition of vegetation (Figure 2.4). The figure clearly shows the trend in height from the bare path through a gradient of decreasing trampling intensity to the untrampled bordering vegetation. The figure also depicts a transect cutting across a path showing the height and zones of the trampled vegetation where:

- **Zone 1** is untrampled, with *Trifolium repens*, *Lolium perenne*, *Poa annua*, *Polygonum aviculare*, *Plantago major*, *Achillea millefolium* and *Agrostis canina*.
- **Zone 2** is lightly trampled, with *Poa annua*, *Polygonum aviculare*, *Plantago major* and *Trifolium repens*
- **Zone 3** is heavily trampled, with *Poa annua* and *Polygonum aviculare*
- **Zone 4** is generally a bare ground

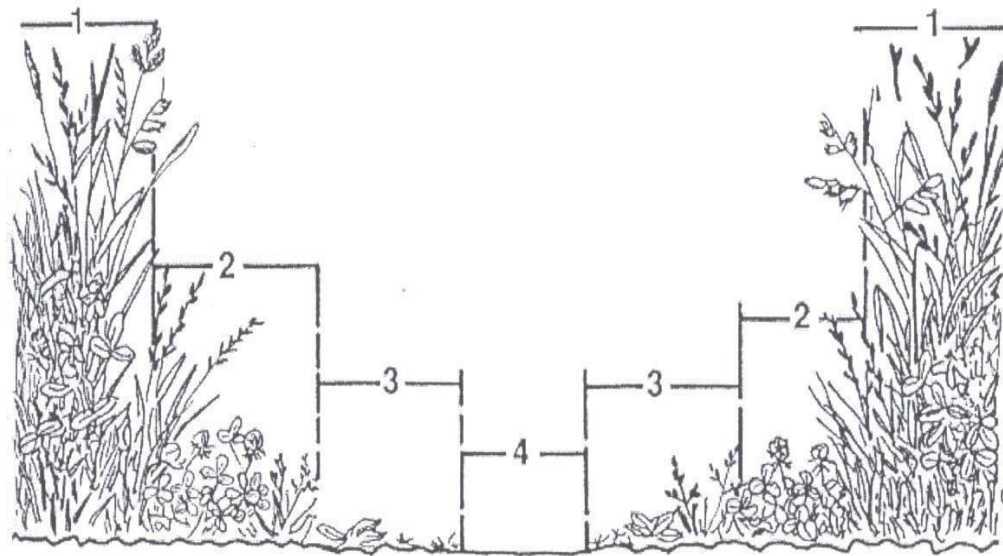


Figure 2.4: Cross section illustration or transect across of trail (Source: Kelcka 1937).

Conradi et al. (2015) demonstrated that species composition changes because species vary in their response to the direct and indirect effects of trampling. Species vary in their ability to resist being damage by trampling and also in their ability to recover from trampling damage. Characteristics and individually or in combinations that make a plant resistant to trampling are:

- a) being either very small or very large
- b) growing flat along the ground or in dense tufts
- c) having leaves and stems that a tough or flexible while characteristics that make a plant susceptible to damage include: (i) Having moderate stature, (ii) Having an erect growth form, and (iii) having woody, brittle or delicate stems and leaves

McManus et al. (2018) stated that vegetation ability to recover from trampling is largely a reflection of reproductive strategy and the location of growing

points of plants. The ability to recover is greatest in annuals, i.e., plants with growing points at or below the ground surface.

Vegetation is also altered by other forces other than those which have been mentioned above. Shrubs and trees are felled for firewood and tent poles. Recreationalists also inflict various mutilations such as hacking and carving with knives, collecting firewood and root exposure. Finally, a substantial amount of impact to vegetation occurs with the constructions of recreational and ecotourism facilities like trail, camping ground and picnic areas. Although several studies informed a negative correlation between recreational intensity and plant cover, plant height, species richness and species diversity (Hammit and Cole 1998; Nepal and Way 2007; Singh 2021), patterns of change should be determined by the original environments (Kobayashi *et al.* 1997), because site-specific and location factors are highly influential on the degree and form of the impact associated with recreational activities. In some cases, the impact opens forest gaps, allowing more light to penetrate. This increases plant biodiversity.

2.5.7.2 Soil

Soil here basically refers to a physical components or physical resources. Examples of physical impact can be seen through soil compaction, root exposure, exposed of mineral soil, loss of vegetation cover; while those of social impacts are human encounter, littering, vandalism, noise pollution, visitor conflict and crowding. In this study, the main focus is on the impacts on the soil, namely, soil compaction and content of organic matter in the soil. This

result of recreational impacts. Some of these changes involve feedback loops, either accentuating the change or stabilizing the situation (Figure 2.5) (Hammitt et al. (2015).

Erosion, compaction, and declining productivity of soils are considered some of the most damaging effects of visitor activities in parks and protected areas. These effects have been studied in detail both in campgrounds and along hiking trails (Teschner *et al.* 1979; Cole 1987; Liddle 1997; Leung and Marion 2019; Dragovich 2015; Rangel *et. al.*, 2019; Salesa and Cerdà 2020).

Research by Kalahroudi et. al. (2023) mentioned that plant roots are part of soil environment and the direct effect of trampling on plants is either to damage or kill them. This result is a reduction of cover and biomass of living tissue and initial increase in plant litter. The reduction in living material may also result in a reduction of root growth. This will, in turn, cause a destabilizing of the soil as the old roots decay and no new ones take their place. The penetration of roots and roots hairs and their subsequent decay normally contribute to the porosity of the soil so, in the long term, there will be a reduction in soil porosity as the surface vegetation is reduced.

Liu et al. (2021) stated in his study that trampling could result in the maceration and physical removal of litter from the path surface as well as a reduction of the depth of organic soil layers. This will also lead to reduction of porosity meaning that there is less space for air and water, and a consequent reduction in the rate of diffusion oxygen required for the respiration of soil, fungi, bacteria

soil animal and plant roots, leading eventually to a drastic reduction in the living processes of the soil. The reduction in soil water also reduces the flow rate and the movement of dissolved mineral elements from their source to plant roots. The recycling processes are also inhibited by the reduction of bacterial and other activity. The resources available to plant are therefore limited by a number of different processes, which all tend to lead to a further reduction of plant growth.

Soil biology and chemistry components under recreation impacts on soil are somehow poorly understood. Sherman et al. (2019) observed that trampled soil had brought about a reduction in arthropods, earthworms, nitrifying bacteria and increases in anaerobic bacteria. The study also showed increase in pH on campsites and trails, and inconsistent changes in concentrations of various soil nutrients in disturbed soils. Soils are known to react to the slightest introduction of chemicals into the environment. Soils act as natural filters and a storage medium for many anthropogenic materials introduced into the ecosystems (Dror et al., 2021).

The environmental disturbances such as introduction of metals, or compaction by trampling by campers are 'recorded' naturally by soils (Magomedov, 2020). Thus, soils are sensitive indicators for the slightest 'environmental disturbance including campsite perturbations' (Corstanje et al., (2016). While soil erosion and compaction issues have been examined in detail, the impacts of chemical introduction to park soils through campers' activities in parks and wilderness

areas have received very little attention and focus mostly on chemical properties related to soil fertility status (e.g., Mallikage *et al.* 2021)

Study by Dror *et al.* (2017), showed that humans are active vectors for the introduction and removal of chemicals in soils. Calcium, phosphorus, copper, zinc, carbon, and nitrogen occurred through the introduction and decomposition of food wastes in recreation site, and through the burning of organic and inorganic materials in fire pits. From a park management perspective, results from study by Mateer *et al.* (2020) should be useful to educate backcountry visitors and campers on the necessity to impose park regulations regarding the disposal of litter, food scraps, and soap water at designated locations. Results of the same study would also provide some ecological basis for the rules and regulations within the park.

One of the most obvious physical impacts is trampling (Figure 2.5). Trampling can be easily noticed along trail and campsites because these areas are frequently used. Also, visitors spend most of their times at these places. Recreational trampling can have an effect on soil and vegetation (Liddle 1975; Bayfield 1979; Mathieson and Wall 1982; Cole, 1983; Bratton 1985; Leung and Marion 1996; Buckley 2000; Tribe *et al.* 2000; Newsome *et al.* 2002; Mason *et al.* 2015; Bar (2017); Piscová *et al.* 2021; Kalahrودي *et al.* 2023).

Within a natural area, visitors normally travel on foot along the nature trails. Thus, trampling is unavoidable since visitors naturally engage their recreational activities at these areas. Effect of trampling begins with an impact

on vegetation when visitors walk on these places. Mason et al. (2015), Kalahroudi et al. (2023) and Gathoni et al. (2022) identified three initial effects, viz.: (i) abrasion of vegetation, (ii) changes to soil conditions (abrasion of surface soil or organic layer and compaction of soils), and (iii) the disturbance of wildlife. Apart from these, Cole and Spildie (1998) listed five primary impact variables associated with trampling, namely, (i) durability of the site environment, (ii) intensity of use, (iii) time of use, (iv) type of use, and (v) user behaviour. These authors also mentioned that vegetation cover, level of endurance and recovery will decrease if it is continually used for a period of one year.

Concerning on the recreational impacts on soil, many studies investigated on soil compaction in relation to the water uptake capability of plants in sustaining growth. The studies found that density was greatly increased, and pore volumes were greatly decreased (Cambi et al. 2017; Nazari *et al.* 2021). Findings of studies on soil also include loss of organic litter, loss of mineral soil, reduced soil moisture, reduced pore space, accelerated soil erosion and altered microbial activities (Lenevych, 2021). In addition, there have been studies on water quality of recreational areas especially on coliform counts, turbidity levels, dissolved oxygen, and temperature (Venohr *et al.* 2018; Abu *et al.* 2020); Cooke and Xia 2020). These studies showed that except for coliform counts, the impacts on water quality are generally less significant.

Schafft *et al.* (2021) reported studies on lake ecology as affected by camping activities that generally show higher macro-invertebrates stimulated by trace

elements, such as iron, which depletes available nitrates. (Schafft *et al.* 2021) described other impact studies including introduction of exotic species, increased nutrients inputs, increased levels of pathogenic bacteria, reduced health of aquatic ecosystems, composition change and excessive algal growth.

2.5.8 Recreation impacts and climate change

At the same time that climate change has the potential to have direct effects, it also has the potential to influence the utilisation and distribution of tourism and recreation experiences. As a consequence of climate change, there is the possibility that interactive effects (Figure 2.6) will take place. These effects have the potential to have an effect on biophysical resources that are also susceptible to disturbance from tourism and recreation activities (Monz *et al.*, 2021). Despite the fact that the damage that is being caused to ecosystems in parks and protected areas as a result of nature-based tourism and recreation is growing in both scale and severity, Monz *et al.*, (2021) stated that there is a lack of research that investigates the extent to which these anthropogenic disturbances interact with one another.

When compared to other activities, tourism and recreation that are based on nature are likely to be more vulnerable to changes in the weather and extreme events. According to Verbos and Brownlee (2017), activities are more likely to be dependent on the weather if they take place in areas with a smaller amount of infrastructure, rely on transportation powered by humans, take place in expansive topography, and require extensive planning.

According to Verrall and Pickering (2020), climate change has already had a negative impact on certain species that are found at extreme latitudes and elevations. Protected areas may experience the loss of species as suitable climate spaces travel beyond the boundaries of the parks that are currently in place. For example, Fang et al. (2018) and Hoffman et al. (2019) have conducted extensive research on the effects of climate change on recreational activities and animal species. According to Monz et al. 2021, the first experimental study of ecological interactions between recreational impacts and climate change was carried out more than twenty years ago. With regard to plants, however, the interactions have not occurred.

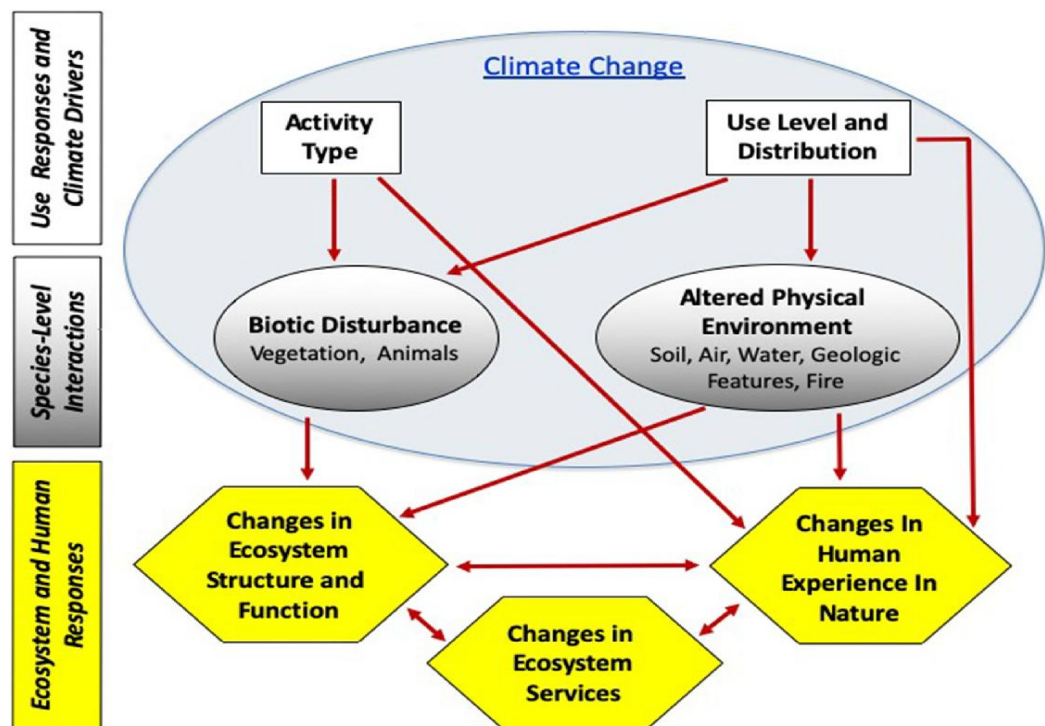


Figure 2.6: A conceptual model of the complex interactions of nature-based tourism and recreation use and climate change and the consequences on biophysical resources (Monz *et. al.* 2021)

2.6 MANAGEMENT STRATEGIES

2.6.1 Adaptive management approaches

Adaptive management is an iterative systematic cycle of improving resource management by learning from management outcomes (Williams & Brown, 2019). Recurrent uptake of this approach is particularly important in the management of recreational impacts in natural areas, where both conditions and visitor activities can change dramatically. For instance, research in Australia and New Zealand has shown successful applications of adaptive management to accommodate recreation alongside conservation in highly visited protected areas (Hadwen et al., 2020). Ongoing monitoring of ecological conditions and Trail usage use patterns can help managers adapt trail rerouting, site closures, and visitor education campaigns to address and mitigate specific impacts (Monz et al., 2021).

Technology has recently improved adaptive management practices. Geographic Information System (GIS) and Unmanned Aerial Vehicle (UAV)-based approaches are used increasingly to assess and monitor changes in vegetation, soil compaction and water quality over time (Tomczyk et al., 2023). Lessons learned from these studies can be applied to tropical ecosystems, such as those in the Maliau Basin, enabling the identification and application of targeted measures to enhance biodiversity and ecosystem services.

2.6.2 Sustainable tourism

A sustainable tourism practices seek to reduce adverse environmental effects while enhancing socio-economic benefits and visitor experience. This involves the establishment of visitor quotas, promotion of low-impact activities, and education

that fosters environmental stewardship (Ballantyne & Pickering, 2015). For example, environmental education and local livelihood opportunities are reflected in the ecotourism programs of Costa Rica's protected areas and are linked to both conservation and local (and national) socio-economic growth (Weaver et al., 2020). Certification schemes (e.g., Global Sustainable Tourism Council (GSTC) standards) help to foster sustainable tourism practices. Through these guidelines, these standards contribute toward mitigating visitor behaviour, ecological footprints, and the nature of potential tourism conflict (Meadema et al., 2020). Such a framework could be beneficial for protected areas in tropical regions such as Malaysia to achieve a balance between recreation and conservation goals.

2.6.3 Best practices in protected area management

Best practices for protected area management stress that ecological, social, and economic factors must be considered in an integrated fashion to provide sustainable outcomes. Implementation varies between and within nations and continents, but there are potential solutions and best practices, including zoning, carrying capacity assessments, and the use of ecological indicators (Marion, 2023). In tropical areas, zoning can be an effective strategy to separate overuse by recreation (typical in urban areas) from sensitive conservation areas because low-impact activities such as ecotourism do not overlap with the practice (Verlic et al., 2021).

A similar best practice is community engagement. Research has demonstrated that community engagement in decision-making processes leads to greater ownership and accountability for conservation results (Gillan et al., 2021). For instance,

participatory approaches in the governance of Malaysia's Kinabalu Park have effectively connected conservation action and indigenous communities' livelihoods (Noriega, 2020).

2.6.4 Policies and guidelines

Policies and guidelines for managing recreation in the tropical protected areas need to be context-relevant and research based. Some of the major policies are based on visitor capacity limitation, zoning for maintaining access to sensitive areas, as well as behavioural limits for visitors (Lei et al., 2022). For example, Brazil's National System of Conservation Units requires each protected area to have a specific management plan, which can include guidelines on recreational use and has significantly decreased losses of biodiversity in ecotourism hotspots (Marsandi et al., 2017). In Malaysia, existing policies could be reinforced under the National Forestry Act 1984 to meet the demand for recreation in biodiversity-rich protected areas such as Maliau Basin. These policies should establish clear guidelines for the development of trails, the monitoring of visitors, and the restoration of habitats. Use of additional framework for integrating biodiversity conservation, such as parameters from Convention on Biological Diversity's Aichi Biodiversity Targets, would be helpful (UNEP, 2019).

2.7 SYNTHESIS

2.7.1 Summary of key themes and findings

Highlights of this piece include the environmental impact of human activities in the tropics, particularly in protected areas such as the Maliau Basin Conservation Area (MBCA). It shows how recreation, while an economic growth driver, can degrade

biodiversity through soil erosion, habitat fragmentation, and disruptions to wildlife. For instance, studies conducted on Pangkor Island have shown the degradation of coral reef and soil erosion as a result of unregulated marine tourism. Likewise, the Matang Mangrove Forest Reserve is threatened by increased birdwatching and dolphin-spotting activities that threaten the ability of the ecosystem to provide critical services such as coastal protection.

The literature also contains some good news. Habitat heterogeneity is considered to be beneficial for species diversity in general, and the Intermediate Disturbance Hypothesis (IDH) explains that moderate levels of recreational activity promote species diversity. In MBCA, for example, restricted hiking has been adjusted through management planning to minimize ecological damage while showcasing biodiversity. Decision-making is guided by frameworks, which set thresholds for acceptable ecological impacts (Limits of Acceptable Change [LAC], Visitor Experience and Resource Protection [VERP]).

Understanding and managing these impacts depends critically on understanding visitor perceptions. Visible damage, including litter and vandalism, is more likely to attract visitors' attention than less visible or longer-term changes like soil compaction and loss of biodiversity (Clarkson et al. 2023). Research conducted at Gunung Gede Pangrango National Park in Indonesia and Bako National Park in (Borneo) Malaysia indicates that littering and vandalism features prominently in visitors' listings of major problems impacting their enjoyment of the recreation experience. Likewise, on Canada's Starkey Hill Interpretive Trail visitors rated visible signs of

apparent tree damage and campfires as more problematic than less obvious impacts such as soil erosion.

2.7.2 Gaps in existing literature and focus for this thesis

Despite a growing body of research on recreational ecology in tropical systems worldwide, there remain significant gaps in knowledge, especially when compared with the extent of the literature on temperate ecosystems. Regarding recreation ecology in Malaysia (the more specific context for the thesis), despite the country's dependence on eco-tourism, little research has been done on its ecological effects and to date national policy is not sufficiently grounded in evidence. Nature-based recreational activities, which can lead to soil erosion and trampling of vegetation, are not well understood for many areas.

CHAPTER 3

CASE STUDY AREA: MALIAU BASIN CONSERVATION AREA (MBCA)

In this chapter, background information about the study site in MBCA is provided mostly from secondary resources. The flow of discussion starts from the etymology of the area and then the history and milestones of MBCA. The location, geological formation, physical features, natural biodiversity is also described in this chapter. Furthermore, the natural attractions for tourism, infrastructure, and facilities tourism recreational activities available here have been alienated. Some general observation on ecological impacts of tourism in MBCA is also discussed.

3.1 OVERVIEW OF THE MALIAU BASIN CONSERVATION AREA (MBCA)

The Maliau Basin Conservation Area (MBCA) that emphasises the importance of understanding tropical rainforest ecosystems and the efforts that are being made to preserve them. Situated in Sabah, Malaysia, the Malaysian Biological Conservation Area (MBCA) is a remarkable location for environmental research due to its remote location, abundant biodiversity, and intricate ecosystems. The region is one of the least disturbed rainforests in Southeast Asia region, and as a result, it offers valuable insights into the conservation of species, the services provided by ecosystems, and the efficiency of protected areas in protecting biodiversity. An examination of the role that the MBCA plays as a living laboratory for the study of natural habitats and the development of strategies for sustainable conservation practices is presented in this overview.

3.1.1 Etymology of MBCA

According to Marsh (1989), the word “maliau” literally means “land of the giant staircases” in the local Pensiangan Murut language. This would mean that the Muruts had been observing the contours of the impressive multi-storey topography in the ancient past in order to coin such a term. This also suggests that the early Muruts would have ventured into the basin in yearly hunting expeditions although they were not known to have settled within the basin area (Marsh 1989).

3.1.2 History of MBCA

The MBCA has a rich history, dating back to the Pensiangan Murut tribes conducting annual hunting expeditions (Scholz, 2003). The Maliau Basin Conservation Area (MBCA) was ‘discovered’ by Western cultures in 1947 but acknowledging its role in Malaysian cultures long before this date. The Geological Survey Department team of North Borneo conducted the first expedition in 1960. The area was later incorporated into the Gunung Rara Commercial Forest Reserve in 1970. In 1976, the Forestry Department's Botanical Survey team attempted to ascend the north escarpment but failed to reach the rim. The Sabah Foundation designated the area as a Conservation Area in 1981, and in 1986, an expedition team of four trekked to Kuala Maliau. The BHP Minerals Company conducted extensive geological survey work, and the first major scientific expedition to the Maliau Basin was jointly organized by the Sabah Foundation and WWF-Malaysia. The Sabah State Government commissioned a Preliminary Environmental Impact Assessment (EIA) in 1991, which revealed that mining activities would still have serious impacts on the basin, including increased access to prospectors, hunters, and gaharu and rattan collectors. The Maliau Basin Conservation Area was elevated in 1997, and the State

Assembly of Sabah elevated it into a Class I Protection Forest Reserve. In 2000, intensive field surveys were started, and in 2001, a first major expedition reached Lake Linumunsut in the northern part of the basin. The Maliau Basin Studies Centre site was officially opened in 2003 by HRH Prince Henrik of Denmark and Tan Sri Datu Khalil bin Datu Haji Jamalul, the Director of Yayasan Sabah.

The Maliau Basin Conservation Area (MBCA) has undergone several developments since 2003, including the Yayasan Sabah Danida Project in 1999, the United Nations Development Programme-Global Environment Facility project in 2003, and the publication of "Maliau Basin Sabah's Lost World" in 2004. The MBCA was initially gazetted as a Protection Area Class 1 in 1997, but later became a Forest Reserve Class 1 in 2012. In 2013, preparations for a Strategic Management Plan and proposals for the site to be added to the World Heritage List led to the creation of the Damai Rainforest Complex. These developments have contributed to the conservation and research efforts of the MBCA.

3.1.3 Location, area, and geological formation of MBCA

MBCA is one of the officially designated or gazetted conservation areas in Sabah which is administered by the Sabah Foundation. It is located about 190 kilometres south-east of Kota Kinabalu, the capital city of Sabah, Malaysia and only forty kilometres from the Indonesian border in Kalimantan (Figure 3.1) (Phillips 2002). In terms of administrative region, it is located with the Sandakan District of Sabah.

MBCA covers an area of approximately or 588 km² (58,840 hectares) including the Maliau Basin itself (390 km²) and additional surrounding area of 198 km² forested

lands in the east and north of the basin rim lake called Lake Linumunsut about 12 hectares which is Sabah's only fresh-water lake (Phillips, 2002). In terms of geographical coordinates, MBCA centred on 4°55'0" and 116°55'0" East (Nais *et al.* 2013).

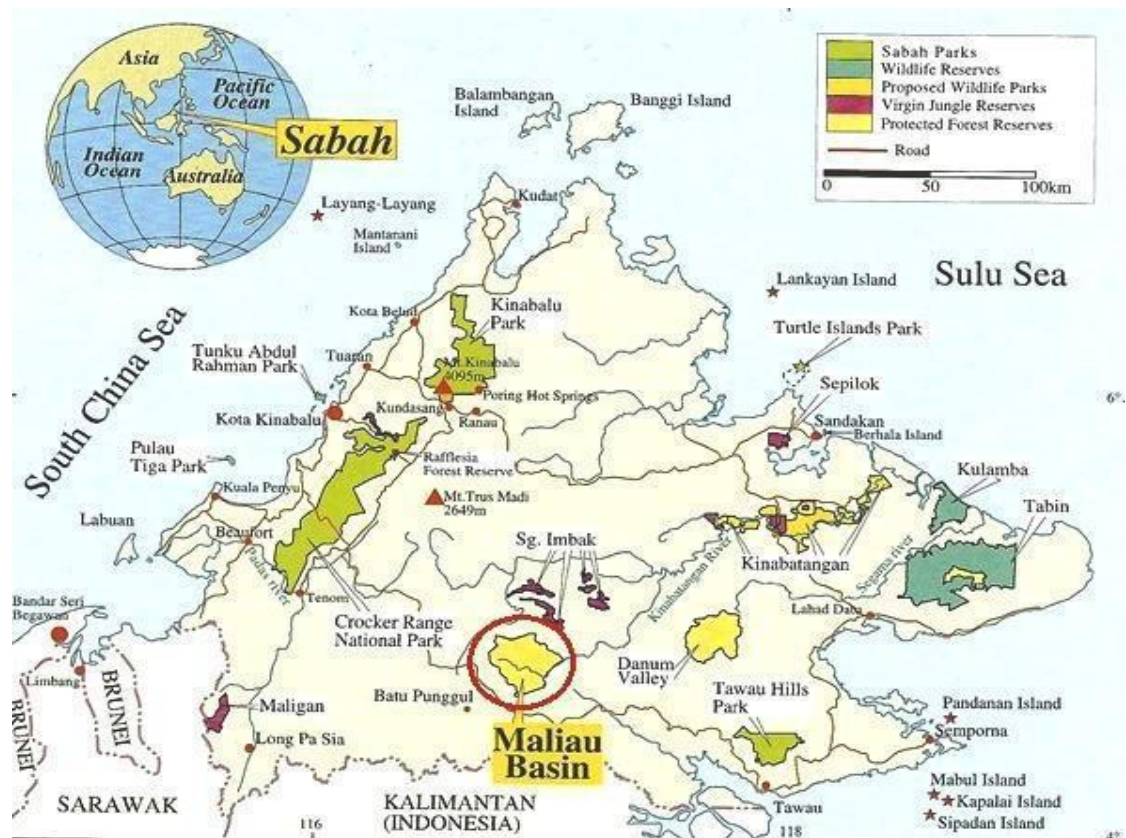


Figure 3.1 Map of Sabah showing various conservation areas including MBCA (In red circle). [Source: Hazebroek *et al.* 2004]

The basin itself is a somewhat circular- or saucer-shaped (Figure 3.2), and it is a unique geological formation created during the past geological history of Sabah. Hall (2011) described the geomorphological formation of Maliau Basin as resulting from the subduction of the proto-South China Sea beneath Northern Borneo which terminated the early Miocene after the collision of the extended South China

continental margin crust. The collision resulted in an uplift and erosion in the interior of Borneo which provided sediment to the north, east and south.

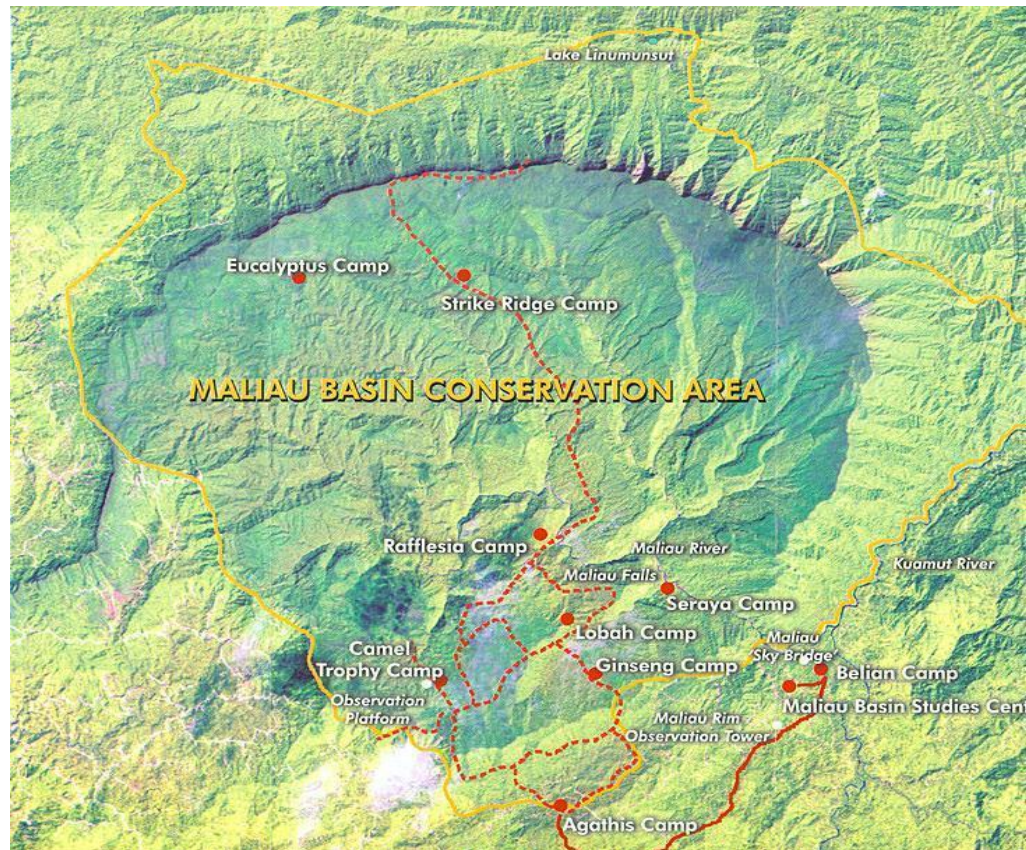


Figure 3.2: The saucer shaped Maliau Basin (Nais *et al.* 2013).

Hall (2011) further explained that in southern Sabah there was wide basin south-east of Crocker Ranges as postulated by Noad (1998), Balaguru *et al.* (2003), and Balaguru & Nichols (2004). Most of the sediment fed into this basin and carried to the Sulu Sea came from Borneo interior (Hall 2011). River and shallow marine sediments are now preserved in a number of structures described as circular basins, which are remnants of the much larger basin supplied by a large river system (Hall 2011). Due to the unique geological features and since the area was little known until quite recently, Maliau Basin is often called as “The Lost World”.

The entire region of the basin is rugged, and the saucer-shaped topography is distinguished by its almost circular parameter, and it is sharply delimited on most sides by cliffs or very steep slope on the outside rim, thus making them insurmountable on foot from most directions. The highest point is located in the north rim reaching over 1,675 metres in elevation. The basin is about twenty-five kilometres wide dominated by sedimentary formation comprised of gently inclined beds of mudstone and sandstone (Phillips 2002).

Geographically, the basin represents a single catchment and is drained by a set of radiating tributaries of the Maliau River. Interestingly, one of its tributaries descends into a stepped geological formation thus forming magnificent series waterfalls known as Maliau Waterfalls or Maliau Falls. Apart from these, there are many other smaller waterfalls that can be found throughout the basin. The main river, i.e., Maliau River, exits into the Kuamut River in the south-west of the basin after passing through a gorge, and eventually, the waters reach the Kinabatangan River which is the longest river in Sabah.

3.2 PHYSICAL FEATURES AND ECOLOGICAL CHARACTERISTIC

3.2.1 Geomorphology and landscape features of MBCA

Maliau Basin forms thrilling features in the landscape of the south central of Sabah (Figure 3.1). Resembling a volcanic caldera, the 25-km-wide basin is made up of sedimentary rocks, comprising gently inclined beds of sandstone and mudstone (Nais *et al.* 2013). The basin surrounded by mountainous rim forms steep outward facing slope and cliffs which is difficult to climb from any direction without special gear. Along the Basin rim, the highest point is Gunung Lotung situated at 1600 m

elevation. The single catchment basin drains and accumulates water into a single stream of the Maliau River. Due to layers of formation of rocks along the way, Maliau River forms several drops of seven-tiered Maliau Fall, where the longest drop is 28 m. Thereafter, the river flows through the Maliau Gorge, and it later joins Kuamut River outside the basin, which is a major tributary of Kinabatangan River, the pristine rain forest of Maliau Basin raises between lowland to montane forest at 300 m to about 1,800 m above sea level. At a lower elevation of mixed dipterocarp forest, more than seventy species of dipterocarps have been recorded apart from a high diversity of fruit trees.

3.2.2 Biodiversity and endemic species of MBCA

At least 12 distinct forest types are found in MBCA, and this gives a good impression of the MBCA's forest uniqueness and diversity (Hazebroek *et al.* 2004). A study by Phillips (2002) found that most of the northern and eastern parts outside of the basin are covered by unlogged hill dipterocarp forests with smaller amounts of lowland dipterocarp forest around Lake Limununsut and the eastern boundary of MBCA. Along the alluvial flats and lower slope of the central valley inside the basin, only about 11 per cent is covered in lowland dipterocarp forest which grades gradually into hill dipterocarp forest on the slopes and ridges (Nais *et al.* 2013).

MBCA has a variety of physical features with the elevation height reaching up to 1700 m ASL. On the ridges between 1,200 and 1,500 m, ASL upper montane forest has rich and unique species. Among the main types of forest are Oak-conifer Forest, upper and lower Agathis forest, upper and lower montane heath forest and montane ericaceous or rim forest (Nais *et al.* 2013). Generally, Agathis forest is dominated by

several species such as *Agathis borneensis*, *Shorea platyclados*, *S. venulosa* and *S. coriacea*.

The southern part of the basin is dominated by heath forest. The mean elevation here is 1,000 m ASL. This part is characterized by dense and slender trees in the genera of *Parastemon*, *Medinella*, *Prunus*, *Rhododendron*, *Vaccinium*, *Elaeocarpus*, *Tristaniopsis* and *Pandanus*. Another important forest type in MBCA is Oak-conifer Forest which is dominated by trees in the genera of *Lithocarpus*, *Dacrydium*, and *Gymnostoma*. Besides that, there are some common epiphytes found including some species of orchids such as *Nephelaphyllum trapoides*, *Coelogyne* sp. and the rare *Bulbophyllum cf. limbatum*. Some orchid species that are endemic to Sabah are also found here such as *Dendrobium parthenium*, *Dendrobium spectatissimum*, *Denrochilum augustipetalum*, *Eria Ignea*, *Eria kinabaluensis*, *Acriopsis gracilis* and *Corybas piliferus*.

There are some other species that endemic to Borneo that also have been recorded including *Dendrobium cinnabarinum*, *Chelonistele lurida*, *Coelogyne planiscarpa*, *Coelogyne tenompokensis*, *Dendrobium kiauensis*, *Dendrobium pictum*, *Dendrobium rosellum*, *Dendrobium sculptum*, *Dendrochilum anomalum*, *Dilochia cantleyi*, *Entomophobia kinabaluensis*, *Epigeneium speculum*. On the high elevation, the montane ericaceous forest is characterized by the presence of stunted trees that includes trees in the family of Ericaceae (*Rhododendron*, *Vaccinium*, and *Diplycosia*), Myrtaceae (*Eugenia*, *Tristaniopsis*), Lauraceae (*Litsea*, *Cinnamomum*), Guttiferae (*Callophyllum*) and Podocarpaceae (*Podocarpus*, *Dacrydium*). In addition, 20 species of *Rhododendron* out of the 35 recorded in Sabah can be found

in MBCA including the rare *Rhododendron javanicum* And *Rhododendron burtii* (Phillipps 2002). Another common species sighted in stunted areas are pitcher plants such as *Nepenthes stenophylla*, *Nepenthes lowii* and *Nepenthes tentaculata*. A newly found in Sabah for *Nepenthes veithii* and also its hybrid *Nepenthes stenophylla* were also found here (Nais *et al.* 2013).

MBCA is very important for floral biodiversity as indicated in floral record recently. More than 1,800 species in 638 genera of 168 families of which fifty-four are red-listed by the IUCN have been found (Nais *et. al.* 2013). These figures include the rare *Rafflesia tengku-adlinii*, at least six types of pitcher plants, 80 species of orchids, new species of *Thismia*, *Benincasa*, and *Zehneria*, new *Gymostoma*, and ginger species (*Geostachys maliauensis*) that is endemic to MBCA. To date, four new plant species have been discovered in MBCA (a tree *Polyosma maliauensis*, two gingers, and a moss), as well as several new records for Borneo including a mango tree, *Mangifera bullata* (Nais *et al.* 2013).

3.3 RATIONALE FOR USING A CASE STUDY APPROACH IN MALIAU BASIN CONSERVATION AREA (MBCA)

The case study approach is particularly suited to exploring complex, real-world phenomena in-depth, making it ideal for studying the Maliau Basin Conservation Area (MBCA). Given the unique ecological, geological, and conservation challenges of MBCA, a case study allows for a comprehensive and detailed examination of the area's characteristics, conservation strategies, and broader implications for biodiversity preservation. This approach enables researchers to delve into the dynamics of environmental management, species conservation, and the role of

protected areas within the context of MBCA, providing valuable insights that might be missed with other research methods.

3.3.1 Understanding case study methodology

The case study methodology involves an in-depth exploration of a particular subject within its real-life context. In the context of MBCA, a case study allows researchers to closely examine the interplay of natural processes, human intervention, and conservation outcomes. This approach is especially effective in studying complex systems where variables cannot be controlled or manipulated, such as natural ecosystems.

3.3.1.1 Explanation of Yin's (2018) case study design principles in MBCA

Yin's (2018) case study design principles provide a structured framework for conducting case studies, ensuring rigor and validity in exploratory research. Yin outlines several key components essential to effective case study design, which are highly applicable to research in MBCA:

Case studies begin by framing specific research questions. In MBCA, these questions could revolve around how conservation efforts are implemented, what factors influence biodiversity, or how ecological restoration strategies are applied. Yin (*ibid.*) emphasizes the importance of selecting a case that provides meaningful insight. MBCA is an exemplary case due to its rich biodiversity, pristine ecosystem, and the challenges it faces from human activity, making it a perfect candidate for detailed examination. Yin (*ibid.*) advocates for a variety of data sources, including interviews, field

observations, and documents. This approach allows for a holistic understanding of MBCA, incorporating local knowledge, scientific data, and conservation policies.

The analysis in Yin's (ibid.) design focuses on identifying patterns and drawing conclusions from multiple data points. In MBCA, data analysis can reveal the effectiveness of different conservation strategies and provide insights into ecological processes at work. While case studies often focus on a specific subject, Yin suggests that they can offer broader lessons. Findings from MBCA can inform conservation efforts in other tropical rainforest ecosystems, making the study both context-specific and broadly applicable.

3.3.1.2 The Role of case studies in recreation ecology research

Recreation ecology examines the impacts of human recreational activities on natural ecosystems. In this field, case studies are invaluable because they allow researchers to investigate the specific environmental pressures exerted by tourism and other human activities. In MBCA, case studies can explore how controlled ecotourism and recreation affect biodiversity, forest regeneration, and conservation outcomes.

By focusing on a defined area like MBCA, case studies enable the detailed tracking of environmental changes and human impact over time. For instance, researchers could investigate how trail use, camping, or guided tours affect soil erosion, wildlife behaviour, or plant species composition. Such findings are crucial for developing sustainable management practices that balance

conservation goals with ecotourism, a significant contributor to funding conservation efforts in protected areas like MBCA.

The case study approach, guided by Yin's design principles, provides a robust and comprehensive framework for exploring the complex ecological and conservation dynamics within the Maliau Basin. This method allows for in-depth understanding of MBCA's unique environment, and through its findings, it can contribute valuable insights to broader environmental conservation efforts and recreation ecology research.

3.3.2 Unique vs. Transferable purposes of the case study

When using a case study approach in ecological research, particularly in diverse environments like the Maliau Basin Conservation Area (MBCA), it is essential to understand the balance between two key research purposes: unique and transferable. These distinct but complementary goals provide the rationale for employing a case study method in a highly complex ecological system like MBCA, which differs significantly from temperate forests in terms of climate, biodiversity, and ecological dynamics.

3.3.2.1 Definition and differentiation

A case study approach is particularly useful in ecological and conservation research, as it allows for the detailed investigation of a specific phenomenon or location, such as the Maliau Basin Conservation Area (MBCA). Case studies typically serve two main purposes: unique and transferable.

Understanding the distinction between these purposes is critical for evaluating the broader impact and applicability of the research.

A case study's unique purpose focuses on capturing the specific characteristics and context of a particular ecosystem, which in this instance is the MBCA. MBCA is often referred to as the "Lost World of Sabah" due to its isolated and pristine environment, making it a unique site for studying tropical rainforest ecosystems. The unique purpose here lies in uncovering ecological phenomena that are exclusive to this area, such as endemic species, ecological processes, and conservation challenges that might not be found elsewhere. This approach emphasizes the intrinsic value of the case, concentrating on its distinctive attributes (Mills *et. al.*, 2019).

On the other hand, the transferable purpose focuses on generating insights that can be applied beyond the specific context of MBCA. While MBCA presents unique ecological characteristics, the study's findings may also provide lessons applicable to other ecosystems, particularly those facing similar conservation challenges. The goal is to derive generalizable principles or strategies that can be adapted to different settings, such as temperate or other tropical forests, enhancing the broader relevance of the research (Gerring, 2021). For example, the adaptive management strategies developed in MBCA might be applicable to other biodiversity-rich areas under threat from human activity.

3.3.2.2 How case studies can fulfill both purposes

The case study method is versatile, allowing it to simultaneously fulfill both unique and transferable purposes. This balance is achieved by focusing on specific, detailed research questions while also exploring broader ecological or conservation themes that resonate beyond the immediate context of the study.

Fulfilling Unique Purposes in MBCA: MBCA is characterized by its isolation, rugged topography, and rich biodiversity, making it an ideal site for studying unique tropical rainforest dynamics. The case study approach allows researchers to capture the distinctiveness of this region. For instance, MBCA is home to many rare and endemic species, including orchids, pitcher plants, and mammals such as the clouded leopard. These species and their interactions with the environment represent site-specific phenomena that may not occur in other ecosystems (Thomas, 2020).

Moreover, MBCA's unique topographical features, such as its steep cliffs and valleys, contribute to the creation of microclimates, which in turn support specialized habitats. A case study approach allows for detailed investigation into how these features influence biodiversity and ecological processes, providing insights that are unique to this particular region. Understanding these dynamics is crucial for developing targeted conservation strategies that are finely tuned to the specific needs of MBCA (Laurance et al., 2019).

Fulfilling Transferable Purposes Beyond MBCA: While MBCA presents unique characteristics, the research conducted there can also contribute to broader ecological knowledge and conservation practices. One of the key benefits of case study research is that it can offer generalizable insights about ecosystem management and conservation, even from such a specific site. For example, studies on the impact of human Trail usage and ecological tourism in MBCA can provide lessons on sustainable tourism practices that are applicable to other forest reserves facing similar pressures (Monz et al., 2020).

In particular, case studies in MBCA can help illuminate broader principles regarding forest resilience and ecosystem services, both of which are concerns in tropical and temperate forests alike. Findings from MBCA about how ecosystems recover from disturbance or how they maintain biodiversity in isolated environments can help inform management strategies in other protected areas worldwide (Gerring, 2021). These findings are not limited to tropical forests; temperate forest ecosystems can also benefit from strategies that prioritize biodiversity protection and sustainable resource management.

Balancing the Unique and Transferable: A well-designed case study balances the investigation of unique, context-specific phenomena with the search for broader patterns and principles that can be applied elsewhere. In MBCA, researchers can conduct in-depth studies on site-specific issues such as endemic species protection, microclimate effects on biodiversity, and remote ecosystem management. At the same time, by focusing on broader conservation themes such as biodiversity preservation, ecosystem resilience,

and human impact on protected areas, the study provides insights that are useful beyond the specific boundaries of the MBCA (Flyvbjerg, 2020).

By combining both purposes, the case study approach in MBCA enriches the global discourse on conservation and ecosystem management. It contributes to a deeper understanding of tropical rainforest dynamics while also offering practical solutions that can be adapted to other ecosystems facing similar environmental challenges.

The case study approach in the Maliau Basin Conservation Area serves both unique and transferable research purposes. It captures the specific ecological and conservation challenges of the MBCA, while also contributing broader insights that can inform management strategies in other ecosystems. By balancing these two purposes, the case study method offers a comprehensive framework for exploring both the uniqueness of the Maliau Basin and the general principles that can apply to global conservation efforts.

3.4 JUSTIFICATION FOR SELECTING MALIAU BASIN CONSERVATION AREA (MBCA) AS THE CASE STUDY

The Maliau Basin Conservation Area (MBCA) is uniquely suited as a case study for recreation ecology research, particularly for examining the effects of recreational disturbance in tropical rainforest ecosystems. Several factors justify its selection, including its ecological significance, alignment with research objectives, and a rigorous selection process. MBCA's pristine environment, high biodiversity, and relatively low levels of human disturbance make it an ideal site for studying the ecological impacts of recreational activities, such as those occurring along the

established recreation trails (Thomas, 2020). The research objective of understanding how recreational disturbance affects tropical rainforests, and correlating these effects with visitor perceptions, aligns perfectly with MBCA's context, where tourism is carefully managed, yet impacts remain underexplored (Monz et al., 2020). Moreover, the selection process considered the availability of comprehensive ecological data, the representativeness of the site as a tropical rainforest ecosystem, and its accessibility for fieldwork, all of which further support MBCA as an exemplary location for this study (Laurance et al., 2019).

3.4.1 Selection criteria for MBCA

The Maliau Basin Conservation Area (MBCA) is an ideal site for recreation ecology research due to its ecological significance, comprehensive availability of data, and its accessibility as a representative tropical ecosystem. Ecologically, MBCA harbors a wide range of biodiversity, including numerous rare and endemic species, making it critical for studying the impacts of human activity on fragile ecosystems (Thomas, 2020). Additionally, the availability of long-term environmental monitoring data enhances its suitability for empirical research, providing researchers with valuable baseline information on the area's flora, fauna, and ecological processes (Laurance et al., 2019).

Despite its remote location, MBCA is relatively accessible for scientific expeditions, further reinforcing its selection as a research site. As a well-preserved tropical rainforest, it offers representativeness of broader tropical ecosystems, allowing findings to be generalized to similar environments (Monz et al., 2020). This combination of ecological richness, data availability, and ecosystem

representativeness makes MBCA a valuable case study in recreation ecology research.

3.4.1.1 Ecological significance

The Maliau Basin Conservation Area (MBCA) is one of the most ecologically significant protected areas in Malaysia and Southeast Asia. Often referred to as the "Lost World of Sabah," MBCA harbors a wide range of ecosystems, including lowland dipterocarp forests, montane forests, heath forests, and swamps. Its geographical isolation has preserved its biodiversity, which includes over 2,000 species of plants, 290 species of birds, and several endangered mammals such as the clouded leopard, Malayan sun bear, and Bornean pygmy elephant (Rahman et al., 2021). This makes MBCA not only a biodiversity hotspot but also a critical area for conservation and scientific research on tropical ecosystems. Ecologically, MBCA represents a nearly pristine environment, providing an opportunity to study human-environment interactions without the heavy historical impacts of deforestation or extensive land use changes that are common in other tropical areas. Its high level of biodiversity and complex ecosystem structures offer an ideal setting for understanding how recreational activities, such as tourism, might affect such environments, which is a central focus of recreation ecology (Ling et al., 2022).

3.4.1.2 Availability of Data and Accessibility

MBCA is one of the most thoroughly studied conservation areas in Malaysia, with numerous research projects conducted on its biodiversity, forest ecology, and conservation efforts. This availability of baseline ecological data is crucial

for recreation ecology research, as it allows scientists to compare pre-existing conditions with those observed after the introduction of human activities. For example, studies on plant diversity, soil conditions, and wildlife presence have already been established, offering a foundation for further studies on the impact of tourism and other recreational activities (Mohamed & Hashim, 2020).

While the area is relatively remote, recent infrastructure improvements, including research stations and designated visitor trails, have made MBCA more accessible for both researchers and controlled eco-tourism. Its accessibility, combined with a limited number of visitors and regulated tourism, allows researchers to study human impacts in a controlled setting, making MBCA particularly suitable for recreation ecology studies (Chung et al., 2023).

3.4.1.3 Representativeness of Tropical Ecosystems

MBCA is representative of Borneo's tropical rainforest ecosystems, which are among the most biodiverse and complex ecosystems globally. The area's tropical climate, diverse vegetation, and wildlife provide a model for studying the broader effects of recreation on tropical forests worldwide. MBCA's inclusion of both lowland and montane forest types allows for the examination of human impacts across different altitudinal gradients and ecosystem types. This makes it possible to generalize findings from MBCA to other tropical forests facing similar challenges from human recreational activities (Zakaria et al., 2022).

3.4.1.4 Alignment with Research Objectives

The research objective is to understand the effects of recreational disturbance on tropical rainforest trails and how these disturbances correlate with visitor perceptions, expectations, and satisfaction. The Maliau Basin Conservation Area (MBCA) is an ideal location for studying both ecological impacts and visitor experiences in a tropical forest context due to its rich biodiversity, relatively undisturbed ecosystems, and controlled visitor access. MBCA's alignment with this research objective is evident in its ecological integrity, which allows researchers to study the impacts of recreational activities in a near-pristine environment.

MBCA's controlled visitor access allows for a comparative analysis of disturbance impacts and their thresholds. Additionally, visitors to MBCA often come with the expectation of experiencing an unspoiled natural environment, providing a rich context for understanding how ecological disturbances, such as trail wear and vegetation damage, influence visitor satisfaction and perceptions of the conservation area's ecological health.

The research can investigate the impact of recreational disturbance on trail degradation, wildlife behaviour, and visitor perceptions, expectations, and satisfaction with their visit. The visible effects of trail degradation or ecological disturbances could significantly influence visitors' perceptions of the area's ecological health. This research can investigate perception of disturbance, expectations vs. reality, and the transferability of established impact assessment methods from temperate to tropical forest ecosystems.

MBCA's tropical rainforest ecosystem provides a contrasting environment to temperate forests, making it an ideal site to evaluate whether impact assessment methods used in temperate regions—such as measuring soil compaction or vegetation recovery—are effective in tropical settings or whether new methodologies need to be developed. The research will also assess which principles from temperate forest management can be adapted to tropical ecosystems, particularly in managing visitor impact on sensitive environments.

In conclusion, the selection of MBCA as a case study for recreation ecology research is justified by its alignment with the research objectives and its ability to address key questions related to the effects of recreational disturbance in tropical forests. MBCA's ecological integrity, controlled visitor access, and representativeness make it an ideal location for examining the impacts of recreational disturbance on both the environment and visitor experiences.

3.4.2 Process of Selection

3.4.2.1 Choosing MBCA over other sites

The selection of MBCA as a case study site involved a comprehensive assessment of several factors, including ecological integrity, existing research infrastructure, and its potential to contribute to recreation ecology knowledge. Other potential sites, such as Danum Valley and Kinabalu Park, were considered, but MBCA was ultimately chosen due to its more isolated and less disturbed condition. This allows for the study of human impacts on a truly pristine ecosystem, offering a unique opportunity to establish baseline impacts of recreation that are not confounded by past human activity (Ling et al., 2022).

The presence of existing research stations and facilities in MBCA also played a critical role in its selection. The presence of Maliau Basin Studies Centre, with its accommodations, laboratories, and proximity to key study areas, makes it logistically feasible to conduct long-term, detailed studies. Other sites lacked this level of infrastructure or were more heavily impacted by tourism, making it harder to isolate the effects of current recreational activities (Chung et al., 2023).

3.4.2.2 Stakeholder involvement and logistical considerations

The process of selecting MBCA involved consultations with multiple stakeholders, including government agencies, conservation NGOs, and local communities. These stakeholders were crucial in ensuring that the research aligns with broader conservation goals while considering local community needs and interests. For example, the Sabah Forestry Department and the Sabah Foundation, which manage MBCA, were engaged in discussions to ensure that research activities would not conflict with ongoing conservation efforts or ecotourism plans (Mohamed & Hashim, 2020).

Logistical considerations, such as the availability of transportation, access to research sites, and the capacity for long-term stays in the area, were also addressed. The infrastructure within MBCA, including a well-maintained road to the research centre and provisions for basic amenities, allowed for a feasible research plan that could support extended fieldwork while minimizing environmental impacts from researcher presence (Zakaria et al., 2022).

In conclusion, MBCA's ecological significance, availability of data, accessibility, and representativeness of tropical ecosystems, alongside its alignment with key recreation ecology research questions, make it an excellent case study site. The structured process of site selection, including stakeholder involvement and logistical planning, ensures that MBCA will serve as a robust model for studying the impacts of recreation on tropical ecosystems.

3.5 MBCA ROLE IN RECREATION ECOLOGY RESEARCH

The Maliau Basin Conservation Area (MBCA), known for its rich biodiversity and near-pristine ecosystems, plays a significant role in recreation ecology research. As one of Southeast Asia's most intact tropical rainforest ecosystems, MBCA serves a dual purpose in the field of recreation ecology: it provides unique opportunities to study rare or site-specific ecological phenomena and offers transferable insights that can be applied to other tropical ecosystems. Furthermore, MBCA's role exemplifies the integration of both unique and transferable purposes, positioning it as a crucial case study for broader ecological and conservation applications. This section explores MBCA's contributions to recreation ecology research by focusing on its unique, transferable, and integrated roles.

3.5.1 MBCA's role as a unique case study

3.5.1.1 Studying rare or unique ecological phenomena

The MBCA is a unique setting for studying rare or singular ecological phenomena, which is a central feature of its role in recreation ecology research. Due to its remote and largely unaltered environment, MBCA serves as a living laboratory for investigating ecological interactions that are specific

to tropical rainforests. The region's isolation, steep topography, and diverse habitats—ranging from lowland forests to montane heath—make it home to numerous rare and endemic species that are sensitive to even minimal disturbance (Thomas, 2020).

For instance, MBCA is inhabited by species such as the Bornean pygmy elephant and the clouded leopard, which are rarely observed in more frequently disturbed tropical forests. These species provide critical opportunities for studying how recreational activities, such as trekking along forest trails, impact wildlife behaviour in environments that have seen little human influence (Laurance et al., 2019). The basin's closed ecosystem also supports unique plant species, such as pitcher plants and orchids, which are highly sensitive to habitat changes caused by human disturbance, making MBCA a key location for investigating the impacts of trail degradation, vegetation trampling, and habitat fragmentation (Pickering & Hill, 2019).

3.5.1.2 Opportunities to observe unaltered human-nature interactions

Another unique aspect of MBCA is its capacity to offer insights into relatively unaltered human-nature interactions. Unlike many other conservation areas, MBCA has strictly limited and regulated visitor access, which allows researchers to study the initial stages of recreational disturbance and how minimal human activity influences the ecosystem. In contrast to more heavily visited sites, where the baseline of natural conditions has been significantly altered, MBCA offers an almost pristine reference point, making it a prime

location for studying the early effects of human interactions with tropical ecosystems (Monz et al., 2020).

By focusing on trails in MBCA, researchers can document the early signs of ecological disturbance, such as soil compaction, erosion, and vegetation loss, and observe how these factors evolve over time with increased recreational use. These early indicators are critical for understanding the thresholds of ecological resilience in tropical rainforests, which may differ from temperate ecosystems commonly studied in recreation ecology (Newsome, 2020).

3.5.2 MBCA's role as a transferable case Study

3.5.2.1 Generalizing findings to other topical ecosystems

While MBCA's isolation and uniqueness make it an invaluable site for studying rare ecological phenomena, the findings derived from this research also have broader applications. One of MBCA's key roles in recreation ecology is providing transferable insights that can be generalized to other tropical ecosystems facing similar conservation challenges. Tropical forests worldwide are under increasing pressure from tourism and recreational activities, and MBCA serves as a model for understanding how these pressures might affect other, less pristine environments.

The impact assessment methods developed in MBCA, such as monitoring trail degradation, visitor impact on wildlife, and vegetation recovery, can inform management practices in other tropical forests where visitor numbers are higher, and human disturbance is more pronounced (Pickering & Hill, 2019).

By studying the impacts of recreational disturbance in MBCA, researchers can establish benchmarks for ecological resilience and determine how much recreational use these ecosystems can sustain without significant long-term damage.

3.5.2.2 Developing models or theories applicable elsewhere

MBCA also plays a crucial role in the development of recreation ecology models and theories that are transferable to other tropical ecosystems. Many recreation ecology models, particularly those developed in temperate regions, may not account for the specific ecological dynamics of tropical rainforests, such as differences in soil composition, rainfall patterns, and biodiversity (Monz et al., 2020). By conducting research in MBCA, scientists can refine these models to better reflect the unique characteristics of tropical forests.

For example, studies on soil erosion and compaction in MBCA's high-rainfall environment can lead to the development of more accurate predictive models for trail degradation in other tropical regions. Additionally, the basin's high biodiversity allows researchers to test hypotheses regarding the impact of fragmentation on species diversity and ecosystem function, providing data that can be applied to conservation efforts in other tropical forest regions (Laurance et al., 2019).

3.5.3 Integration of unique and transferable roles

One of the most significant roles MBCA plays in recreation ecology research is the integration of both unique and transferable purposes. While MBCA provides site-

specific insights into the ecological effects of recreational disturbance, the findings also have wider implications for other tropical ecosystems. This dual role allows MBCA to serve as both a reference point for studying minimally disturbed environments and a model for developing conservation strategies that can be adapted to more heavily impacted tropical forests.

For example, the research conducted in MBCA on trail management and visitor behaviour not only helps conservation managers in MBCA but also provides guidelines for managing visitor impacts in other tropical conservation areas. The adaptive management practices tested in MBCA, such as restricting trail access during sensitive periods or reinforcing trails to prevent erosion, can be adapted to suit the needs of other ecosystems with different levels of human interaction (Newsome, 2020).

Additionally, MBCA's role in studying visitor perceptions of trail degradation and environmental quality is applicable across various tropical forest contexts. Understanding how visitors perceive environmental changes and their expectations for wilderness experiences in MBCA can inform sustainable tourism practices elsewhere, helping balance conservation goals with the need for ecotourism (Pickering & Hill, 2019).

In conclusion, the Maliau Basin Conservation Area plays a vital role in recreation ecology research by serving both unique and transferable purposes. Its pristine environment provides a rare opportunity to study specific ecological phenomena and unaltered human-nature interactions, while the findings from MBCA contribute to

broader conservation models and theories that can be applied to other tropical ecosystems. Furthermore, MBCA integrates both roles, acting as a key case study that advances our understanding of recreation ecology in tropical rainforests while offering practical insights for managing visitor impacts in similar environments worldwide.

3.6 RELEVANCE OF THE MALIAU BASIN CONSERVATION AREA (MBCA) AS A CASE STUDY AREA TO WIDER TROPICAL ECOSYSTEMS

The Maliau Basin Conservation Area (MBCA) is a globally significant site for recreation ecology research, offering valuable insights not only for local and regional conservation efforts but also for understanding broader tropical ecosystem dynamics. Its relevance extends beyond its borders, providing a microcosm through which global ecological challenges can be better understood. This section explores the MBCA's connections to Malaysian and Bornean ecosystems, its implications for Southeast Asia, and its broader global significance.

3.6.1 Connections to Malaysian and Bornean ecosystems

3.6.1.1 Similarities in biodiversity and ecological challenges

MBCA's significance within Malaysian and Bornean ecosystems is underscored by its rich biodiversity, which mirrors the wider ecological patterns found across Borneo. The tropical rainforests of Borneo, including those in Sabah where MBCA is located, are home to some of the world's highest concentrations of biodiversity. These forests host a wide array of species, many of which are endangered or endemic, such as the Bornean orangutan, pygmy elephant, and various rare flora species (Laurance et al., 2019).

The ecological challenges faced by MBCA, such as deforestation, habitat fragmentation, and the pressures of human activity, are reflective of broader issues across Malaysian and Bornean ecosystems. Like other parts of Malaysia, MBCA faces the threat of habitat loss due to land-use changes, though it remains one of the most well-preserved areas. By studying the ecological impacts of recreational activities in MBCA, researchers can draw parallels with other Malaysian ecosystems that face similar challenges, thus providing a model for managing and mitigating human-induced disturbances in other protected areas (Monz et al., 2020).

3.6.1.2 Shared conservation goals and policies

MBCA is integral to Malaysia's broader conservation strategies, aligning with national and regional goals aimed at preserving biodiversity and promoting sustainable development. Malaysia has established a number of protected areas, including MBCA, under the framework of the Heart of Borneo initiative, which aims to protect the island's central rainforests through cross-border conservation efforts. Research conducted in MBCA contributes directly to the National Policy on Biological Diversity (2016-2025), which emphasizes the importance of conserving forest ecosystems and mitigating the effects of human activities, such as tourism, on these areas (Thomas, 2020).

MBCA also serves as a reference point for conservation policies across Borneo, including the development of sustainable tourism practices that align with both local economic goals and global environmental commitments. As a key component of Malaysia's efforts to balance conservation and

development, MBCA's research outcomes inform the management of other protected areas throughout the region.

3.6.2 Implications for Southeast Asia

3.6.2.1 Regional ecological patterns and human impacts

MBCA's significance is not confined to Malaysia and Borneo but has broader implications for understanding ecological patterns and human impacts across Southeast Asia. The region's tropical rainforests, which span Indonesia, Thailand, and the Philippines, among other countries, face similar pressures from deforestation, agriculture, and tourism. MBCA, as one of the most intact tropical rainforests, provides a valuable case study for understanding how recreational activities, such as trail use and ecotourism, affect tropical ecosystems at both local and regional scales (Newsome, 2020).

Recreation ecology research in MBCA allows for the assessment of how human activity influences ecological patterns, such as species distribution and habitat connectivity, across Southeast Asia. Given that many of the region's forests are part of transboundary conservation initiatives, insights from MBCA can help in designing effective strategies for managing tourism and human interaction with sensitive ecosystems elsewhere in the region. This is particularly important in areas where tourism is rapidly expanding, such as Indonesia's rainforests and Thailand's national parks.

3.6.2.2 Cross-border conservation initiatives

MBCA's research also has the potential to inform cross-border conservation initiatives, particularly in the context of the Heart of Borneo program, a collaborative effort involving Malaysia, Indonesia, and Brunei. This initiative aims to protect one of the largest remaining areas of contiguous tropical rainforest in Southeast Asia. MBCA's research outcomes, especially regarding the management of recreational impacts, can provide valuable data for neighbouring countries to implement sustainable tourism practices that minimize ecological disruption (Pickering & Hill, 2019).

By contributing to cross-border conservation efforts, MBCA plays a crucial role in promoting collaborative environmental governance in Southeast Asia. Its role in this context demonstrates the importance of transnational efforts in addressing ecological challenges that do not adhere to political boundaries, particularly in the face of climate change and increasing human activity in the region.

3.6.3 Global Significance

3.6.3.1 MBCA as a microcosm of tropical rainforest biomes

On a global scale, MBCA represents a microcosm of tropical rainforest biomes, making it a valuable site for studying the dynamics of such ecosystems worldwide. The tropical rainforests of Borneo are part of the greater Indo-Malayan realm, one of the world's most biodiverse regions. MBCA's largely intact ecosystems offer a controlled environment for examining the impacts of human activities, such as recreational use, on

tropical rainforests. The lessons learned here are transferable to other tropical regions in South America, Central Africa, and Southeast Asia, where rainforests face similar threats from tourism and development (Laurance et al., 2019).

Research conducted in MBCA contributes to a broader understanding of how tropical rainforests function under stress, how they recover from human-induced disturbances, and how to implement best practices for mitigating ecological damage. The insights gained from MBCA can inform global discussions on sustainable forest management, biodiversity conservation, and the development of ecosystem resilience in the face of increasing human activity (Thomas, 2020).

3.6.3.2 Contributions to global biodiversity and climate regulation

MBCA is not only critical for its biodiversity but also for its role in global climate regulation. Tropical rainforests like MBCA act as carbon sinks, sequestering large amounts of carbon dioxide and helping to mitigate the impacts of climate change. The preservation of MBCA and similar ecosystems is essential for maintaining the Earth's climate balance. By studying how human activities, such as tourism, affect the health of these forests, researchers can develop strategies to enhance their role in climate regulation (Newsome, 2020).

Moreover, MBCA's biodiversity contributes significantly to global biodiversity conservation efforts. The area's flora and fauna are part of the global pool of genetic diversity, which is critical for the resilience of ecosystems in the face

of environmental changes. The loss of biodiversity in areas like MBCA would have far-reaching consequences, not just for the region but for the planet as a whole, as tropical rainforests are vital for the health of global ecosystems.

The Maliau Basin Conservation Area is a critical site for recreation ecology research, offering insights that are relevant to Malaysian, Bornean, Southeast Asian, and global contexts. Its connections to regional biodiversity, shared conservation goals, and policies position it as a vital case study for understanding the impacts of recreational disturbance on tropical ecosystems. At the same time, MBCA's role in global biodiversity conservation and climate regulation underscores its broader significance. Through its contributions to both local and global ecological research, MBCA stands as a key player in the ongoing efforts to balance conservation with human activity in the world's most sensitive and biodiverse ecosystems.

3.7 MBCA AS A CASE STUDY: CONTRIBUTIONS TO THE STUDY OF RECREATION ECOLOGY

The Maliau Basin Conservation Area (MBCA) offers a unique opportunity to contribute to the study of recreation ecology, particularly within the context of tropical ecosystems. As one of the most pristine rainforests in Southeast Asia, MBCA's remote location, ecological diversity, and controlled tourism provide an ideal setting for examining the interactions between human activity and natural environments. The area's relevance extends to both practical applications, such as improving conservation efforts and shaping policy, and theoretical advancements, such as enhancing our understanding of recreation ecology.

3.7.1 Enhancing understanding of recreation ecology

3.7.1.1 Insights into human impacts on tropical ecosystems

Recreation ecology seeks to understand the effects of human activities, particularly tourism and outdoor recreation, on natural ecosystems. While much of the foundational research in recreation ecology has focused on temperate ecosystems, MBCA provides critical insights into the less-studied realm of tropical ecosystems, where both biodiversity and ecosystem sensitivity are typically higher.

Ecological Disturbances: MBCA's rich biodiversity and complex ecosystem make it an ideal site for studying how recreational activities, such as hiking and trail use, influence tropical ecosystems. For example, soil compaction, vegetation damage, and wildlife disturbance are common impacts of recreational activities in any ecosystem, but their effects can be magnified in tropical rainforests due to the fragility of the ecosystem's structure (Pickering & Hill, 2019). MBCA allows researchers to study these impacts in detail, offering insights into the specific responses of tropical ecosystems to human presence, including how vegetation and wildlife interact with frequently used trails (Monz et al., 2020).

Species Sensitivity: MBCA's status as a biodiversity hotspot offers a unique opportunity to examine how rare and endemic species, such as the Bornean pygmy elephant and various rare orchids, respond to human activity. Research conducted in MBCA has the potential to highlight the specific vulnerabilities of tropical species to habitat disturbance caused by recreational

activities, which can inform broader conservation efforts in other biodiversity-rich areas (Laurance et al., 2019). The area also provides a natural laboratory to test the limits of ecosystem resilience—how much human activity tropical ecosystems can absorb before significant ecological degradation occurs.

3.7.1.2 Data supporting sustainable management practices

In addition to advancing theoretical knowledge, MBCA's research contributes practical data that supports the development of sustainable tourism and recreation management practices. MBCA offers a controlled environment for testing management strategies aimed at balancing the needs of conservation with those of recreation.

Visitor Management: One of the key contributions of MBCA's research is the development of visitor management practices that minimize environmental impact while maintaining a high-quality visitor experience. This includes strategies such as the design of resilient trail systems, zoning of high-traffic areas to avoid sensitive habitats, and the implementation of visitor education programs (Newsome, 2020). Data collected in MBCA, such as visitor patterns and their ecological impacts, can inform the design of trails and recreational facilities in similar protected areas, especially in tropical regions.

Adaptive Management: MBCA also serves as a testing ground for adaptive management techniques, where ongoing monitoring of human impacts is used to adjust management strategies in real time. For example, studies in MBCA may reveal the threshold levels of trail use before significant ecological

damage occurs, allowing managers to regulate visitor numbers or reroute trails to mitigate impacts. This data-driven approach ensures that tourism development in MBCA and other areas can continue in a sustainable manner, balancing conservation needs with economic and recreational interests (Monz et al., 2020).

3.7.2 Informing policy and conservation efforts

3.7.2.1 Evidence-based recommendations for MBCA and similar areas

One of the critical contributions of MBCA's research is its role in informing conservation policy through evidence-based recommendations. By studying the specific impacts of recreational activities on MBCA's ecosystems, researchers can provide actionable insights for both MBCA and other similar protected areas.

Conservation Policies: Data gathered from MBCA's recreation ecology research can directly influence conservation policies aimed at minimizing human impact on sensitive tropical ecosystems. For instance, findings on soil erosion, vegetation loss, and wildlife disturbance can inform trail design guidelines, restrictions on visitor numbers, and habitat protection measures. MBCA's research can provide best practice models for other tropical protected areas, offering scalable solutions to common conservation challenges (Pickering & Hill, 2019).

Sustainable Tourism Development: MBCA's findings are also relevant for national and regional policies on sustainable tourism. Tourism is an important

economic driver in many tropical regions, but it must be managed carefully to avoid damaging the very ecosystems that attract visitors. Research in MBCA can help shape sustainable tourism policies by identifying the types and levels of tourism that tropical ecosystems can support without compromising their ecological integrity. This includes recommendations on the development of low-impact tourism infrastructure, such as eco-friendly accommodations and minimally invasive trail systems (Newsome, 2020).

3.7.2.2 Role in shaping regional and global conservation strategies

MBCA's contributions to recreation ecology extend beyond local and national borders, influencing both regional and global conservation strategies. As tropical rainforests are a crucial component of global biodiversity and climate regulation, the lessons learned from MBCA are of significance to tropical conservation efforts worldwide.

Regional Conservation Strategies: In the context of Southeast Asia, where rapid economic growth and urbanization have increased pressures on natural ecosystems, MBCA's research can help shape regional conservation strategies. Collaborative efforts such as the Heart of Borneo initiative, which involves Malaysia, Indonesia, and Brunei, rely on sound scientific data to develop cross-border conservation strategies. MBCA's research outcomes can inform these efforts by providing empirical evidence on how to manage recreation in ways that support biodiversity conservation (Laurance et al., 2019).

Global Conservation Efforts: MBCA's research also plays a role in contributing to global conservation goals, particularly those related to biodiversity conservation and climate regulation. Tropical forests like MBCA are vital for maintaining global biodiversity, as they host a disproportionate number of the world's species. Additionally, they are crucial for carbon sequestration, helping to mitigate climate change. Understanding how to manage recreational activities in tropical forests is essential for preserving these global ecosystem services. The insights gained from MBCA can therefore inform global discussions on sustainable land use, ecosystem management, and climate policy, ensuring that tropical forests continue to provide their critical functions in the face of increasing human activity (Thomas, 2020).

The Maliau Basin Conservation Area serves as a key case study for advancing the field of recreation ecology, offering valuable contributions both to theoretical knowledge and practical conservation efforts. MBCA enhances our understanding of human impacts on tropical ecosystems and provides the data necessary to support sustainable management practices. Furthermore, its research informs evidence-based conservation policies that can be applied not only within MBCA but also in other protected areas facing similar challenges. On a broader scale, MBCA plays a pivotal role in shaping regional and global conservation strategies, contributing to efforts to safeguard biodiversity and regulate climate through the careful management of tropical forests. Its dual role as both a research hub and a conservation model underscore its importance in global environmental science and policy.

3.8 NATURAL ATTRACTIONS IN MBCA

3.8.1 Flora/ Vegetation

A brief summary of the flora in MBCA as a focal point for attractions was introduced by referencing Hazebroek's (2004) study on the flora in MBCA, which concluded that its diversity and uniqueness make it very impressive. In 2013, Nais et al. reported that numerous IUCN-endangered and Sabah- and Borneo-endemic species were discovered in the MBCA. Additional new species have been discovered. Due to these discoveries, flora has become one of the most significant natural attractions. Phillips (2002) also noted that the floral beauty of MBCA contributes to the area's worldwide popularity.

3.8.2 Wildlife

There are many published literatures on faunas and wildlife in MBCA. One of the publications was by Phillipps (2002) entitled *Fauna a Last Refuge* and he stated that MBCA and its buffer zones have an impressive list of mammal species. More than eighty mammals out of Borneo's total of 221 have so far been recorded from the entire MBCA and its buffer zones, including the first Sabah record for the Least Horseshoe Bat and possibly of the Black-eared Pygmy Squirrel as well as a possible sighting of the almost extinct Golden-Red Bay Cat, which is restricted to the island of Borneo.

Apart from mammals, other fauna is also important such as the birds, reptiles, amphibians, and butterflies. Birds like the kingfisher and the hornbill are among the attractive species found in MBCA. Besides, diverse species of frogs, snakes, and butterflies make wildlife an important attraction in the basin.

3.8.3 Waterfall

For years, waterfalls have become one of the main attractions in MBCA. Many of the trails such as Ginseng Trail, Nepenthes Trail as well as Seraya Trail that have been established brought the visitor tour to a water fall either Maliau Falls or Takob-Akob Falls. The most spectacular waterfall is the Maliau Falls with its seven tiers of cascading water. The local Murut people believe that this fall is home to a mythical water dragon. This waterfall riverine is one of the most beautiful features in the basin. In fact, the basin is thought to have more waterfalls in its 390 square km than any other place in Malaysia (Phillips, 2002). Some other fascinating waterfalls in MBCA are Sabandar Falls, Laurentius Falls, and Giluk Falls.

3.8.4 Lakes

Lakes can be a major natural attraction in any protected area. Lakes offer a beautiful natural landscape with a combination of flora and water elements. In many places, lakes may become a centre of attraction to wildlife, particularly for food. Linumunsut Lake is the only lake in MBCA, is thought to be Sabah's only natural freshwater lake, other than the ox-bow lakes (Phillipps, 2002). Linumunsut Lake which covers about 12 hectares is located at the base of Maliau's northern escarpment and is surrounded by pristine dipterocarp forests. However, due to rough terrain and accessibility, the majestic lake of Linumunsut has not yet become the main attraction in MBCA.

3.9 TOURISM RECREATIONAL ACTIVITIES IN MBCA

MBCA is a conservation area that offers various recreational activities, including jungle trekking, nature viewing, photography, boating, swimming, Maliau Sky Bridge,

birdwatching, self-guided nature trails, night drives, and night walks. These activities provide opportunities to explore the area's diverse wildlife, wildlife, and natural landscapes. Some popular spots include Maliau Rim, Maliau Observation Tower, and a 33-meter tree observation platform. Photography is also available for capturing unique flora and wildlife. Boating in the Maliau River allows visitors to observe riverine ecology. Swimming in the river is allowed if weather permits. Birdwatching is available at any trail, and self-guided nature trails are available for short distance trekking. Night drives provide opportunities to experience night life in the forest, while night walks offer a more intimate experience using senses of hearing and smell.

3.10 SUMMARY

To date, there is an apparent lack of attention given to recreation ecology research by the administrators of park and recreation resources in Malaysia. The assertion that Malaysia currently lacks an established visitor impact monitoring system for managing recreational resources in its protected areas is supported by recent studies, for instance a 2022 study on Kinabalu Park found that, despite the presence of tourism impact management and a substantial staff, there is no system in place to evaluate the human impacts on flora and fauna (Daim et. Al., 2022). Similarly, a 2022 study highlight the absence of monitoring systems for assessing human impacts on biodiversity in protected areas, underscoring the need for long term monitoring schemes (Abang Abdulrahman et al., 2022). These finding suggest that, as of the dates of these studies, Malaysia has not implemented a standardized visitor impact monitoring system across its protected areas. This study addresses this knowledge gap and contributes to a better understanding of these issues.

Amidst the growing concerns on issues related to the environment and impacts of human activities, there has been a noticeable increase in environmental awareness among Malaysians, highlighting the importance of research in outdoor recreation and nature tourism (Sabaruddin et al., 2023; Saidon et al., 2022). While research in this field has predominantly focused on tourism demand, user preferences, attitudes, and marketing strategies, scholars have emphasized the need for more studies on ecological impacts (Ajuhari et al., 2023). For instance, Abdullah et al. (2020) examined tourist characteristics and their opinions toward sustainable practices in Mount Kinabalu, underscoring the necessity for further research on environmental impacts. Studies by local researchers focus more on tourism and recreation demand, user preferences, attitudes, and marketing (Azlizam 2001 and Hassan et al. 2017) than on ecological impacts. The Forestry Department of Malaysia emphasizes planning and management of forest and timber production rather than recreation.

A similar scenario is also apparent at the Department of Wildlife and National Park, Malaysia, where more effort has been devoted to wildlife management and enforcement activities. According to their official objectives, the department aims to strengthen wildlife conservation programmes through management, enforcement, enrichment and research of wildlife (<https://www.wildlife.gov.my/index.php/en/11-info/14-objective>). Recreation ecology research have primarily concentrated on temperate areas, where studies are well established in North America, Europe, Australia, and New Zealand (Monz et al., 2019; Newsome et al., 2019). While temperate biomes are well covered by this effort, tropical regions, especially Southeast Asia, are still remarkably underrepresented in this particular field (Leung

et al., 2018). The Maliau Basin Conservation Area (MBCA) in Malaysia presents a valuable case study to address this research gap, as it is a pristine and highly biodiverse rainforest that is increasingly subjected to recreational activities such as ecotourism and scientific expeditions.

Malaysia's tropical forests, including the MBCA, represent a unique opportunity to study the ecological impacts of recreation in an environment that differs considerably from the temperate systems in which much of recreation ecology has been formulated. In contrast to managed national parks in Western countries, MBCA is a relatively undisturbed, remote wilderness area, making it an excellent location for examining the beginnings of recreation-induced ecological change. The results from this study could help guide conservation efforts not only in Malaysia but across tropical rainforest systems in general, where the practice of ecotourism is growing but poorly understood (Buckley, 2020).

Due to the lack of studies on ecological impacts of recreation in Malaysia, this research is essential. Although some forms of recreational activity have focused on the social aspects of nature-based tourism in Malaysia (Shamsor Nahar et al., 2016), systematic investigations into biodiversity responses to recreational disturbance remain scarce. This research will contribute to bridging that knowledge gap by employing biodiversity indices and impact assessment methods that can be applied to other tropical forest conservation areas. Additionally, the results will provide evidence-based guidance for sustainable management in MBCA and other similar protected areas across Southeast Asia.

CHAPTER 4

RESEARCH METHODOLOGY

This chapter discusses the methods used in this study, from the research concept and approach to the details of the research sites, and of the experimental design. This chapter also presents the study site and field techniques, the laboratory procedures, the visitor perception survey, using a questionnaire method, and data analysis procedures.

4.1 RESEARCH CONCEPT AND APPROACH

The present study adopts a somewhat different concept and approach from what has been done by previous researchers in temperate regions (Cole 1995; Newsome et al., 2021; Hall & Cole, 2022). This is in order to better understand the ecological impacts of recreational activities along nature trails in a tropical conservation area. One of the innovative aspects of the research design was the combinations of both physical scientific ecological investigations with data obtained from perception study based on specifically designed questionnaires. In doing so, the results of the different methodologies are compared to see what relationships can be observed or derived. This mixed method research is a pioneering study in the tropical forest using an approach where both physical and quantitative social science methods are combined. Additional supporting data, such as yearly visit frequency statistics, climate, and weather conditions of the area through the year, and site maps were obtained from secondary sources. These secondary data, where appropriate, were analysed accordingly and were used to support the results of the primary study.

This study was initially designed to measure the effects or impacts of recreational use of trails on forest ecology. The possible ecological impacts considered were as follow:

- i. The disturbance to the vegetation particularly by human trampling,
- ii. Biodiversity and abundance of vegetation,
- iii. Soil compaction and erosion,
- iv. Soil organic matter degradation,
- v. Reduction in soil water content,
- vi. The disturbance to the wildlife,
- vii. Variation in light penetration to the forest floor.

Based on the works of Nepal and Way (2006) and the practicality of data collection within the available time, and of data analysis, the scope of ecological impacts of recreational activities along the trails in MBCA was finalised. This was where (i) four of the ecological components were selected, namely: vegetation, wildlife, soil and light and (ii) an additional study component, namely the perception studies included to capture the human aspect of natural area tourism in MBCA was selected. (see Section 4.8). Thus, despite of the ecological and physical factors that could be quantified and analysed, the study also attempted to relate to the human element, i.e., to evaluate the perceptions of the visitors or “eco-tourists”, as they are commonly known, on the perceived ecological impacts. In this way, the human perspective was also taken into consideration.

The study attempted to evaluate expectations and attitudes of visitors towards recreational activities in MBCA which were considered vital to the understanding of

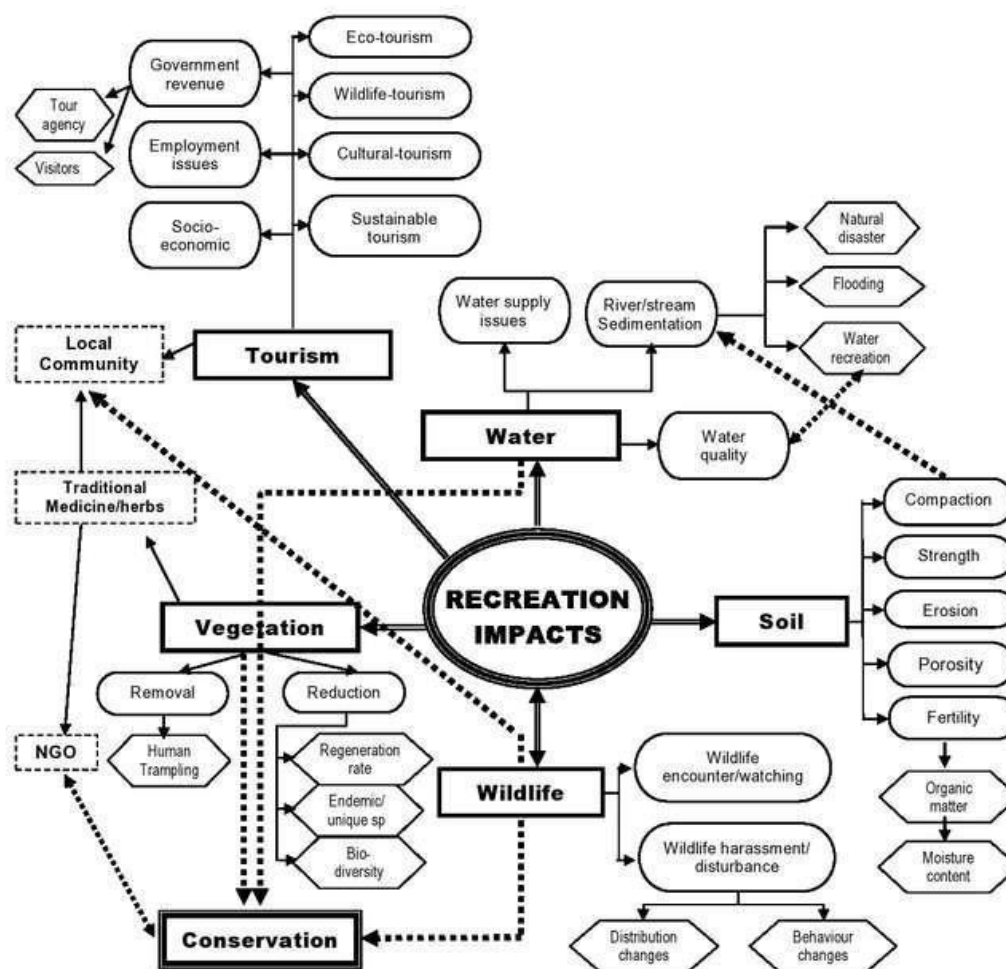
the subject under investigation. Data collected for this part of the study were obtained through carefully designed questionnaires based on relevant past studies such as Cole (1986), Whinam and Chilcott (2003), Cole and Monz (2003), or have examined the difference between disturbed and disturbed sites (Kuss and Hall 1991; Cole 1995). The questionnaires were designed to capture data on respondent motivation, participation, satisfaction, and anticipation towards the ecological impacts and the natural area (specifically that of the forest as in MBCA) tourism experience. This quantitative social science methods were employed to understand and quantify human interactions with the environment within the Maliau Basin Conservation Area (MBCA).

4.1.1 Conceptual framework

This research employs a comprehensive conceptual framework to investigate the impacts of recreational activities on the ecological integrity of the Maliau Basin Conservation Area (MBCA). The framework, as illustrated in Figure 4.1 below, provides a systematic approach for analyzing the multifaceted effects of recreation, emphasizing the interconnections between physical, ecological, and social variables. This section outlines the framework's components, each reflecting specific measurable variables relevant to MBCA, and establishes the methodological rationale for their inclusion in this research.

Ecological impact assessment focuses on vegetation and soil, where recreation-induced degradation can have cascading effects on biodiversity. Human trampling, vegetation removal, and soil compaction are primary physical impacts in recreational zones. To measure these, plots are established across high and low-impact sites,

assessing species composition, and biodiversity loss (Zhou et al., 2020). Soil properties, including compaction, moisture content, and organic matter, are measured through soil sampling and penetration tests to evaluate the degradation linked to visitor use (da Silva *et al.*, 2019). Comparative analyses between impacted and control sites help isolate recreation's direct effects on soil and vegetation integrity.



Legend/symbol

- ▼ The main ecological factor of recreation ecology
- ▼ Interconnection between ecological factors and outer aspect
- ▼ Sub-factor and subsection of the ecological factors

Figure 4.1: Conceptual and Analytical Framework of the Ecological Impacts of Recreation

Wildlife is a critical component of MBCA's biodiversity, with recreation known to influence animal distribution and behaviour, particularly in sensitive tropical ecosystems. This study utilizes direct observation and distance sampling to monitor wildlife occurrence and distribution along trails of varying recreational intensity (Wilson et al., 2019). Quantitative data on wildlife encounters frequencies, and distribution shifts due to recreational activities are gathered. This data informs conservation management by identifying thresholds of recreational activity that avoid significant disruption to wildlife behaviour (Ahmed & Majid, 2023). Additionally, statistical analyses are used to correlate trail usage intensity with specific behavioural responses in wildlife, facilitating evidence-based guidelines for managing human-wildlife interactions.

The framework incorporates socioeconomic variables associated with tourism, acknowledging both the positive economic contributions and potential environmental stressors. Socioeconomic factors particularly visitor demographics are considered essential data points in understanding tourism's broader impacts on the community (Singh et al., 2020). This study quantifies tourism's socioeconomic footprint through surveys, examining both benefits and community perceptions of tourism's ecological costs (Garg & Gupta, 2021). By focusing on sustainable tourism components, eco-tourism, and wildlife tourism, the research also identifies tourism practices that may alleviate pressures on MBCA's ecosystems (Aziz & Saad, 2019).

The methodological approach, grounded in this conceptual framework, is designed for transferability to other tropical ecosystems. While the framework is tailored to MBCA's unique characteristics, its modular structure covering tourism, vegetation,

soil, and wildlife, renders it adaptable for similar conservation areas worldwide. This adaptability allows for comparisons across case studies in tropical environments, enriching the broader discourse on recreation ecology and sustainable tourism management in biodiversity-rich areas (Johnson et al., 2021).

This conceptual framework serves as a foundational element in this study's methodology, guiding the structured assessment of recreation impacts on MBCA's ecosystems. Each component of tourism, vegetation, wildlife, and soil is operationalized through specific, measurable variables and data collection methods aligned with recent methodological standards in recreation ecology. By integrating physical, ecological, and social factors, this framework provides a comprehensive approach that informs both site-specific management practices and generalizable insights for tropical conservation.

4.1.2 Research paradigm

The research paradigm adopted is pragmatism, as the mixed method was used to fulfil the research gaps which were elaborated in Chapter 1 and 2. Esteves (2004) define Research paradigms and methods as the “set of activities a research community considers appropriate to the production of understanding (knowledge)”.

Paradigms outline the way professionals and practitioners perceive the discipline, and directly shape many of its aspects such as services, techniques, and tools (Smyth & Morris 2007). While Pragmatism can be defined as the quality of dealing with a problem in a sensible way that suits the conditions that really exist, rather than following fixed theories, ideas, or rules (Smyth & Morris 2007).

4.1.3 Methodology

In studying the impact of recreation on ecology, using a mixed-methods approach can be particularly valuable because it broadens the ways we understand and interpret ecological change. Mixed methods combine both natural and social science techniques, which enriches the study's framework by allowing different types of evidence to interact. This approach shapes the study's ontology (its view of reality) by acknowledging that ecological impacts are complex and may not be fully captured by natural science data alone. Additionally, it influences the epistemology, or the nature of knowledge, in the study by integrating varied perspectives, such as observational data and statistical trends. Together, these methods create a more holistic picture of how recreational activities influence ecological systems, supporting a nuanced and well-rounded understanding of both measurable impacts and specific details unique to the setting.

4.1.4 Research ethics

This research has been conducted in strict adherence to internationally recognized research ethics and principles, ensuring alignment with the standards outlined by both the Economic and Social Research Council (ESRC) and the Natural Environment Research Council (NERC), two prominent bodies under the United Kingdom Research and Innovation (UKRI) framework. Both councils provide robust ethical guidelines designed to maintain the integrity and accountability of research in the social and environmental sciences, respectively, thus addressing the multifaceted ethical considerations of studies like this one, which combine human and ecological dimensions.

The ESRC framework for research ethics establishes six core ethical principles (ESRC, 2015) that prioritize the rights, safety, and well-being of research participants, as well as the overall quality of the research conducted. For studies involving ecological components, the NERC principles on environmental responsibility and the sustainable use of biodiversity further complement these ethical considerations (NERC, 2012). Taken together, these guidelines form a comprehensive ethical foundation that upholds high standards for conducting rigorous and responsible research, particularly in sensitive and protected environments. The six key principles that form the ethical backbone of this research are as follows:

- i. Ensuring quality and integrity of your research
- ii. Seek informed research consent.
- iii. Confidentiality and anonymity of this research respondent
- iv. Voluntarily participation of research participant
- v. Harm to research participant must be avoided.
- vi. The research is independent and impartial.

The research design, review, and implementation were conducted with rigorous attention to maintaining high levels of integrity and quality. This aligns with ESRC's emphasis on ensuring the reliability and robustness of research (ESRC, 2015) and NERC's framework that promotes ethical research within environmental contexts (NERC, 2020). The research questions, as detailed in Chapter 1, highlighted specific gaps within recreation ecology, particularly regarding recreational impacts on tropical forest ecosystems. These gaps informed the study's focus on the Maliau

Basin Conservation Area (MBCA), where both ecological impact and visitor experience were examined. In line with both ESRC and NERC guidelines, the research aimed to extend ecological knowledge by applying methodologies adapted from temperate to tropical rainforest settings, thus ensuring relevance and integrity in the study design (Franklin & Bell, 2018; Miller et al., 2021).

This research required field data collection within the MBCA, necessitating prior consent and collaboration with the management authority. In accordance with NERC's emphasis on ethical collaboration with local stakeholders (NERC, 2020) and ESRC's requirement for informed consent (ESRC, 2015), permission was obtained through a formal application process. This approach ensured respect for local authority and compliance with conservation priorities. Upon arrival, a detailed presentation was delivered to MBCA management, articulating the research's objectives, methods, and intended outcomes. This transparency in communication aligns with principles of ethical engagement, where mutual understanding and clear communication are prioritized to foster trust and respect in research partnerships (Hayward et al., 2017; Chappell et al., 2020).

The methods applied in this study incorporated both natural scientific and social science approaches, discussed further in this chapter. Scientific research conducted along MBCA forest trails followed both local and international regulations to minimize ecological disruption, as outlined in the NERC framework for environmental stewardship (NERC, 2020). Specific care was taken to adhere to these guidelines to avoid unintended environmental impacts, emphasizing the study's ecological responsibility (Pereira et al., 2019). The questionnaire component involved

participants who were either visitor and tour guides. Participation was entirely voluntary and ensured anonymity, as required by ESRC and reflected in broader ethical guidelines within environmental and social sciences (ESRC, 2015; UNEP, 2021).

Throughout this research, ethical considerations were consistently prioritized, with explicit mention of participant confidentiality and anonymity at the beginning of the questionnaire (Appendix 4.0). The participants' autonomy and voluntariness were paramount, aligning with the ESRC's principles to protect participant welfare and autonomy (ESRC, 2015). Additionally, the research adhered to the NERC principle of conducting studies independently and impartially to prevent conflicts of interest that could bias findings or impact conservation efforts (NERC, 2020). This impartiality supports the broader aim of contributing to environmental understanding while respecting and protecting both human and ecological stakeholders involved (Smith et al., 2021).

4.2 STUDYING THE MBCA

The report by WWFNM (1996) and the study by Chan and Baum (2007) showed nature-based tourism in protected areas increasing worldwide. These helps provide the context to explain the significance of undertaking the recreation ecology impact study in a Malaysian tropical forest. Apart from the inherent fragility of tropical ecology, the uncontrolled use and visitor behaviour in this environment provides a good reason for doing such a study in Malaysia. Despite many previous studies on recreation ecology with established approaches in the developed and temperate

areas, the literature review suggested that there were none so far undertaken in the tropics and specifically in Malaysia.

The study was conducted in the Maliau Basin Conservation Area or MBCA from year 2010 to 2012 (see Chapter 3 for detailed description and justification of its selection and utility as a case study). The area was selected because although MBCA is one of the seven prime conservation areas in Sabah (see Section 1.7), there has been little recreation ecology research on the site. MBCA is a protected pristine forest located at the heart of North Borneo Island. It has been gazetted or listed as a Class One (1) Forest Area under the Sabah State Forestry Category.

4.2.1 Field site location

Within MBCA, trails have been established for access to the various parts of the area (Figure 4.2). The nature trails in MBCA were created by the Sabah Foundation management during the formative years of MBCA. The trails provide access to places of interest within MBCA. Details of these routes are provided in section 4.2.3. The study was carried out along five selected trails (Figure 4.2).

4.2.2 The trails

The management history of a protected area is crucial for selecting an appropriate research trail. It helps researchers align their objectives with conservation goals, identify existing trails, and minimize impacts on sensitive habitats or ecosystems. Understanding the history also helps to comply with regulations and identify collaboration opportunities. By considering the management history, research can

be conducted with respects the ecological integrity and management objectives of the protected area.

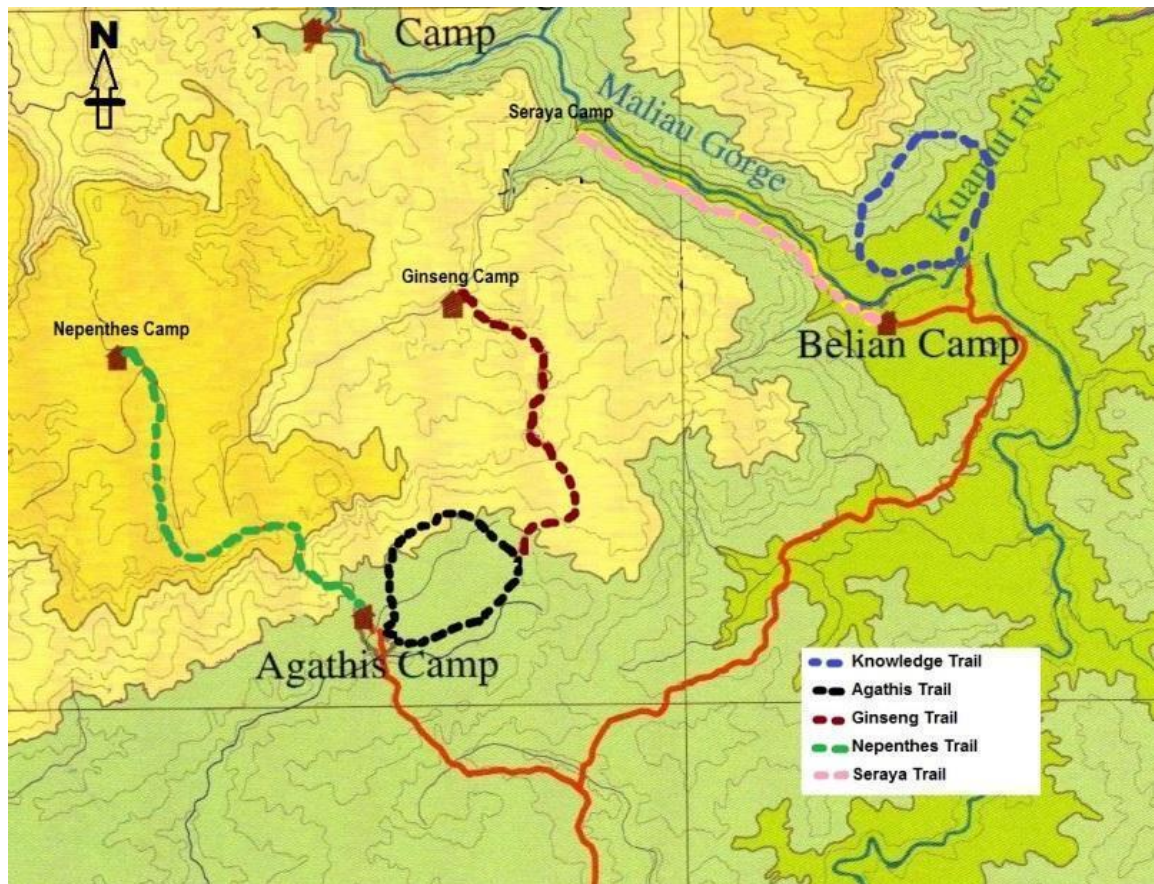


Figure 4.2: Location map of the selected trails (sketch from map *Hazebroek et al. 2004*).

Transects across the trails allow the assessment of the forest structure, particularly vegetation height, density, and type. At the beginning of the study period, prior to the selection of the five trails and location of the points along the trails, an initial reconnaissance survey was undertaken. This was carried out along the various trails in MBCA. The selection of the five trails for the reconnaissance survey was intentional, based on prior knowledge or planning. These trails were chosen because

they represented a range of conditions or levels of impact relevant to the study's goals. This choice aimed to provide a representative sample of the MBCA trail network, rather than simply identifying sample locations.

Identification of the key main vegetation types, plant families, and fauna associated with trail disturbance were conducted. Location of the points was based on the vegetation stand in order to have a more uniform forest stand condition (although the type of forest or vegetation may not be uniform) for the trail points used in the study.

Irregularities caused by such factors as forest gaps or tree falls and unacceptable level of forest disturbance were taken into considering in choosing the trail points. These irregularities introduce bias to the data and were therefore avoided for the location of trail points. Thus, the trail points were not necessarily equidistant from each other, and this was in part based on the method of convenient sampling (Larsen 2007) (Table 4.1). Once a trail point was established, transects were laid down perpendicular to the trail (Figure 4.8).

Following the methods of Cole (1986), the ecological impact study involved sampling (vegetation and physical environment) and observations (wildlife) along the five selected trails (Figure 4.5; Table 4.1). These trails were: (1) Knowledge Trail, (2) Agathis Trail, (3) Ginseng Trail, (4) Nepenthes Trail and (5) Seraya Trail.

Table 4.1: The five selected trails for the study in MBCA

Trail	Length (km)	Wide (m)	Features
1. Knowledge	1.0	2 – 3	Easy to access and very close to main reception building and hostel. Moderate terrain but has many spots of attraction along the trail
2. Agathis	1.5	2 – 3	Easy to access but takes about 1 hour (10km) drive from the reception building. Moderate terrain and has many spots of attractions such as unique species.
3. Ginseng	9.0	2 – 3	Long distance trail but lots of attractions. Undulating mix terrain but in average the slope is average. Trail crosses many types of forest species.
4. Nepenthes	7.5	2 – 3	Long distance trail with lots of attractions. Mix slope terrain from flat to very steep slope trail. Different geographical feature offer variety of attractions
5. Seraya	6.8	2 – 3	Moderately long distance and newly opened trail. Alignment mostly along the riverside up to the stream. Starting point was close to reception building and hostel.

4.3 HYPOTHESES AND EXPERIMENTAL DESIGN

This study aimed to investigate five primary components to evaluate the ecological impacts within the Maliau Basin Conservation Area (MBCA). These components include:

- (1) ecological impacts on the vegetation,
- (2) ecological impacts on the soil,
- (3) ecological impacts on the wildlife,
- (4) light intensity in the plots,
- (5) visitor perceptions on ecological impacts.

The experimental design, based on a strategic sampling layout and data collection process outlined and depicted in Figure 4.3 including the secondary data of Trail usage intensity record to each trail selected (Table 4.1). The figure 4.3 highlights the plot locations color-coded to indicate position relative to the trail centre-line:

- 1) Red for plots on trails,
- 2) Brown for proximal plots adjacent (2.5 m) to trails, and
- 3) Green for distal (control) plots 6 m from the trail.

Wildlife surveys were conducted at the scale of whole trails (rather than plots), and visitor perception data were collected one per participant visit to the MBCA.



Figure 4.3: Overall experimental design for the whole study

Figure 4.3 illustrates schematically the comprehensive experimental setup, including integration of all research components. This approach provided a balanced analysis

of both ecological data and human perceptions, allowing for a robust understanding of the impacts of recreational activities within the MBCA.

4.3.1 What impact does recreational disturbance have on ecological indicators along trails and trail surroundings?

Visitor activities along trails cause physical disturbances to forest ecology, a phenomenon known as recreational disturbance. Previous studies globally (see Chapter 2) indicate that the extent of this disturbance is influenced by trail usage intensity and proximity to trails, with higher impacts expected in frequently visited areas and those closest to trails. To systematically assess these impacts, four key ecological indicators were identified which includes vegetation, soil, wildlife, and light. These indicators provide a comprehensive measure of ecological changes resulting from recreational activities.

Hypothesis 1: Increased usage intensity is positively associated with increased levels of ecological disturbance among trails with different levels of usage.

Hypothesis 2: Increased trail usage intensity is positively associated with increased levels of ecological disturbance as a function of distance away from the trail.

To assess these relationships between the trail usage intensity and the ecological disturbance, the following specific hypotheses have been proposed for each of the ecological indicators:

H1A: trail usage intensity varies inversely with vegetation biodiversity along trails.

H2A: trail usage intensity varies inversely with vegetation biodiversity among on-trail, proximal and distal plots.

Ha: There is a significant relationship between trail usage intensity and flora species abundance, richness and diversity indicators

Ho: There is no significant relationship between trail usage intensity and flora species abundance, richness and diversity indicators

H1B: Trail usage intensity varies directly with soil compaction along trails.

H2B: Trail usage intensity varies directly with soil compaction among on-trail, proximal and distal plots.

Ha: There is a significant relationship between trail usage intensity and soil compaction along trails.

Ho: There is no significant relationship between trail usage intensity and soil compaction along trails.

H1C: Trail usage intensity varies inversely with soil moisture content along trails.

H2C: Trail usage intensity varies inversely with soil moisture content among on-trail, proximal and distal plots.

Ha: There is a significant relationship between trail usage intensity and soil moisture content along trails

Ho: There is no significant relationship between trail usage intensity and soil moisture content along trails

H1D: Trail usage intensity varies inversely with soil organic matter content along trails.

H2D: Trail usage intensity varies inversely with soil organic matter content among on-trail, proximal and distal plots.

Ha: There is a significant relationship between trail usage intensity and soil organic matter content along trails.

H₀: There is no significant relationship between trail usage intensity and soil organic matter content along trails

H1E: Trail usage intensity varies directly with light intensity along trails.

H2E: Trail usage intensity varies directly with light intensity among on-trail, proximal and distal plots.

Ha: There is a significant relationship between trail usage intensity and light intensity along trails

H₀: There is no significant relationship between trail usage intensity and light intensity along trails

H1F: Trail usage intensity varies inversely with wildlife abundance along trails.

H2F: Trail usage intensity varies inversely with wildlife abundance among on-trail, proximal and distal plots.

Ha: There is a significant relationship between trail usage intensity and wildlife species abundance and diversity indicators along trails

H₀: There is no significant relationship between trail usage intensity and wildlife species abundance and diversity indicators along trails

The formulation of this experimental design drew upon established literature (Dean and Voss 1999; Montgomery 1997; Maxwell and Delaney 2004; SAS 2005; McLeod 2007; Ryan 2007). The design incorporated a paired (left and right) structure to

minimize bias from forest type variability along the main trail, enhancing the reliability of comparisons.

4.3.2 What is the relationship between recreational disturbance and visitor experiences and perceptions?

The relationship between recreational disturbance and visitor perception is an important aspect of understanding how visitors and management authorities interpret and respond to ecological impacts within protected natural areas. Recreational activities, such as hiking and wildlife observation, may contribute to disturbances, including vegetation trampling, soil erosion, and wildlife displacement. However, visitor perception of these impacts is subjective and influenced by factors such as personal awareness, conservation knowledge, and prior outdoor experiences (see Chapter 2 for extensive discussion of this).

This study aims to explore and describe visitor perceptions rather than test a specific hypothesis. Since perception studies often involve understanding attitudes and subjective experiences, a hypothesis is not required. Instead, the findings will be used to provide insights into how visitors recognize and interpret ecological disturbances, offering valuable information for conservation management without the need for hypothesis driven testing.

4.3.2.1 Ecological disturbance is related to visitor perception

Visitor perception of ecological disturbance varies depending on the visibility of environmental changes, awareness levels, and expectations of pristine nature. Some visitors may notice and express concern over disturbances such

as damaged vegetation, muddy trail or eroded trails, while others may perceive them as natural or insignificant.

Importantly, this study does not seek to quantify or establish a predictive relationship between ecological disturbance and visitor perception through hypothesis testing. Instead, it adopts a descriptive and interpretive approach, recognizing that visitor perception is inherently subjective. The absence of a hypothesis allows for a more flexible analysis of patterns and themes emerging from visitor responses, ensuring that the study captures the complexity of human-environment interactions within MBCA.

4.4 RESEARCH METHODS

To evaluate the impacts of recreation in the Maliau Basin Conservation Area (MBCA), a combination of ecological and social research methods was employed. The research methods were chosen to systematically assess changes in ecological indicators which are vegetation, soil conditions, wildlife presence, and abiotic factors such as light intensity, alongside visitor perceptions. The following subsections outline the specific procedures used to gather and analyse data.

4.4.1 Vegetation

Assessment of the impacts along the trail through the forest was initiated by quantifying relevant parameters i.e., both biological and physical parameters. This approach allows initial comparisons with the trail edge and natural forest. A comparative study between heavily and moderately used trails might be of particular interest. Comparisons between heavily and moderately used trails continue to

provide insights into varying levels of degradation and biological resilience (Sato et al., 2020; Pickering et al., 2021). This rapid examination is based on past study which showed that effect of trampling is fairly limited, extending only about one meter from the trail's edge (Dale and Weaver 1974; Dawson *et al.* 1974).

Recent studies have expanded on the methodology of assessing trail impacts, emphasizing both biological and physical parameters to monitor trail conditions effectively (e.g., Monz et al., 2019; Leung et al., 2020). These studies stress the importance of comparing trail edge impacts with those found deeper within natural forest areas. Some plant species decrease near trails; especially woody plants since they are brittle (like low shrubs or tree seedlings), (Tonnesen and Ebersole 1997), but also more delicate herbaceous plants. Studies also note the differential response of plant species to trampling, with woody plants showing more susceptibility to damage than herbaceous plants, which is consistent with Tonnesen and Ebersole's findings and further supported by recent field observations (e.g., Bochet & García-Fayos, 2019; Van Wagtendonk et al., 2022).

Previous research has consistently shown grasses and sedges are most tolerant of trampling (Dale and Weaver 1974; Douglas *et al.* 1975). Recent studies across various ecosystems continue to support these findings, highlighting the robust resilience of grass and sedge species under trampling pressure (Newsome et al., 2021; Hall & Cole, 2022). Expanding on Dale and Weaver (1974) and others, newer research affirms that trampling impacts tend to be spatially limited near trails, yet continue to affect sensitive plant life (Monz & Marion, 2019; Ballantyne et al., 2021). This information is then combined with that collected from the trail use logbook and

interviews with members of site staff and guides, to gain an overview of the current state of the trail. Modern methodologies incorporate logbook data, photographic monitoring, and qualitative interviews with staff and guides to build a comprehensive understanding of trail impacts and conditions (Blake et al., 2020; Leung & Marin, 2021). In addition, there were some general observations and photograph monitoring during the fieldwork period (Figure 4.4). Botanical samples of species of interest were collected for the herbarium study, which facilitate accurate plant identification (Parks et al., 2019; Barbosa et al., 2021).



Figure 4.4: Five (5) selected Trails of Maliau Basin Conservation Area (MBCA)

Assessing recreation impacts to the ecology along the trails conducted using methodology developed by Cole (1978 and 1995) and applied by several researchers (Marion and Cole 1996) with a little modification. Transect line located at most attracted point along every trail and aligned perpendicular to the trail. Five (5) plots were systematically located along transect as shown in Figures 4.7 and 4.8. Each plot size is 1m x 1m with interval distance of 2.5m apart. The 2.5m distance interval selected in order to locate the control plots at 6m which is beyond 5m from the trail edge as indicated in figure 4.7. One plot was located on the trail as comparison while another two plots were located both sides of the trail for effective impact assessment. The final outer plots were located beyond 5m off-trail for control purpose with the assumption that 5m off-trail was minimally affected by recreational activities (Marion *et al.* 2006). Comparison of plants found in the trailside and control quadrats allowed evaluation of how differences in morphological characteristics affected a plant's resistance to trampling damage. This also enabled classification of plants relative to the trail-side disturbance regime (Marion 2006).

There were ten points selected for each trail and transect lines were established in every point that consist of five sampling plots of 1m x 1m quadrats. Thus, in all five trails consisted of fifty points and this made a total of 250 plots in this study. The selection of the point was based on convenient plot sampling. Further clarifications on the experimental design are as in Figures 4.5, 4.6 and 4.7. Assessment and measurement were conducted in the 1m square plots for vegetation, soil compaction, soil sampling and light intensity. Plant within each quadrat were counted and identified to the species level where possible. Plant that unable to be identified on the field sampled and brought to the office for further identification process.

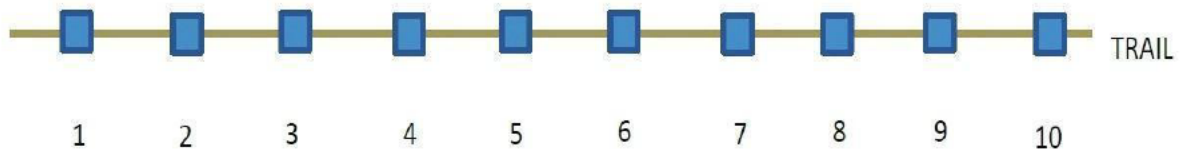


Figure 4.5: The 10 points laid on each trail

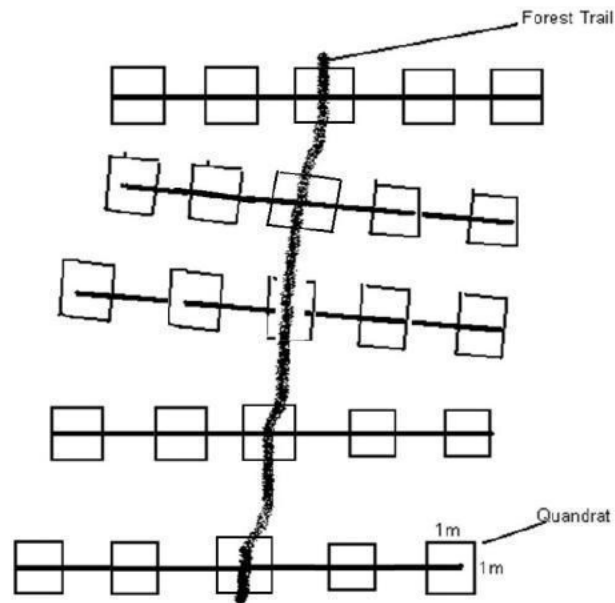
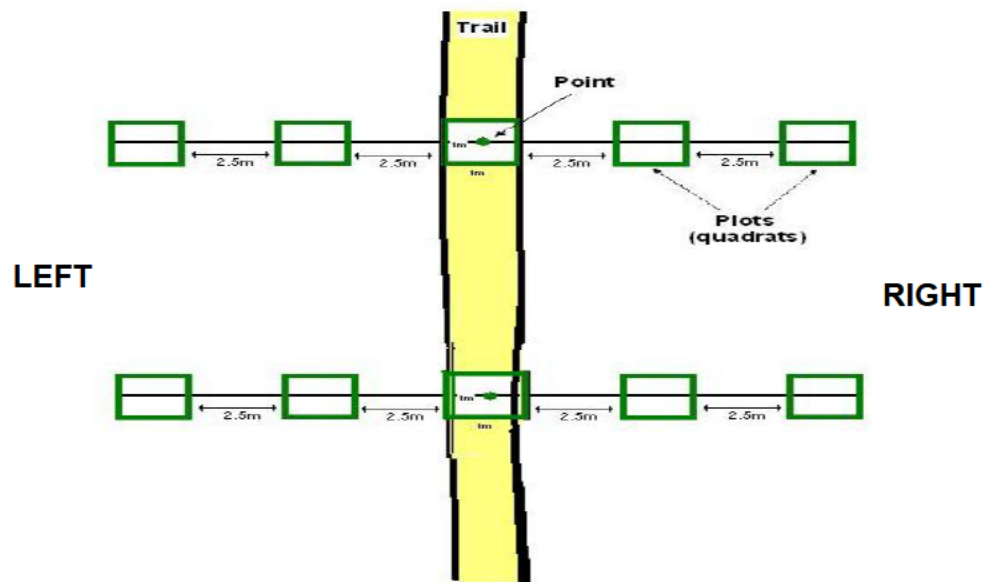


Figure 4.6 (above) and 4.7 (below): Plots and quadrats along the trail (NTS) using the paired (left and right) design method (modified Cole 1995 method) (Note: only five trail points are shown out of ten)



As can be observed in Table 4.1, the trails are not of the same lengths and conditions. However, the technique of data collecting was consistent. Along each trail, ten points were marked of approximately the same distance to one another (Figure 4.6). Photographs of trails are shown in Figure 4.4, whilst the photographs of transects and quadrats are shown in Figures 4.8 and 4.9.

The plots were used to capture data on vegetation and soil parameters. Soil compaction or resistance values were measured using a Field Scout Compaction Meter SC900, an instrument that allows rapid multiple readings within each quadrat. Three (3) reading of repetition in every quadrat were taken. An additional parameter i.e., light level or luminosity was also included in data sampling, and this was measured using a hand-held digital light meter with an instant read out in units of “lux”.

4.4.2 Detailed methodology for the vegetation study

Study on vegetation impact along the trail in MBCA can be express by several ways. One of the approaches was the calculation of biodiversity index using several calculation methods. Furthermore, a similarity index was also important to aid evaluation because of the vegetation variation along the trail.

4.4.2.1. Plant diversity (vegetation part of biodiversity)

In forest area, most plant diversity occurs in the ground layer (or the undergrowth); thus, it is specifically important to sample this community (Johnson *et al.* 2006). This is the approach adopted in this study.



Figure 4.8: Distance measurement for transect length and plots establishment



Figure 4.9: sampling Plots in 1m x 1m quadrat

The basic assumption of measuring diversity is that it describes the relationship of individuals of varying categories within a community. In this study, the vegetation biodiversity index was considered as very essential information that indicates the relationship of recreational use of trail with ecological impacts. Logically, different conditions of vegetation would vary in tolerance to the ecological impacts. Generally, as often observed, due to the high intensity of light as a result of increased exposure some types of ground vegetation grow more vigorously with heavy disruption.

4.4.2.2 Assessment and Measurement of vegetation in the sampling quadrats

The ground and low vegetation observed in the plots fell under several categories of habits or growth forms, namely small trees, shrubs, grasses, palms, ferns, and climbers including lianas (woody climbers). The plants under these different categories are different in terms of girth, height and dispersion.

Datasheets were designed for recording of the plants in the plots shown in Figure 4.9 and 4.10. Species identification and the number of plant individuals in each plot were included as parameters for calculating biodiversity value. Preliminary species identifications were done at the same time of plant counting with the help of trained assistants in botany who are staff of MBCA (Figure 4.11). Species identifications were confirmed at the herbarium (Sandakan Herbarium or SAN, and Forestry School herbarium in UMS). The data were then transferred to Microsoft Excel, and the keyed-in data were later analysed using Statistical Package, SPSS.



Figure 4.10: Plant counting, and identification of every species found



Figure 4.11: Unidentified Plant sample to be referred to botanist in the office laboratory

4.4.2.3 Diversity Indices for vegetation data

The plot data captured the number of species as well as the number of individuals for each species. Using the data, several indices were calculated, based on the experimental design and the stated objectives of the study, in a way that the data can be properly analysed to give meaningful results. These were:

- Species Richness Index (S)
- Simpson Index (D)
- Shannon-Weiner Index (H)
- Margalef Evenness Index

The above indices are explained below:

Species Richness Index

Species Richness Index is the total number of different species present in the total area of all quadrats which is calculated using the formula below.

Species richness is a measure of the number of species found in a sample. The larger the sample, the more species would be expected to find. To estimate species richness, the number of species (S) is divided by the square root of the number of individuals in the sample (N). This particular measure of species richness is known as D, the Menhinick's index.

$$D = \frac{S}{\sqrt{N}}$$

Where,

S equals the number of different species in the sample

N equals the total number of individuals in the sample

This is the simplest measure of species diversity index among all of the measures of species diversity. It does not consider the proportion of each species within the quadrats. It also does not indicate how the diversity of the population is distributed or organised among those particular species. However, this index is important for further calculation of other diversity indices.

Simpson Index (D)

Simpson Index (D) is a measurement that accounts for both richness and proportion (percent) of each species to the total number of species in all quadrats. This index assumes that the proportion and profile pattern of individuals in an area indicates their importance to diversity as shown by Simpson (1949). The index however appears in three different inter-related forms, namely:

1. **Simpson's Index:** $D = \sum ()$, where the probability that two randomly selected individuals of a species in a sample belong to the same species.
2. **Simpson's index of diversity:** $1 - D$, where the probability that two randomly selected individuals of a species in a sample belongs to different species.
3. **Simpson's reciprocal index:** $1/D$, where the number of equally common species that would produce the observed Simpson's index.

In the context of analysing vegetation biodiversity in the Maliau Basin Conservation Area (MBCA) for assessing recreation impact, the most relevant version of Simpson's Index would be Simpson's index of diversity ($1 - D$) (White et al., (2021). This form of the index reflects the probability that two randomly selected individuals belong to different species, providing a clearer measure of community diversity and species evenness, which is crucial for assessing biodiversity impacts due to human activity.

Simpson's Index (D) and Simpson's Reciprocal Index ($1/D$) are less suitable for assessing recreation impact on vegetation biodiversity in the Maliau Basin Conservation Area (MBCA) due to their focus on species dominance and evenness, which limits their ability to capture the nuanced effects of recreation on ecosystem diversity. Simpson's Index (D) emphasizes dominant species, making it less sensitive to changes in rare species often affected by recreation, while $1/D$, though a measure of evenness, is difficult to interpret in highly diverse systems like MBCA, where it may obscure subtle but ecologically significant shifts (Magurran, 1988; Morris et al., 2014; Chao & Jost, 2012; Peet, 1974). In contrast, Simpson's Index of Diversity ($1 - D$) better captures both species richness and evenness, providing a more direct reflection of diversity changes critical for evaluating recreation impacts.

In all of the three forms above, D can be observed to have been influenced by two parameters of percent of each species present and richness. So, for a given Species Richness (S), D will decrease as the percent of the species

becomes more equitable. Thus, species pattern must be observed carefully in order to interpret the value effectively.

$$D = \sum \left(\frac{n}{N} \right)^2 \quad \text{or} \quad D = \frac{\sum n(n-1)}{N(N-1)}$$

Where,

n = the total number of individuals of a particular species

N = the total number of organisms of all species

The value of D is ranges between 0 and 1.

Shannon-Weiner Index (H)

Shannon-Wiener Index (H') is most commonly used index in ecological studies. The values range from 0 to 5, usually ranging from 1.5 to 3.5. It's calculated:

$$H' = -\sum \left[\left(\frac{n_i}{N} \right) \times \left(\frac{n_i}{N} \right) \right]$$

Where,

ni = number of individuals or amount (e.g., biomass) of each species (the ith species) and

N = total number of individuals (or amount) for the site, and

ln = the natural log of the number.

Advantages and Disadvantages of Shannon Weiner Index are:

1. Relatively easy to calculate
2. Fairly sensitive to actual site differences
3. There are several instances where H' is similar between sites even though sites are different.

Margalef Index

Margalef's index was used as a simple measure of species richness (Margalef, 1958). The index equation is followed:

$$D = \frac{(S - 1)}{\ln N}$$

Where,

S = total number of species

N = total number of individuals in the sample

$\ln$ = natural logarithm

4.4.2.4 Justification for combination of biodiversity indices methodology

Using a combination of biodiversity indices such as the Species Richness Index (S), Simpson Index ($1-D$), Shannon-Weiner Index (H), and Margalef Evenness Index presents a robust methodological approach to assess the impact of recreation on vegetation in the Maliau Basin Conservation Area (MBCA). Each index provides unique insights into various aspects of community structure, allowing for a comprehensive analysis of how

recreational activities influence biodiversity. This multi-index approach capitalizes on the strengths of each index: Species Richness captures the sheer number of species, Simpson's Index highlights species dominance, Shannon-Weiner integrates richness with evenness, and Margalef Evenness specifically measures the distribution of individuals across species. By combining these indices, researchers can effectively address the limitations of using a single index, gaining a more detailed understanding of ecosystem health and resilience under recreational pressure (Tuomisto, 2019; Jost, 2020).

The primary advantage of using this combination package lies in its ability to capture different facets of biodiversity, which are essential for understanding the multi-dimensional impacts of recreational disturbance. Recreation may not uniformly impact all biodiversity metrics. For instance, increased recreational use may cause a shift in community composition without an immediate decrease in species richness. In such cases, the Simpson and Shannon-Weiner indices may reveal a rise in species dominance or a decrease in evenness even when richness remains stable. This heightened sensitivity to changes in community structure allows for earlier detection of ecosystem changes, which is crucial for conservation management (Moreno & Calderón-Patrón, 2020). Moreover, by comparing indices, researchers can better interpret specific trends, such as whether shifts are due to reduced species diversity, increased dominance of resilient species, or even distributional changes among individuals in the community. This combination package is

therefore an effective tool for identifying nuanced patterns of recreational impact that a single index might overlook.

Additionally, the opportunity to use these indices together provides a methodological foundation for trend analysis over time. Observing how different indices respond across a gradient of recreational impact or over multiple sampling periods allows researchers to detect if certain indices show changes earlier than others. For example, if Species Richness remains constant while Shannon-Weiner and Simpson's indices exhibit fluctuations, this may suggest that recreational activities are not yet impacting species counts but are altering species composition and distribution patterns. Such patterns can indicate early stages of impact, where some species may still be present but are either declining in abundance or becoming more dominant due to their resilience to disturbance. This trend analysis, enabled by the combination of indices, offers valuable insights into the pace and nature of ecosystem changes, helping guide timely interventions to mitigate further biodiversity loss (Magurran & McGill, 2019; Zhang et al., 2021).

The applicability of this combination also lies in its ability to adapt to different research questions within conservation contexts. Each index can be used to address specific aspects of recreational impact. Species Richness and Shannon-Weiner Index offer general insights into the diversity of an area, ideal for assessing overall ecosystem health. Simpson's Index, with its focus on dominance, is particularly suited to understanding whether certain hardy species are becoming disproportionately abundant, a common scenario in

disturbed habitats. Meanwhile, Margalef's Evenness Index hones in on the distribution of individuals across species, useful for detecting shifts in community balance that may arise due to recreational pressures. This versatility allows researchers to tailor the indices to the particular objectives of their study, maximizing the relevance and interpretability of the findings (Chao et al., 2020; Chazdon & Laestadius, 2021).

The methodological opportunity to compare these indices offers a unique chance to evaluate their effectiveness and efficiency across varied environmental conditions. This is parallel with the last objective that has been laid in chapter 1. Recent studies emphasize the importance of using multi-index approaches to capture comprehensive biodiversity metrics, especially in ecologically sensitive areas impacted by human activity (Socolar et al., 2021; Hermoso et al., 2021). The comparative application of these indices enables researchers to evaluate which index—or combination of indices—provides the clearest and most reliable trends in response to recreational impact. Furthermore, this approach is instrumental in refining biodiversity assessment techniques by identifying which indices are most responsive or stable under different degrees of disturbance. Such comparative effectiveness and trend analysis can strengthen methodological best practices in recreation ecology, ensuring that biodiversity assessments remain relevant and accurate as ecological conditions shift over time.

In summary, employing a combination of Species Richness, Simpson, Shannon-Weiner, and Margalef Evenness indices provides a methodologically

rigorous approach to assessing the impact of recreation on biodiversity in the MBCA. This multi-faceted approach not only enables comprehensive trend analysis and early detection of ecological shifts but also enhances the methodological robustness by allowing for a comparative evaluation of indices. As recent literature supports, such integrated biodiversity assessments are critical for adaptive management in conservation areas, offering essential insights into both immediate and long-term ecological impacts of human activities (Tuomisto, 2019; Chazdon & Laestadius, 2021).

4.4.3 Soil testing, sampling and parameter analysis

4.4.3.1 Soil Compaction

Soil is very important in the forest area. Soil types and features help determine the type of ecosystem and the species of vegetation growing in an area. Dasmann (1972) described soil as the basis of all terrestrial life, much more than just inert dirt but alive and produced and maintained by interactions between living and organisms, rock, air, water, and sunlight. Soil impacts are among the most frequently mentioned of all the effects of outdoor recreation activities. At first sight the consequences of recreation activities to the soil are compaction and erosion mostly due to trampling (Liddle 1997). In most cases, these impacts result in a series of changes of soil condition particularly organic matter and moisture content. In theory, compacted soil has less content of moisture and organic matter.

Soil compaction due to recreation activities is one of the aspects studied by many researchers such as Dale and Weaver (1974), Quinn and Morgan

(1980), Hylgaard and Liddle (1981), Cole (1982), Kuss and Graefe (1985), Gomez-Limon and De Lucio (1995), Marion and Cole (1996), Belnap (1998). More recent studies on this topic include those by Ivanenko (2023), Saputra (2024), Ospan (2024), and Sardar & Islam (2025). Soil compaction prevents moisture penetration, reduces nutrient and chemical uptake, and hinders plant root growth.

In this study, the measurement of soil compaction was carried out in the 1m square quadrates using handheld tool called Field Scout Compaction Meter SC900 (Figure 4.12 and 4.13). This electronic soil compaction meter was a quite versatile compaction meter. Soil depth readings are determined by a sonic depth sensor.



Figure 4.12: Measurement of soil compaction inside a 1 m x 1 m quadrat

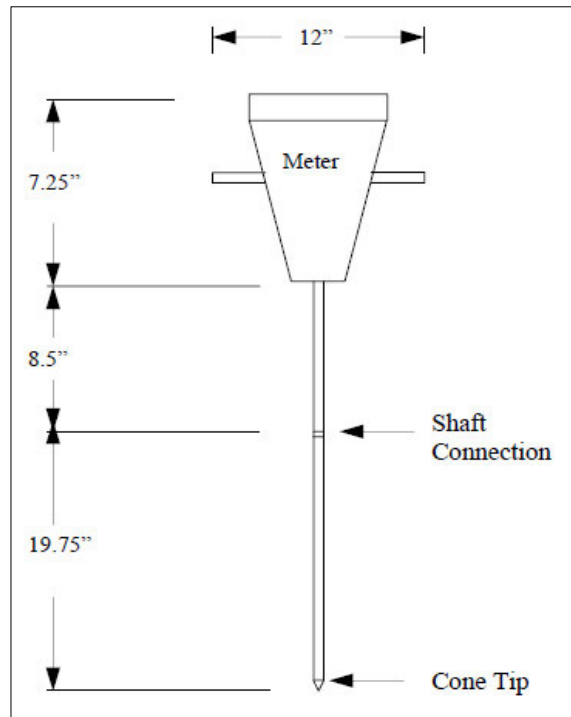


Figure 4.13: The figure indicated the specification of the Field Scout Compaction Meter SC900. Cone tips make it easy to penetrate soil up to 30cm depth.

Cone index values are measured by a load cell sensor and can be displayed in PSI or Kpa. The tool has shaft-mounted probe that allows to easily and rapidly taking many measurements (Figure 4.13). The shaft can be dissembled into two pieces for easy storage and transport. The meter's built-in data-logger can record data from several points and eliminates the need to record data manually. Through the software, data can be downloaded.

The measurement of soil compaction was carried out for every quadrat. Measurement conducted up to 15cm depth which is the usual depth effected by trampling. As mentioned earlier, soil compaction causes not only changes in structural but also soil content mainly moisture and organic matter.

However, the moisture and organic matter content of soil can only be determined by carrying laboratory analysis, thus soil sampling in every plot of study was very essential.

4.4.3.2 Soil Organic matter (SOM) and Soil Moisture Content (SMC)

Differ from soil compaction, Soil organic matters and Soil Moisture Content were unable to be determined in the field instantly. Soil sample need to be taken out and being analysed in the laboratory for organic content. Several standard procedures were carried out as soon as was possible in order to minimise post-sampling changes.

Soil sampling

The soil sampling was carried out within or inside sampling plots. Soil samples were taken at 15cm depth using auger (Figure 4.14). In order to have a good sample an area needed to be clear of any debris. Then the auger was inserted into the soil at



Figure 4.14: Auger for soil sampling



Figure 4.15: Soil sampling to the depth of 15cm

no more than 45-degree angle from vertical as shown in Figure 4.15. The soil samples were transferred to an appropriate container. Soil samples taken were brought to the laboratory for further processing as soon as possible to avoid decreasing sample quality.

Laboratory procedure to determine soil moisture (SMC) and organic matter (SOM) content

Soil samples from the field contained water but the amount depended on soil properties and the preceding weather conditions. Samples were air-dried at 40 degrees Celsius. Even when air-dried, the soil still contained some

remaining water, or soil moisture content (MC). Further, determination of MC and SOM followed a standard procedure as shown in the Figures 4.16, 4.17 and 4.18 below (the detailed procedures are described in the appendix).

The determination of MC and SOM content was conducted in continuous process. Firstly, the air-dried soil samples were weighed together with porcelain cup using a balance of precision to 0.001g (Figure 4.16). Further, the porcelain cup with air dried soil was transferred to an oven at temperature of 105 degree Celsius for overnight (Figure 4.17). Later the porcelain cup was taken out and cooled in a desiccator and reweighed again.

The calculations of MC of the soil as a percentage of the dry soil weight were carried out using the equation below:

$$\frac{W2 - W3}{W3 - W1} \times 100\%$$

MC percent =

W1 = Weight of porcelain cup (g)

W2 = Weight of air-dried soil + porcelain cup (g)

W3 = Weight of oven dried soil + porcelain cup (g)



Figure 4.16: Scooped Soil sample into porcelain cup and then weighed in controlled scale



Figure 4.17: Air-dried soil in the porcelain cup placed in oven at 105°C overnight

After the oven-drying procedures were completed then further analysis of soil organic matter (SOM) was conducted. The oven-dried soils were heated to 500°C for another 24 hours to burn off the organic matter content of the soil samples (Figure 4.18). Later the samples were placed in desiccator to cool down and reweighed again for W4 value.



Figure 4.18: Oven dried sampled then placed in the furnace at to 500°C for 24 hours to burn SOM

With the W4 value the calculation of SOM of the soil can be done using the equation below:

$$\text{SOM percent} = \frac{W3 - W4}{W3 - W1} \times 100\%$$

Where,

W4 = Weight of mass of burnt soil + porcelain basin (g)

4.4.4 Wildlife

In this study, the wildlife aspect is included as one of the important nature tourism attractions to MBCA. The scope of this ecology covers distribution of organism and its abundance (Buckland 1993, 2001). The wildlife in this census was limited to bird, small mammal, butterflies, amphibian and reptiles.

The priority given in this part of this study is to consider the most cost-effective way to survey a wildlife or faunal population and later come out with very reliable data in order to apply them in the management. New survey techniques are well developed today, and some are inexpensive and without physical contact with study animal. One of them is Distance Sampling which was introduced and refined by several statisticians (Buckland 1993; 2001; Burnham 1980). Unlike all the simple indices, Distance Sampling fits a detection function to the observed distances in order to estimate the proportion of objects missed by the survey (Thomas 2002). In the absence of complete census, Distance Sampling is a reliable survey method available to produce useful information

4.4.4.1 Distance sampling using transects line method

The longest transect walked in any one day is not likely to be more than 5km. This is because censusing is often restricted to periods of high animal activity, and the quality of the data collected will decline as the observers begin to tire. For more precise estimates in well-defined areas or habitats, it might be better to do many short transects. It then becomes easier to avoid some of the bias related to time of day. The trail or transect can be partitioned into distance intervals along its length. For example, markers every 50 m along transects

can help the observers to follow the correct track and also allow habitat information to be collected for specific transect sections. The habitat data can then be related to the occurrence of animal species at particular sections of the transect

4.4.4.2 Data Collection

In the transect, the observer walks at a fairly constant speed, looking either side of the line walked, and estimate the perpendicular distance from the line to each animal contact. There are two ways of estimating the distance: 1) A direct estimate of the distance between the animal and the surveyor can be made, or 2) An estimation of the distance between the observer and the animal away from the line. These methods are illustrated in Figure 4.19. However, in this study the animal encounter frequency and number of individuals seen were more significant.

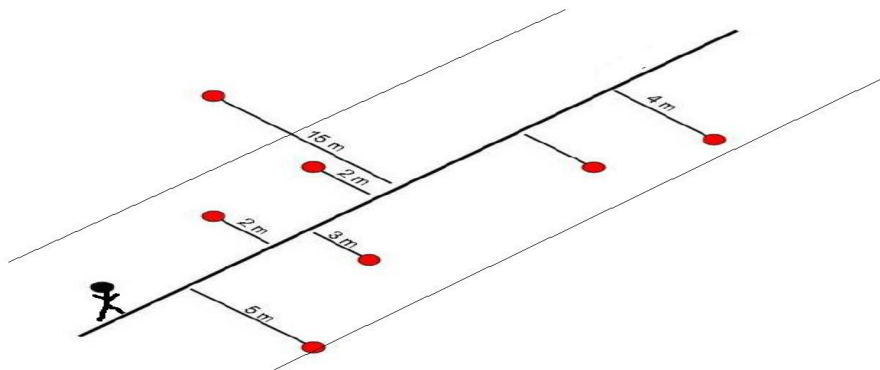


Figure 4.19: Distance estimation/measurement along transects (Modified from Buckland 1993)

Two critical situations of using the method are the dense and high forest canopy and more than one category of animals going to survey. Under these conditions perhaps observers should concentrate whilst slowly moving along the transect to avoid missing animals. Besides the manual recording using simple form (as in Table 4.2), equipment such as digital cameras (Figure 4.20) were used to take photographs of objects. Another situation arose when recording moving animals (i.e., birds) in Distance Sampling methods because the aim of producing a snapshot of all the animals recordable from the transect line. It was impossible to know if those animals were normally part of the population of that area. Although it was worthwhile recording these observations, they were not used in the calculations since they would produce overestimates.



Figure 4.20: Digital Camera (Nikon D7000).

A distance estimate and a count of the number of animals in each contact were all that was required to calculate density. However, the following were also recorded:

- The species of the individual animals (if possible).
- The date and time of day
- The location of the survey (Trail)
- The weather conditions
- The habitat types

This information can often throw light on the biology of target species and is also useful when it comes to analysing and interpreting the results for management purpose.

Table 4.2: Recording form of wildlife observation along trails

Date & Time : _____
 Weather : _____
 Start : _____ Finish : _____

Transect/Trail	Species	Approx Distance	Remarks
1.			
2.			

4.4.4.3 Efficacy of Wildlife Impact Assessment using Distance Sampling Methods

To bridge the apparent disconnect between the recognition of wildlife's role in attracting visitors to the Maliau Basin Conservation Area (MBCA) and its integration into the study, a deeper exploration of the methods and their effectiveness in assessing wildlife impacts is essential. The chosen methodologies, specifically distance sampling of wildlife frequency and species richness analysis, are crucial for understanding the effects of recreational disturbance on wildlife, particularly in a biodiversity hotspot such as the MBCA with varying trail usage intensity. This section will thus discuss the objectives these methods sought to achieve, how they align with the research goals, and justify their selection and application in evaluating the impacts of recreation on faunal wildlife within the MBCA.

4.4.4.4 Justification for Wildlife Focus

Tourists are drawn to the MBCA largely because of its rich biodiversity, particularly its faunal species, which include various mammals, birds, and other wildlife endemic to tropical rainforests. The research highlights the importance of wildlife as a central attraction for MBCA visitors, underscoring the need to incorporate faunal wildlife considerations in the ecological impact assessment. Literature on recreation ecology emphasizes that visitor activities can disturb wildlife in protected areas, potentially altering species distribution and behaviour, leading to long-term biodiversity implications (Reed & Merenlender, 2020). Therefore, evaluating the impacts of recreational

activities on wildlife biodiversity, particularly in sensitive habitats with varying degrees of human presence, is crucial to inform conservation strategies.

4.4.4.5 Objectives of Distance Sampling and Species Richness Methods

The distance sampling and species richness methodologies were selected to estimate the impact of recreational disturbance on wildlife accurately. Distance sampling, a widely accepted method in wildlife monitoring, measures the frequency and spatial distribution of wildlife encounters across designated transects. By estimating animal abundance and density, distance sampling provides valuable insights into how recreational disturbance influences wildlife presence along trails with varying Trail usage intensities (Royle et al., 2019). The method allows researchers to detect changes in wildlife distribution, a possible indicator of disturbance response, particularly for species that might avoid trails with higher human traffic. Species richness, on the other hand, is crucial for assessing biodiversity changes in areas affected by recreation. This index captures the number of different species observed and provides an essential baseline for understanding how recreational activities influence the diversity of species present. According to Sutherland et al. (2020), species richness is sensitive to disturbance and habitat degradation, making it a useful indicator in recreation ecology studies. Together, these methods allow for a multifaceted approach that examines both species presence and diversity, reflecting wildlife responses to varied levels of disturbance.

Distance sampling was employed to capture data on wildlife frequency across different trail segments, correlating with human Trail usage intensity. In areas

of high Trail usage, reduced animal abundance could suggest that species are avoiding these zones, potentially due to noise, visual cues, or other disturbance factors associated with human presence (Duffus & Dearden, 2021). By documenting frequency changes, the research can infer how varying recreational pressures influence wildlife behaviour, offering a way to quantify the immediate effects of disturbance on fauna within the MBCA.

Monitoring species richness along trails with different levels of human activity helps to determine whether high Trail usage areas exhibit lower biodiversity compared to less frequented ones. A decline in species richness in heavily trafficked areas could indicate that specific species are more sensitive to disturbance or that habitat conditions are degrading due to recreational impacts. Research on similar tropical environments has demonstrated that high human disturbance correlates with a reduction in sensitive species, making species richness a valuable indicator of biodiversity impact (Gallagher et al., 2021).

The primary research question, "What impact does recreational disturbance have along tropical forest trails?" is directly addressed through these methodologies. Distance sampling quantitatively reveals potential shifts in wildlife encounter rates as a function of human presence, while species richness analysis offers a qualitative perspective on biodiversity maintenance or loss across Trail usage gradients. These methods are validated by their extensive use in tropical ecosystems for monitoring species responses to

anthropogenic stressors, providing a solid framework for answering the research question within the MBCA's context (Watson et al., 2020).

Recent literature emphasizes that combining distance sampling with biodiversity indices like species richness provides a robust framework for evaluating recreational impacts. According to Fretwell et al. (2023), using multiple biodiversity indices allows for a more nuanced understanding of disturbance effects, particularly when aiming to detect both direct behavioural responses and broader biodiversity shifts. Additionally, studies in similar conservation areas suggest that recreational disturbance can lead to both spatial avoidance by certain species and reduced species richness, supporting the approach adopted here (Brockmeyer et al., 2019).

By incorporating distance sampling and species richness assessments, this research effectively addresses the importance of faunal wildlife to the MBCA's tourism appeal and its vulnerability to recreational disturbance. These methodologies capture both direct and indirect impacts of Trail usage on wildlife, aligning with the broader conservation and recreational management goals of the MBCA. As the study leverages established ecological tools validated by recent research, it provides a reliable basis for evaluating how recreational disturbance may alter faunal biodiversity along MBCA trails, ultimately contributing valuable insights into the sustainable management of this unique conservation area.

4.4.4.6 Methodological Constraints in Wildlife Assessment Along MBCA Trails

The methodological limitations of this research regarding wildlife assessment highlight significant constraints, particularly concerning the exclusion of large mammals from the wildlife census and the omission of alternative methods such as camera trapping. While large mammals are often key indicators of ecosystem health, their exclusion may lead to an incomplete picture of wildlife responses to recreational disturbance in the Maliau Basin Conservation Area (MBCA). This exclusion could be attributed to logistical challenges and the species' typically lower encounter rates on trails due to their sensitivity to human presence (Fretwell et al., 2023).

The decision of not using camera traps which one of the most effective tools for monitoring cryptic or human-averse species was largely due to their high cost. The financial investment required for large-scale camera deployment across MBCA trails was unfeasible. Instead, the research mimicked an ecotourist experience, aiming to identify what species are observable along MBCA trails, rather than conducting a comprehensive study of species distribution and biodiversity across the entire MBCA. This approach aligns with the study's focus on assessing recreational impacts, but it diverges from scientific wildlife surveys, which typically require systematic sampling across varied habitats and include techniques to mitigate detection biases. By relying on direct observation along trails, the research inherently favours species more tolerant of human presence, potentially underestimating the diversity and sensitivity of MBCA's wildlife (Sutherland et al., 2020). This methodological

choice underscores the study's prioritization of ecological impact assessment from a recreation perspective rather than a full-scale wildlife biodiversity assessment.

In essence, the study's limitations reflect a balance between financial constraints and research objectives. Despite, methods such as camera traps could mitigate human disturbance biases, the cost barriers are significant, and the approach ultimately reflects an ecotourism perspective. The resulting data provide valuable insights into the types of species tourists might encounter but should be interpreted with caution when drawing conclusions about MBCA's broader biodiversity (Brockmeyer et al., 2019).

4.4.5 Light Intensity

Light plays a very important role in the growth, survival, and regeneration of tropical rain-forest plants (Richards, 1952; Schulz 1960; Longman and Jenik 1974; Whitmore 1989). In normal conditions, the forest floor received less than one per cent of light due to high density of vegetation and these results in the mature forest floor clear of shrubs. Gaps and clearings will induce the growth of new shoots and boost several primary species such as grasses, ferns, and new seedlings. Trails with average width of two to three metres were assumed to offer higher intensity of light and decreases dramatically towards off-trail areas.



Figure 4.21: LX101 Lux meter

LX101 Lux Meter (Figure 4.21) was used to measured light intensity for every sampling quadrat in each trail to monitor the changes. The value was then calculated as a percentage of light intensity for clearer representation between trails and open area.

4.4.6 Visitor Experience and Perception Study

Besides the ecological and physical aspects of the study, questionnaire surveys were used to gain information from the relevant parties particularly the nature tourists. This was considered important in gathering information on perceptions of visitors towards the ecological disturbance caused by the recreation activities. In this research, a self-administered questionnaire was developed. There are several reasons for this selection:

- i. A self-administered questionnaire was considered appropriate in terms of viability and to match with the field survey setting (i.e., logistic, spatial and time constraints). The use of self-administered questionnaire was deemed

suitable since there are many and dispersed survey locations, as well as a time constraint in conducting the survey. Therefore, other survey techniques such as interviews or face-to-face discussions were inappropriate as they would require a longer period.

- ii. The self-administered questionnaire was distributed or delivered to the visitors and guide as respondent by trained assistants, who were staff of MBCA. This has the advantage of providing more information regarding the questionnaire and tends to be more efficient, while at the same time reducing the chance of interviewer bias. The trained research assistants were always available on-site to answer any questions a respondent might have.
- iii. Self-administered questionnaires provide more privacy and anonymity to the respondent.
- iv. Distributing questionnaires personally to the respondent can greatly increase the number of completed questionnaires obtained and significantly reduces the cost of data collection.

4.4.6.1 Sample and sampling procedure

A non-probability sampling technique was applied in this study. More specifically, this research utilized purposive sampling based on the author's familiarity with the population (Patton 1990). In other words, the Respondent has already identified to answer the questionnaire. The sample consisted of Malaysian (domestic) and foreign tourist only, however scientist and researcher were not included.

Questionnaires were then checked through pre-test on ten average respondents in order to make sure this early version were feasible in this study. After gaining some responses, several corrections were done to avoid confusion and misunderstanding among potential respondents when answering the questionnaires. It is preferable to use clear, short, simple, and friendly sentences to obtain exact responses. This is important since there were also respondents who only had lower secondary school education and possibly could not answer some of the questions that were long, full of difficult terms, and complicated. Questionnaires that are friendly in nature and easily understood heightened the focus of the respondent during the answering process. This was especially important when they were already exhausted from walking the forest trail.

4.4.6.2 Questionnaire design

Generally, the questionnaire was design to accommodate the four concepts of Trail usage to an ecotourism site which is their motivation, participation, satisfaction, and anticipation. Thus, the questionnaire was sub-divided into several sections where each of them requires specific perception and evaluation from the respondents. The Questionnaire was set-up as simple as possible but avoiding ambiguity (refer to appendix). The sections were as follows:

Section 1: Demographic or respondent background

Section 2: Visit background

Section 3: Site information source and motivation to visit

Section 4: On-site recreation activities

Section 5: Visitor perception on nature trail and activities carried out

Section 6: Visitor rating and preference and visitor suggestion for improvement and intention for repeat visit.

The questions are a combination of closed ended format and Likert scale basis. A Likert scale is a technique that is normally used to allow respondents to indicate the importance they attach to a particular factor, or their level of agreement with a statement, by using a standard set of responses (Veal 2006). In this research, the priority rating for each indicator was done according to a scale of 1 to 4 only to eliminate the bias of respondent always being neutral, whereby 1 represented the strongly agree while 4 shows that the indicator is strongly not agree. Assessment via Likert scale is felt to be suitable for assessing the respondent's perceptions towards recreation activities.

Barbie (2003) supported the use of this technique as one of the best methods to measure attitudes. Section 1 asked for information about the respondent background and profile, while Section 2 was only the background of the visit. In Section 3, respondent was asked about their motive of visit and also the source of information about MBCA. Section 4 deals with their participation in recreation activities, then Section 5 was about respondent perception toward activities and nature trail in MBCA. Respondent satisfaction and anticipation were asked in Section 6.

The questionnaire used was in two versions with English and Malay. It was done to help the respondent (especially local visitors) to understand the questions asked more easily. The translation was necessary because some of them are not proficient in English.

4.4.6.3 Quantitative Social Science method

The perception study conducted within the Maliau Basin Conservation Area (MBCA) employs social science methods that are quantitative rather than qualitative in nature. This distinction is critical to clarify, as the approach focuses on measurable data gathered through structured survey tools rather than on open-ended, narrative responses typical of qualitative methodologies.

In this study, exclusively utilized closed-ended survey questions, including Likert-style items, to ensure the consistency and reliability of responses across participants. Closed-ended questions are particularly effective in perception studies like this one, as they allow respondents to express the intensity of their agreement or disagreement with predetermined statements, thus providing a quantifiable measure of perception. The use of closed-ended and Likert-style questions aligns with the study's quantitative approach, ensuring that data collected could be systematically analysed to reveal patterns, trends, and statistical significance in perception across the participant group.

This methodological choice supports the study's aim to yield data that can be readily compared and quantified, aligning with the structured nature of the research objectives. Therefore, the selection of a quantitative survey design,

free from open-ended questions, enhances the study's rigor by emphasizing objectivity and reproducibility, providing a robust basis for statistical analysis without introducing the interpretive variability associated with qualitative responses.

4.5 DATA ANALYSIS

Technically, the study begins with literature review that helps clarify concepts and framework to explore relevant issues and the lack of research on recreation ecology particularly in tropical rainforests. This thesis adapted a standard method by Cole (1978; 1995) as its methodology for vegetation and soil study, while for wildlife, distance sampling method were used based on method by Buckland (2001). Lastly, questionnaires were also distributed to visitors.

For data analysis, the research is divided into three main categories i.e. (a) secondary data (b) physical data and (c) respondent perceptions. Secondary data particularly Trail usage record have an important role in determining the ranking of the trail. Research on the physical aspects has been designed to measure the effects of recreational use of trails on forest ecology. Among the factors that have been considered here are the disturbance to the vegetation particularly by human trampling, soil compaction, soil organic matter, soil moisture content, light penetration to the forest floor, and wildlife density. An assessment for normality was conducted, followed by the Kruskal-Wallis test with post-hoc Mann-Whitney analysis to determine significant differences among and between trails and plot sample sets. The expectations and attitudes of visitors were also considered and studies through questionnaire surveys. This approach considers the perceptions and satisfaction of

visitors towards the ecological impacts and the forest tourism experience. Visitor perception data was analysed through coding and the development of Attractiveness and Condition Scores, as well as an Overall Experience Score. The Kruskal-Wallis test was used to examine variations among and between different responses. This Chapter deals with discussions on the analysed differences observed for recreation ecological impacts along the trails at varying distances from the trails.

The data analysis approach is design so that will align with the research objectives and concept of this study. This study aims is to understand the ecological impacts of recreational disturbance on Maliau Basin Conservation Area (MBCA) trails and visitor perceptions. It focuses on tropical forest ecosystems and the transferability of established methods of impact assessment. The research aims to critically appraise literature, develop appropriate methods for impact assessment, evaluate ecotourism impacts on MBCA trails, and develop criteria for ecological impact indicators.

4.6 EXPECTED RESULT

In this research study examining recreational impact on the Maliau Basin Conservation Area (MBCA), the expected results on physical are framed around two primary comparative analyses: one focusing on varying Trail usage intensities across different trails, and the other examining distinct plot locations categorized by their disturbance levels. These comparisons will provide insights into how recreational activities may differentially affect key ecological variables such as vegetation diversity, soil compaction, soil properties, and light intensity. The findings are anticipated to support or refute the hypotheses, contributing valuable information to the understanding of recreation ecology within sensitive tropical ecosystems.

4.6.1 Comparison among Different Trails' Trail usage Intensity

In assessing the five different trails in the MBCA with varying Trail usage intensities, the study aims to determine whether recreational disturbance correlates with measurable differences in ecological variables. If the alternative hypothesis (H_a) is supported, the results will likely demonstrate that trails with higher Trail usage intensity exhibit more clear ecological impacts, as follows:

i. Vegetation Diversity

Higher Trail usage levels are expected to lead to a reduction in plant diversity. Increased trampling intensity can damage vegetation, resulting in fewer plant species, especially those less resilient to physical disturbance. For trails with lower Trail usage, higher vegetation diversity is anticipated, maintaining a richer range of species that contribute to the ecosystem's overall biodiversity.

ii. Soil Compaction

Soil compaction, a common impact of recreational activities, is anticipated to be more pronounced on trails with higher foot traffic. Compacted soil restricts water infiltration, root penetration, and oxygen exchange, negatively impacting plant growth. Trails with lower Trail usage intensities may retain soil characteristics closer to natural, undisturbed conditions, with less compaction and healthier soil structure conducive to native vegetation.

iii. Soil Properties

Soil Moisture Content (SMC) and soil organic matter (SOM) content may also vary among trails with different Trail usage levels. In highly trampled trails, the disturbance could decrease moisture due to compaction and increased erosion then reduce organic matter as vegetation cover diminishes. Comparatively, trails

with minimal use may demonstrate more stable and favourable soil properties, supporting a richer ecosystem.

iv. Light Intensity

Light intensity in the understory could increase along highly visited trails due to reduced vegetation density, which often results in gaps within the canopy. In contrast, trails with fewer visitors may maintain more consistent canopy cover, regulating light levels and promoting a microenvironment conducive to shade-adapted species. This expected variation in light intensity could further reflect the impact of trail use on vegetation structure and health.

If the null hypothesis (H_0) is not rejected, suggesting no clear differences in these ecological variables among trails, it may imply that the MBCA ecosystem exhibits a level of resilience to recreational activities, or it could indicate that disturbance thresholds are insufficient to yield observable differences at current Trail usage levels.

4.6.2 Comparison among Different Plot Locations (On-trail, Proximal and Distal (Control))

The second part of the physical study examines ecological differences across plots categorized by disturbance levels: heavily disturbed (On-trail), disturbed (Proximal), and less-disturbed (Distal/control) plots. If the alternative hypothesis (H_a) is supported, results will likely show gradations in ecological characteristics that align with the disturbance gradient, with the following specific patterns anticipated:

i. Vegetation Diversity

Heavily disturbed plots are expected to exhibit the lowest plant diversity, as intensive recreational use and environmental stress may selectively disadvantage sensitive species, leading to a simplified plant community dominated by disturbance-tolerant species. Moderately disturbed plots are anticipated to show intermediate vegetation diversity, while undisturbed (control) plots should display the highest diversity, providing a baseline of species richness representative of the natural MBCA ecosystem.

ii. Soil Compaction

In heavily disturbed plots, compaction is expected to be high due to frequent and intensive trampling, leading to increased soil density, reduced porosity, and potentially altered hydrological dynamics. Moderately disturbed plots may present moderate soil compaction, while less-disturbed plots are expected to exhibit low compaction, reflecting conditions that support healthy root development and water permeability.

iii. Soil Properties

Soil moisture content (SMC) and soil organic matter (SOM), are also likely to vary according to disturbance level. In heavily disturbed plots, moisture content and organic matter loss may be more apparent due to erosion and vegetation removal. Disturbed plots could show moderate impacts, while undisturbed plots are expected to maintain optimal moisture levels and organic matter content, supporting diverse plant and microbial life.

iv. Light Intensity

Light intensity measurements may reveal higher levels in heavily disturbed plots due to sparse canopy cover resulting from vegetation loss. This

increased light availability can favour certain opportunistic species but may reduce habitat suitability for shade-tolerant plants. Less-disturbed plots, conversely, are expected to maintain stable, lower light intensity levels due to a continuous and dense canopy layer that regulates sunlight penetration.

If the null hypothesis (H_0) is not rejected, suggesting no significant differences between the plot categories, this could indicate that disturbance effects are less pronounced than hypothesized, potentially pointing to resilience in the MBCA's vegetation and soil composition or to the need for a longer timeframe to detect changes due to disturbance.

4.6.3 Implications for Trail Management and Conservation

These anticipated results are crucial for understanding the relationship between recreational use and ecological integrity within MBCA's sensitive environment. Should significant differential impacts be confirmed, the study will inform trail management strategies aimed at balancing visitor access with conservation. High-Trail usage trails may benefit from targeted management interventions, such as reinforcing pathways, limiting visitor numbers, or promoting fewer sensitive areas for recreational use. Conversely, if no significant differences are detected, the study could highlight MBCA's resilience or reveal a need for adaptive management in light of projected future increases in Trail usage.

By identifying the specific impacts of trail use and disturbance levels on ecological variables, this research will contribute to sustainable recreational management and help establish guidelines for minimizing human impact on MBCA's unique

ecosystems. The results will also enhance the broader understanding of recreation ecology, providing valuable data for other conservation areas facing similar challenges.

4.6.4 Expected Results of the Perception Study in MBCA

The perception study in MBCA aims to reveal visitors' attitudes and opinions regarding the ecological impacts of recreational activities in the conservation area. Through the self-administered questionnaire, it is expected that:

i. Awareness and Concern

A significant proportion of visitors, especially those with an interest in nature conservation, will demonstrate awareness and concern regarding the ecological disturbances caused by trail use and recreational activities.

ii. Satisfaction with Experience

Overall visitor satisfaction is anticipated to be high, with respondents appreciating the unique biodiversity and natural scenery of MBCA. However, some may express concerns about visible environmental degradation on heavily used trails, indicating potential dissatisfaction if ecological impacts become too evident.

iii. Preference for Minimal Impact

Many visitors may indicate a preference for low-impact activities and support for measures that reduce environmental harm, such as maintaining specific trails, limiting visitor numbers, or introducing educational signage on ecological preservation.

iv. Suggestions for Improvement

Respondents may suggest improvements like enhanced trail maintenance, better information on low-impact practices, and controlled access to certain trails to minimize degradation. These suggestions will provide valuable feedback for managing visitor activities sustainably.

v. Repeat Trail usage Intentions

High satisfaction levels, particularly among visitors motivated by ecotourism, will likely correlate with strong intentions for repeat visits. Concerns about ecological impact, however, could moderate this intention if disturbances detract from the natural experience.

These insights will be instrumental for MBCA management, helping align conservation goals with visitor expectations while promoting ecologically responsible tourism practices.

CHAPTER 5

ECOLOGICAL IMPACTS OF RECREATION IN THE MBCA

Chapter 5 presents the results of the experiments designed to test the two hypotheses outlined in Chapter 4:

Hypothesis 1: Increased trail usage intensity is positively associated with increased levels of ecological disturbance among trails with different levels of usage.

Hypothesis 2: Increased trail usage intensity is positively associated with increased levels of ecological disturbance as a function of distance away from the trail.

5.1 SECONDARY DATA: VISITOR NUMBERS

The analysis of visitors in the Maliau Basin Conservation Area (MBCA) was based on the overall visitor records from year 2006 to 2010. The analysis was carried out and presented in two categories based on yearly and monthly visitors, and the average visitor numbers for every trail in the MBCA.

5.1.1 Yearly and monthly visitor numbers trends

The number of visitors coming to MBCA averaged 3436 ± 107 people per annum. Five-year visitor data (Figure 5.1) showed that the trend of visiting increased year by year except in year 2008 where it dropped slightly by about 97 people from the previous year. Monthly average visitor data are shown in Figure 5.2. The results show that frequency of visitor attendance to MBCA was highest in August, probably due to public holidays during the summer besides the mild rainfall. The number of visitors dropped significantly in the wet season from October to December.

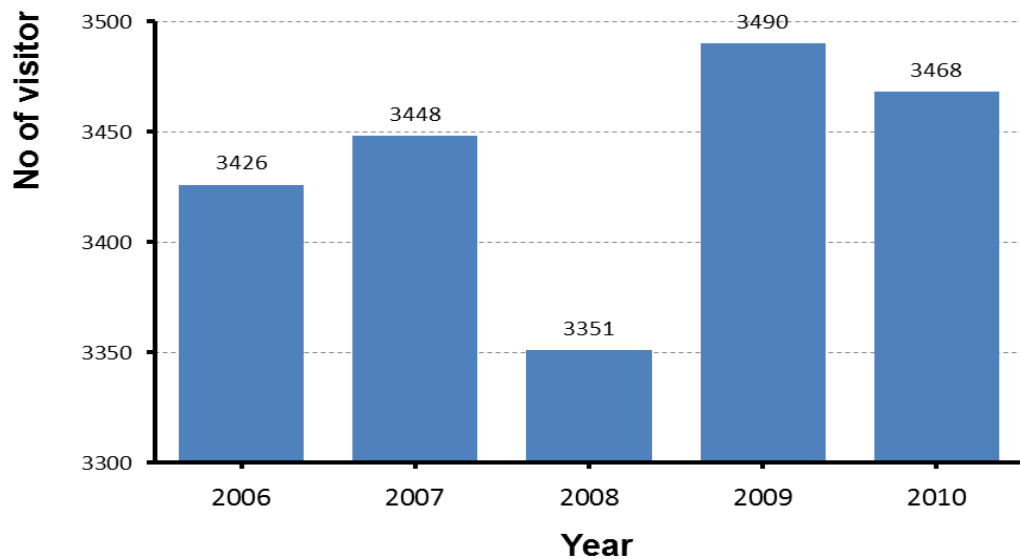


Figure 5.1: Total visitors to MBCA from 2006 to 2010

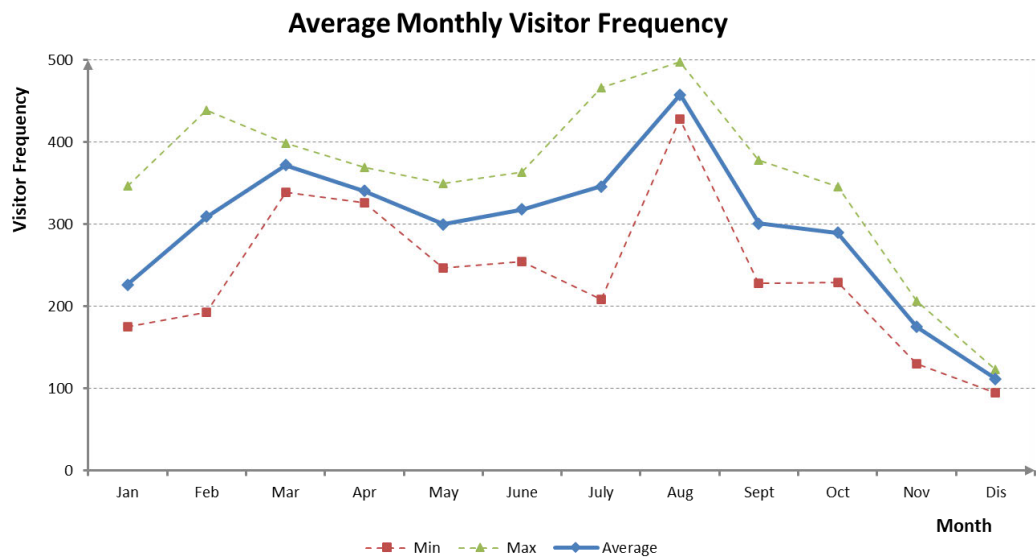


Figure 5.2: Monthly average of visitor to MBCA based on 5 years' data

5.1.2 Average visitors per year on selected trails

Visitor data for five years from 2006 (Figure 5.3), showed that the Knowledge Trail received the most visitors with an average of 1,380 people per year followed by the Agathis Trail with 725 peoples.

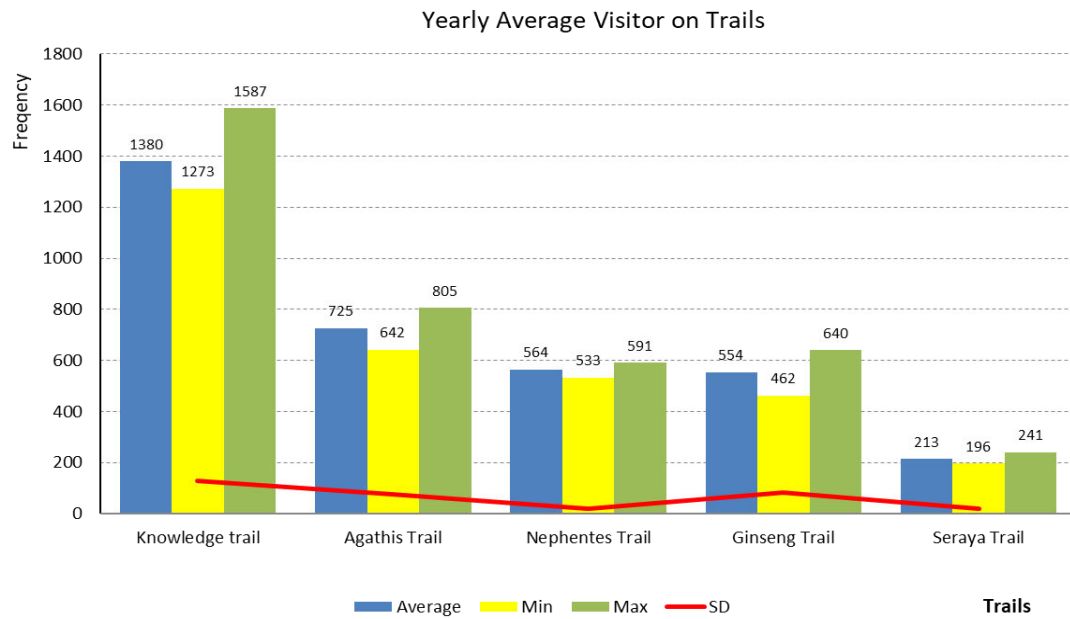


Figure 5.3: Yearly average visitors with respect to the different trails

The average plus-minus standard deviation for the visitor count in every trail has been calculated and shown in the figure 5.4 below.

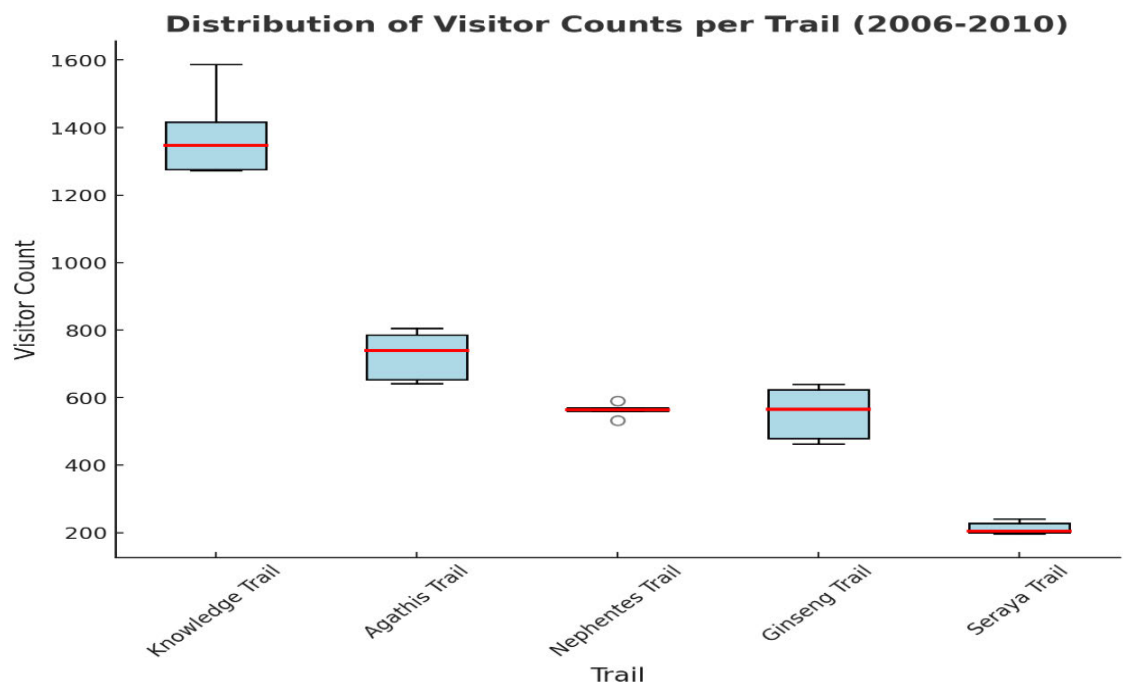


Figure 5.4: Distribution of visitor counts on each trail

Table 5.1: Trail ranking based on visitation status

Trail	Visitation frequency Status	Ranking	Average Visitor per year	%
Knowledge	Heavy	1	1,380	38.8
Agathis	Moderately heavy	2	845	23.8
Nepenthes	Moderate	3	564	15.8
Ginseng	Moderate	4	554	15.6
Seraya	Low	5	213	6.0
TOTAL			3,556	100

Nepenthes and Ginseng Trails had similar numbers of visitors due to long-distance hiking and limited accommodation at the camp site. The Seraya Trail was the least visited trail due to low camping capacity. Furthermore, the trail was not officially opened for ordinary visitors until the year 2010. Table 5.1 presents the ranking of the trails based on the average visitors per year.

5.2 RAINFALL

As a rainforest area, MBCA received high amounts of rainfall every year. The forest was always wet with total average rainfall from 2,300mm to 2,800mm per year based on five (5) years recorded data (Figure 5.5).

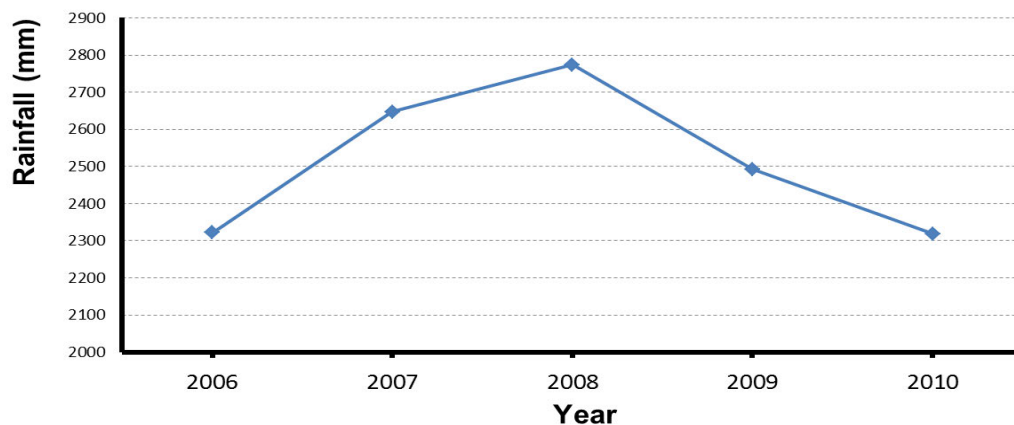


Figure 5.5: Total average of rainfall per year in MBCA

5.3 PRIMARY ECOLOGICAL DATA

5.3.1 Normality tests

For most factors, such as light intensity and SOM, the assumption of normality was rejected using both Kolmogorov-Smirnoff and Shapiro-Wilk tests across several trails and locations. However, some factors, such as soil compaction and species richness, exhibited mixed results, with instances of both normal and non-normal distributions depending on the trail or location. Combined with the unsuitability of ecological indices for parametric analysis (Section 4.5), these findings confirm that non-parametric statistical tests are appropriate in analysis of the data. One-way Kruskal-Wallis tests with post-hoc pairwise Mann-Whitney tests were used to assess significance of observed differences between trails and plot locations in the analyses that follow.

5.3.2 Hypothesis 1: Between-trail effects

Hypothesis 1: *Increased trail usage intensity is positively associated with increased levels of ecological disturbance among trails with different levels of usage.* A total 250 plots were sampled across 5 trails (50 per trail) as described in Chapter 4. This section describes the data collected in each of the sampled parameters (flora, soil, light and wildlife) and the results of analyses to test the specific hypotheses H1A-H1F described in Section 4.3.1.

5.3.2.1 Vegetation

Table 5.2 shows a general descriptive analysis of vegetation for all selected trails in the MBCA. Aggregated over all 250 plots there were 63 unique flora

families along all the trails combined. These were represented by 131 species and 5,945 individuals.

The highest number of individuals counted was on Agathis trail (1577) and the lowest on Nepenthes (760); despite this, Nepenthes recorded the highest number of unique species (116) and families (61), with the lowest counts in both these parameters on Ginseng trail (49 species and 30 families). Biodiversity indices were generally high with the Simpson index (D) and the Shannon-Weiner index (H') as 0.951 and 3.555 respectively. Overall Evenness E on plants was shown to be 0.73. The species richness aggregated over all trails (n = 250 plots) indicated by the Margalef index (S) was 14.96.

H1A: *trail usage intensity varies inversely with vegetation biodiversity along trails.*

Table 5.2: Summary of vegetation data and indices calculated using aggregate of all plots (n = 50) on each trail, and all plots (n = 250) on all trails.

Particulars	All trails	Knowledge (1,380)	Agathis (845)	Nepenthes (564)	Ginseng (554)	Seraya (213)
Total Families	63	31	40	61	30	41
Total Unique Species (Species richness)	131	55	69	116	49	62
Total number of plants or individual	5945	1032	1577	760	1299	1277
Margalef index (S)	14.96	7.21	9.10	11.46	6.56	8.25
Simpson index (1-D)	0.951	0.879	0.885	0.924	0.915	0.891
Shannon-Weiner index (H')	3.56	2.74	2.73	3.30	2.88	2.85
Evenness (E)	0.73	0.70	0.65	0.76	0.74	0.70

Note: Bold indicates maximum value among the five trails. Numbers in brackets are mean annual visitor numbers (trail usage intensity) from Table 5.1.

Figures 5.6 and 5.7 show descriptive statistics for counts of individual plants and unique species, respectively, in 50 plots along each of the five trails. Kruskal-Wallis tests indicated significant differences between the five trails for both parameters ($p < 0.05$), and post-hoc pairwise Mann-Whitney tests confirmed significant differences between Nepenthes and all other trails (plant counts, $p < 0.05$) and between Ginseng and Knowledge, Nepenthes and Seraya trails (unique species, $p < 0.05$). The highest maximum and mean counts of unique species were observed at trails with intermediate trail usage intensity (Agathis, Nepenthes and Ginseng, Figure 5.3) and the lowest mean unique species at Knowledge trail (highest usage intensity).

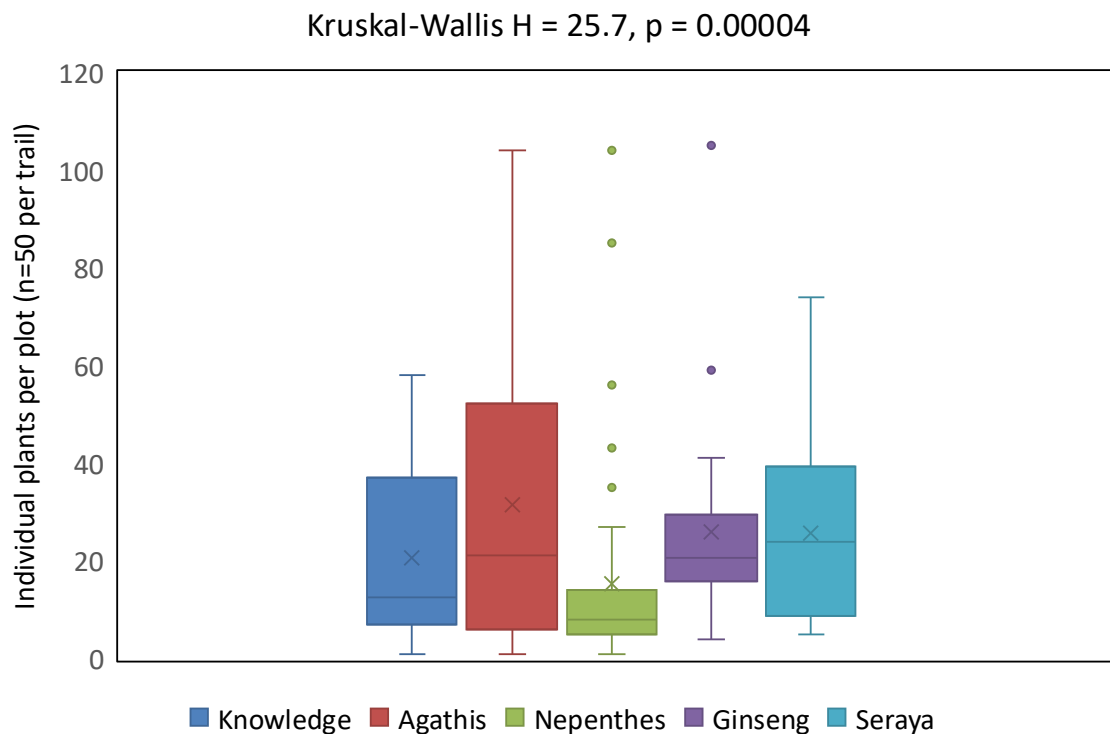


Figure 5.6 Descriptive statistics for counts of individual plants in plots (n = 50) at five trails in the MBCA. X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

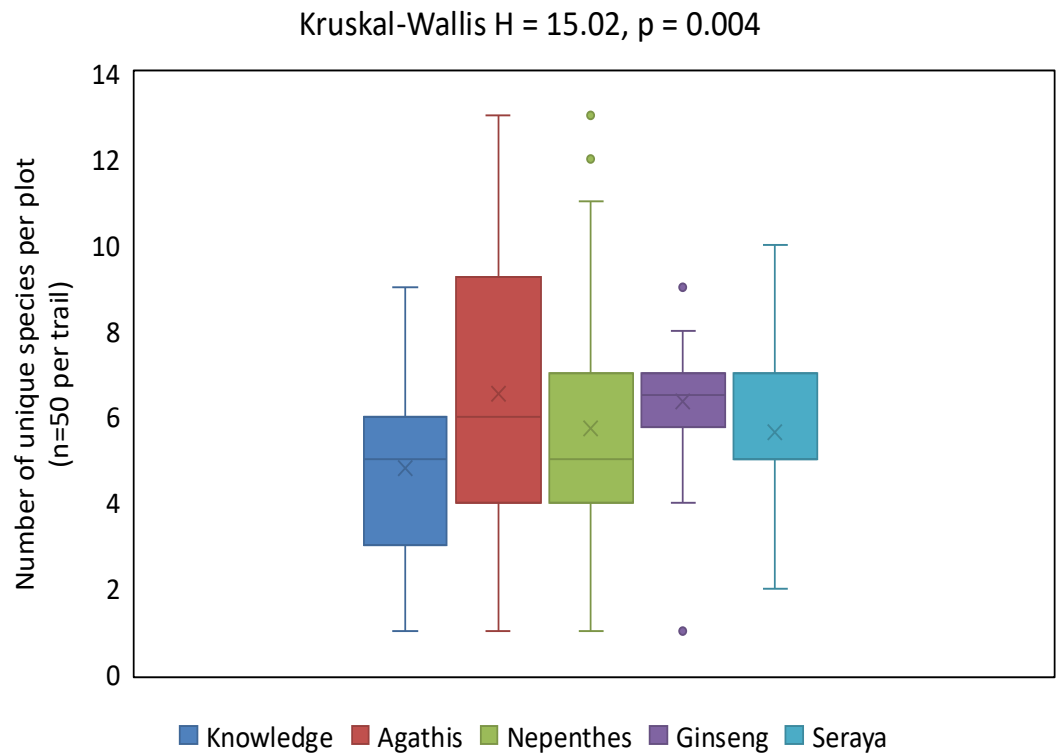


Figure 5.7 Descriptive statistics for counts of unique species in plots (n = 50) at five trails in the MBCA. See Fig 5.6 caption for description of symbols.

Table 5.2 summarises the ecological indices for the five trails (n = 50 plots per trail) calculated from the plot data shown on individual and species counts shown in Figures 5.6 and 5.7. Nepenthes trail showed the highest calculated values for species richness (Margalef), diversity (Shannon-Weiner, Simpson 1-D) and evenness indices. Kruskal-Wallis indicated significant variation among trails (indices calculated at plot scale, n = 50 per trail, p < 0.05) and post-hoc Mann-Whitney tests confirmed specific pairwise differences between Knowledge-Nepenthes and Knowledge-Ginseng, and between Nepenthes/Ginseng and Seraya. Figure 5.8 illustrates these relationships for

the Margalef Index, highlighting that the highest mean, median and maximum values were obtained from plots on trails with intermediate trail usage levels.

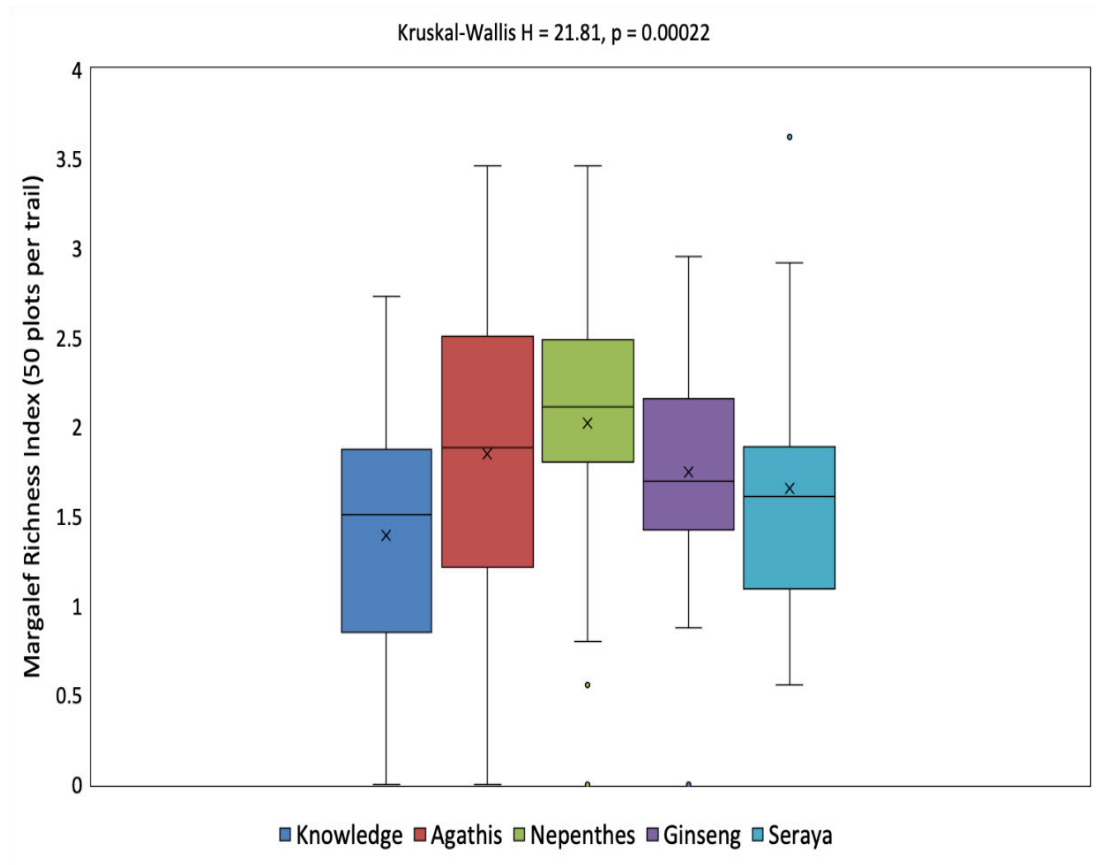


Figure 5.8 Descriptive statistics for Margalef Index calculated in plots (n = 50) at five trails in the MBCA. X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

5.3.2.2 Soil compaction

H1B: Trail usage intensity varies directly with soil compaction along trails.

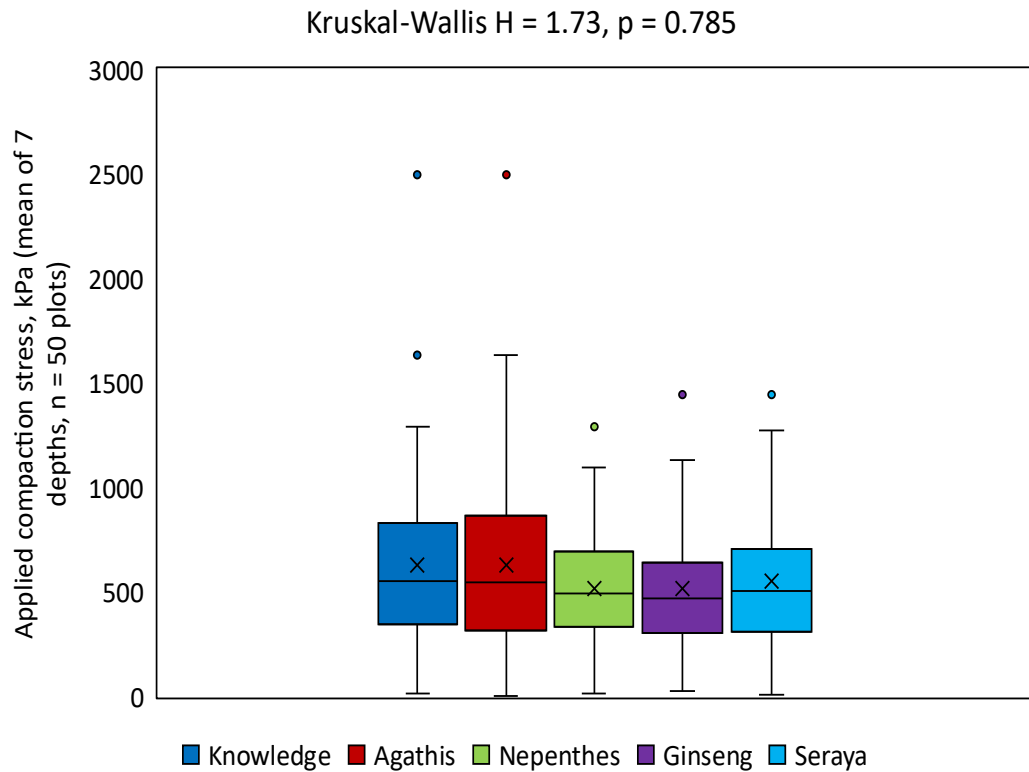


Figure 5.9 Descriptive statistics for soil compaction as mean applied stress (kPa) averaged over seven depth intervals at 50 plots for each trail. X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

Figure 5.9 shows that there was no significant difference in observed soil compaction between the five different trails ($n = 50$ plots per trail, Kruskal-Wallis $H = 1.73$, $p > 0.05$). No significant pairwise differences were noted in post-hoc Mann-Whitney tests. At the highest levels of trail usage intensity (Knowledge and Agathis), elevated mean (628 kPa and 629 kPa, respectively) and maximum (c. 2,500 kPa, compared with c. 1,400 kPa for other trails) compaction suggested an effect of trail usage intensity on soil compaction.

5.3.2.3 Soil moisture content (SMC)

H1C: Trail usage intensity varies inversely with soil moisture content along trails.

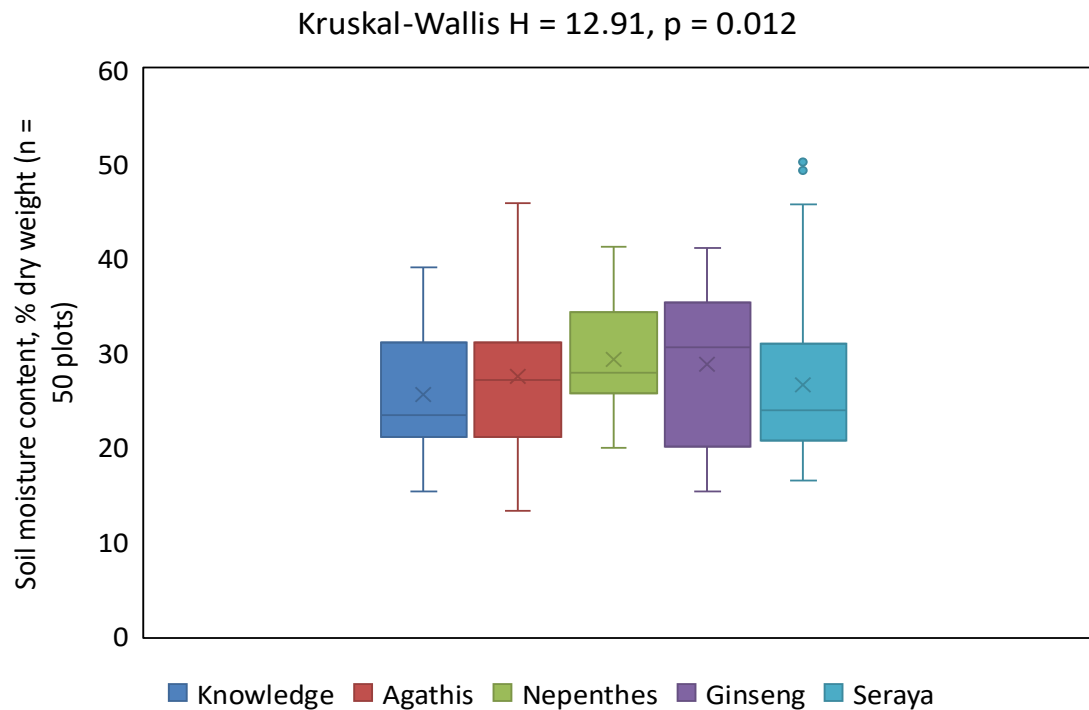


Figure 5.10 Descriptive statistics for soil moisture content as % dry soil weight at 50 plots for each trail. X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

Figure 5.10 shows that there was significant difference in observed soil moisture content among the five different trails (n = 50 plots per trail, Kruskal-Wallis H = 12.91, p < 0.05). Post-hoc Mann-Whitney tests indicated the source of this variability was significant pairwise difference between Knowledge-Nepenthes and Nepenthes-Seraya. At intermediate levels of trail usage intensity (significantly Nepenthes trail, but Figure 5.10 suggest a less significant

effect at Agathis and Ginseng also), elevated mean soil moisture compared with both the highest and lowest trail usage intensity suggested an effect of trail usage intensity on soil compaction, but this is not linear.

5.3.2.4 Soil Organic Matter (SOM)

H1D: *Trail usage intensity varies inversely with soil organic matter content along trails.*

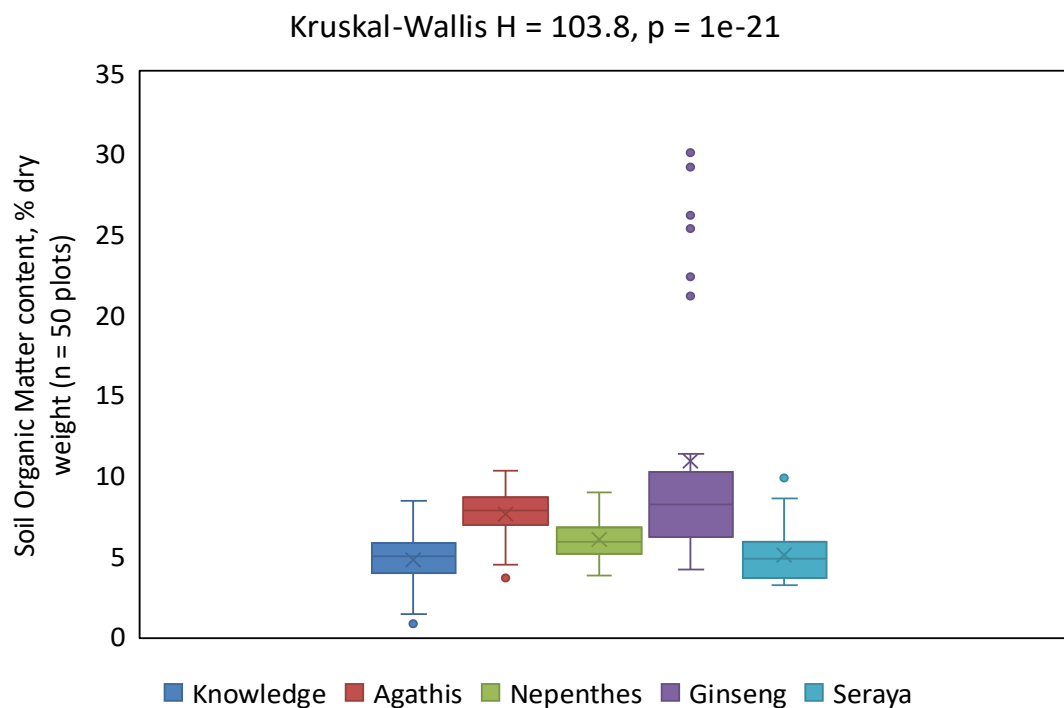


Figure 5.11 Descriptive statistics for soil organic matter content as % dry soil weight at 50 plots for each trail. X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

Figure 5.11 shows that there was significant difference in observed soil organic matter content among the five different trails (n = 50 plots per trail, Kruskal-Wallis H = 103.8, p < 0.05). Post-hoc Mann-Whitney tests indicated significant

pairwise difference between all trail pairs except Knowledge-Seraya and Agathis-Ginseng. At intermediate levels of trail usage intensity (Agathis, Nepenthes and Ginseng), elevated mean soil organic matter compared with both the highest and lowest trail usage intensity suggested an effect of trail usage intensity on soil organic matter, but this is not linear.

5.3.2.5 Light intensity

H1E: Trail usage intensity varies directly with light intensity along trails.

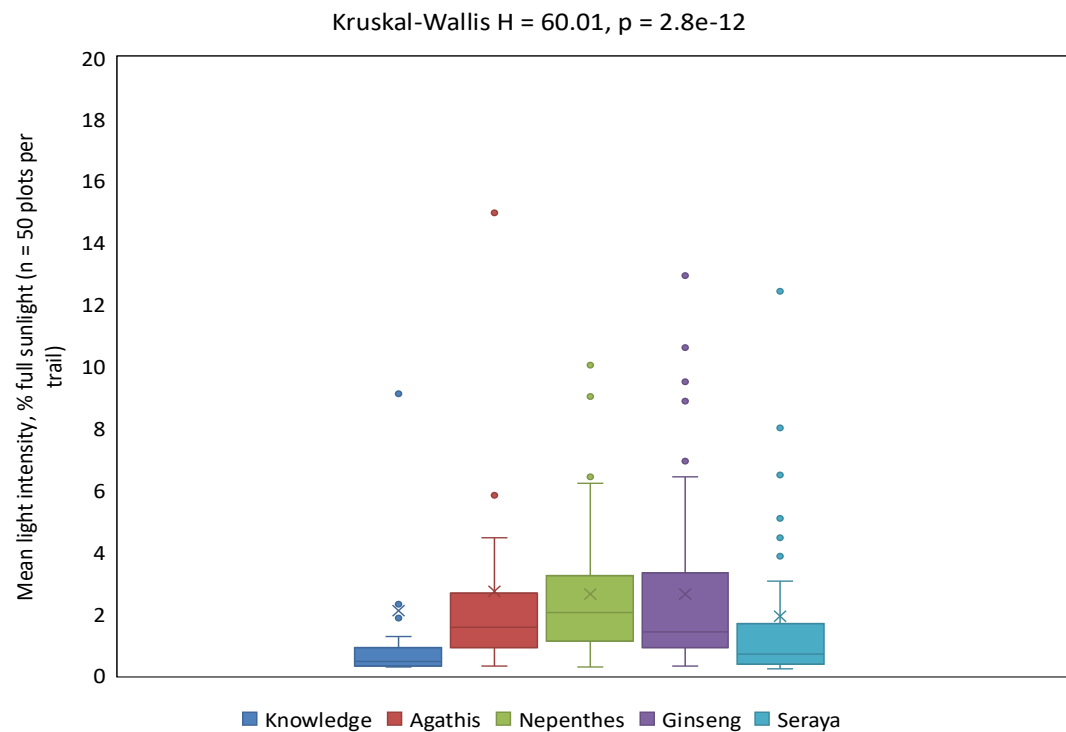


Figure 5.12 Descriptive statistics for light intensity as % full sunlight (670 lux) at 50 plots for each trail. X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

Figure 5.12 shows that there was significant difference in observed light intensity among the five different trails ($n = 50$ plots per trail, Kruskal-Wallis $H = 60.01$, $p < 0.05$). Post-hoc Mann-Whitney tests indicated significant pairwise difference between the highest and lowest trail usage intensity trails (Knowledge and Seraya) and the three intermediate trail use intensity trails (Agathis, Nepenthes, Ginseng) which had significant higher mean and maximum light intensities than the two most and least used trails. The large number of upper-end outliers among all data sets is likely the result of location-specific heterogeneity in the forest canopy.

5.3.2.6 Wildlife (fauna)

H1F: *Trail usage intensity varies inversely with wildlife abundance along trails.*

Table 5.3 Counts of individuals, unique species and faunal groups at five trails in the MBCA

	Knowledge (1,380)	Agathis (845)	Nepenthes (564)	Ginseng (554)	Seraya (213)
Individuals	51	50	62	50	55
Species	34	33	30	33	36
Groups	8*	6	6	6	6

Note:

* Two groups, molluscs and arthropods noted at Knowledge only, $n = 4$ individuals

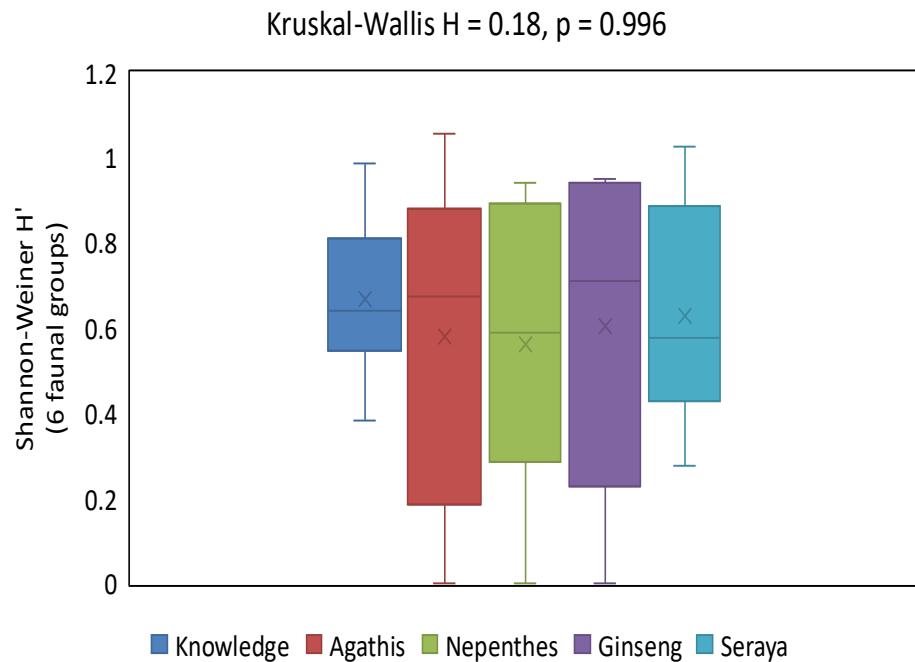
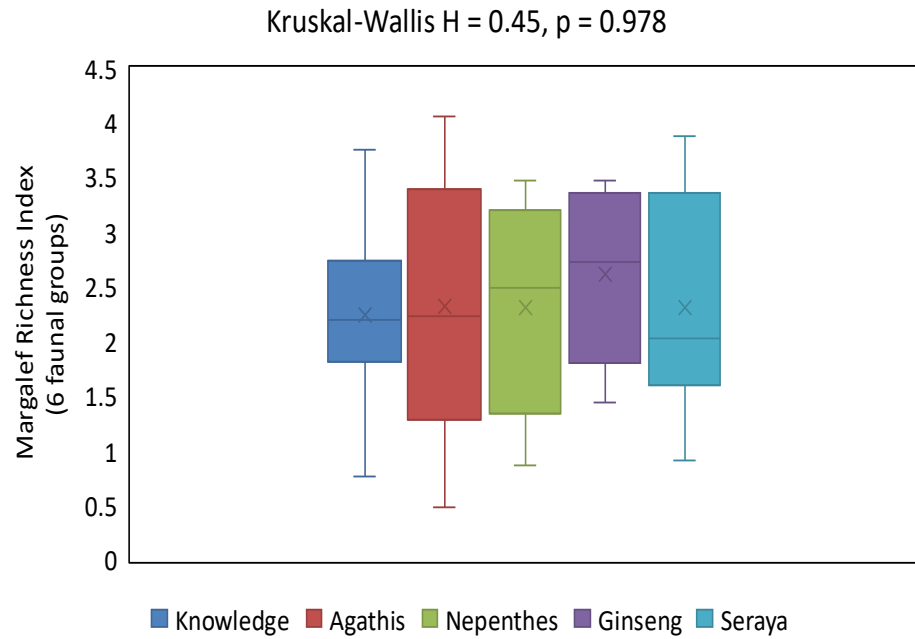


Figure 5.13: Descriptive statistics for Margalef index (top panel) and Shannon-Weiner diversity index (bottom panel) calculated for six faunal groups (amphibian, bird, butterfly, insect, mammal, reptile) for each trail. X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

Table 5.3 and Figure 5.13 show that there were no significant differences in the richness or diversity of wildlife (fauna, recorded in six groups) observed along the five different trails (Margalef Kruskal-Wallis $H = 0.45$, $p > 0.05$; Shannon-Weiner $H = 0.18$, $p > 0.05$). Figure 5.14 presents the faunal community composition observed along each trail. There is a slight decrease in the number of mammalian species observed on trails with a higher trail usage intensity (Knowledge and Agathis, 6 and 7 respectively) compared with the lower usage intensity trails (9, 10, 11 on Nepenthes, Ginseng and Seraya respectively).

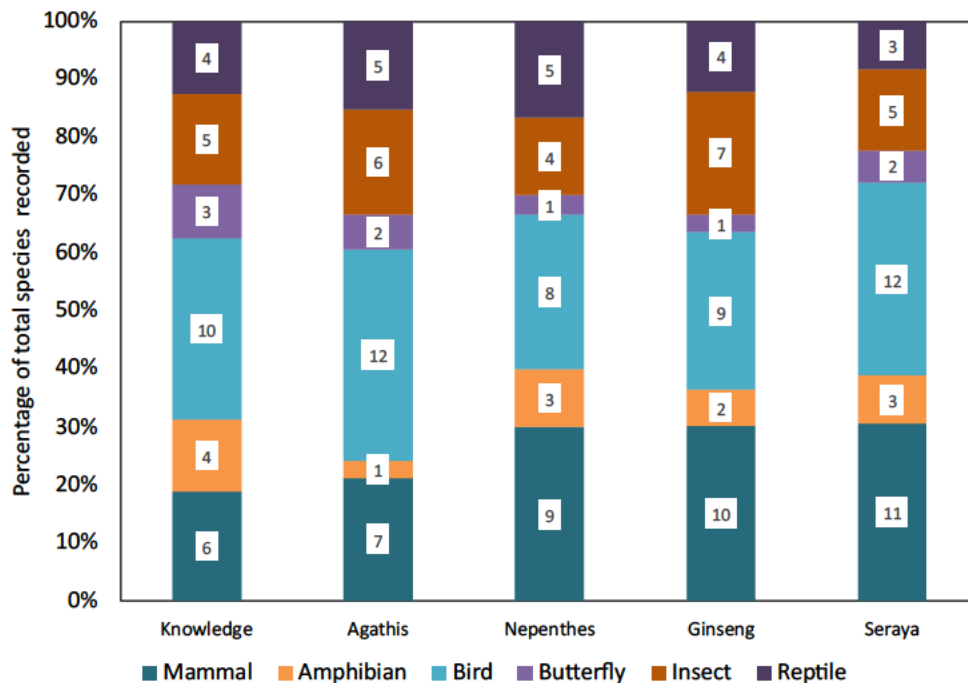


Figure 5.14 Percentage composition of faunal communities observed by distance survey during transects along five trails in the MBCA. Bars represent percentage of total species observed, data labels show actual numbers of species in each of six faunal groups (mammal, amphibian, bird, butterfly, insect, reptile).

5.3.3 Hypothesis 2: Distance from trail effects

Hypothesis 2: *Increased trail usage intensity is positively associated with increased levels of ecological disturbance as a function of distance away from the trail.* A total 250 plots were sampled at three locations relative to trail centre lines (on-trail plot centres 0 m, proximal plot centres 3.5 m, distal plot centres 7 m) as described in Chapter 4. A paired left-right sampling design resulted in a population of 50 on-trail plots, 100 proximal plots (50 left + 50 right) and 100 distal plots (50 left + 50 right). This section describes the data collected in each of the sampled parameters (flora, soil, light and wildlife) and the results of analyses to test the specific hypotheses H1A-H1F described in Section 4.3.1.

5.3.3.1 Vegetation

H2A: *trail usage intensity varies inversely with vegetation biodiversity among on-trail, proximal and distal plots.*

Table 5.4 shows an analysis of plant and biodiversity parameters across three distances from trail. The number of plants increases with distance from trail, with an average of 803 plants in on-trail plots, 2,247 in proximal plots, and 2,891 in distal plots. Similarly, the number of species follows the same trend, ranging from 54 in on-trail plots to 96 in proximal plots, then 105 in distal plots. Biodiversity indices calculated using aggregate of all plot data from each distance from trail also highlight similar pattern, where Margalef's richness index is lowest in on-trail plots (7.924) and highest in distal plots (13.476). The Simpson's Biodiversity Index (1-D) and Shannon-Weiner Index (H') both show higher diversity in proximal and distal plots compared with on-trail ones.

Table 5.4: Overall vegetation diversity in all plot distance/disturbance

Parameters	Plot Distance		
	On trail	Proximal	Distal
No of individual plants	803	2247	2891
No of unique species	54	96	105
Margalef's Richness index	7.924	11.921	13.476
Simpsons Biodiversity Index (1-D)	0.920	0.940	0.954
Shannon-Weiner Biodiversity Index (H')	2.992	3.364	3.582
Pielou's Evenness Index (E)	0.750	0.740	0.770

Finally, Evenness Index indicates similar species evenness across all disturbance levels, with values ranging narrowly from 0.740 to 0.770, suggesting relatively uniform distribution of species despite disturbance levels. These results highlight how disturbance influences plant abundance, species richness, and biodiversity.

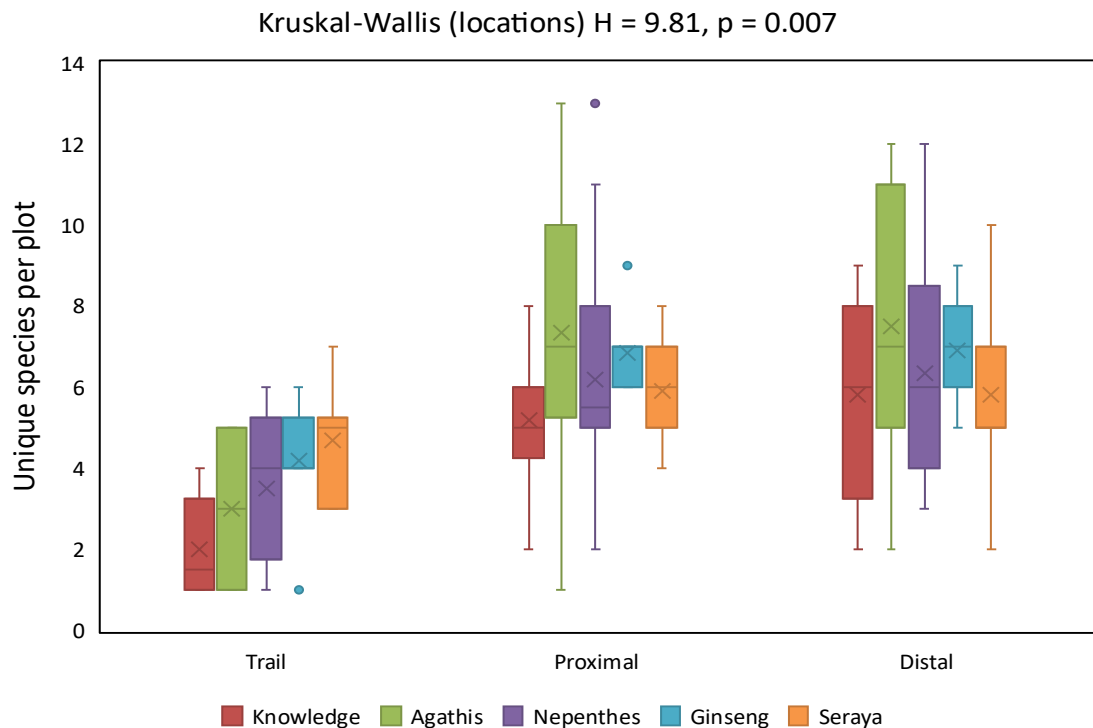


Figure 5.15 (Previous page) Descriptive statistics showing distribution of unique species observed per plot as a function of distance from trail centre (locations), disaggregated by the five trails. Kruskal-Wallis statistic refers to data aggregated across all trails (on-trail, $n = 50$, proximal $n = 100$, distal $n = 100$). X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

Figure 5.15 builds on data presented in section 5.3.2, where plot data are grouped by trail, retaining that level of disaggregation while grouping plot data primarily by their location relative to the trail (on-trail, proximal, distal). Among these different locations, there is significant difference between samples (Kruskal-Wallis, $p < 0.05$). The data show two key significant features, (i) significantly (post-hoc Mann-Whitney, $p = 0.005$, $p = 0.007$) lower number of species counted between on-trail, proximal and distal locations, respectively; (ii) significant (Kruskal-Wallis $H = 13.18$, $p = 0.008$) differences between trails with different usage intensities *for on-trail plots only*; post-hoc Mann-Whitney tests confirm the significant pairwise differences between Knowledge-Ginseng/Seraya ($p = 0.004$, $p = 0.001$ respectively) and Agathis-Seraya ($p = 0.034$). Off-trail (proximal and distal) sample populations are not significantly different from each other (Kruskal-Wallis $p > 0.05$) and show no significant differences as a function of trail usage intensity (post-hoc Mann-Whitney $p > 0.05$). Figure 5.16 illustrates that these two features are also evident in the Margalef and Shannon-Weiner indices calculated per plot and grouped as a function of location relative to the trail (on-trail, proximal, distal). Among these different locations, there is a significant difference between samples (Margalef, Kruskal-Wallis $H = 21.81$, $p = 0.0002$; Shannon-Weiner, Kruskal-Wallis $H =$

17.80, $p = 0.0013$). For both indices, *for on-trail plots only*, there is significant difference between trails with different levels of trail usage intensity (Kruskal-Wallis $H = 12.31$, $p = 0.014$).

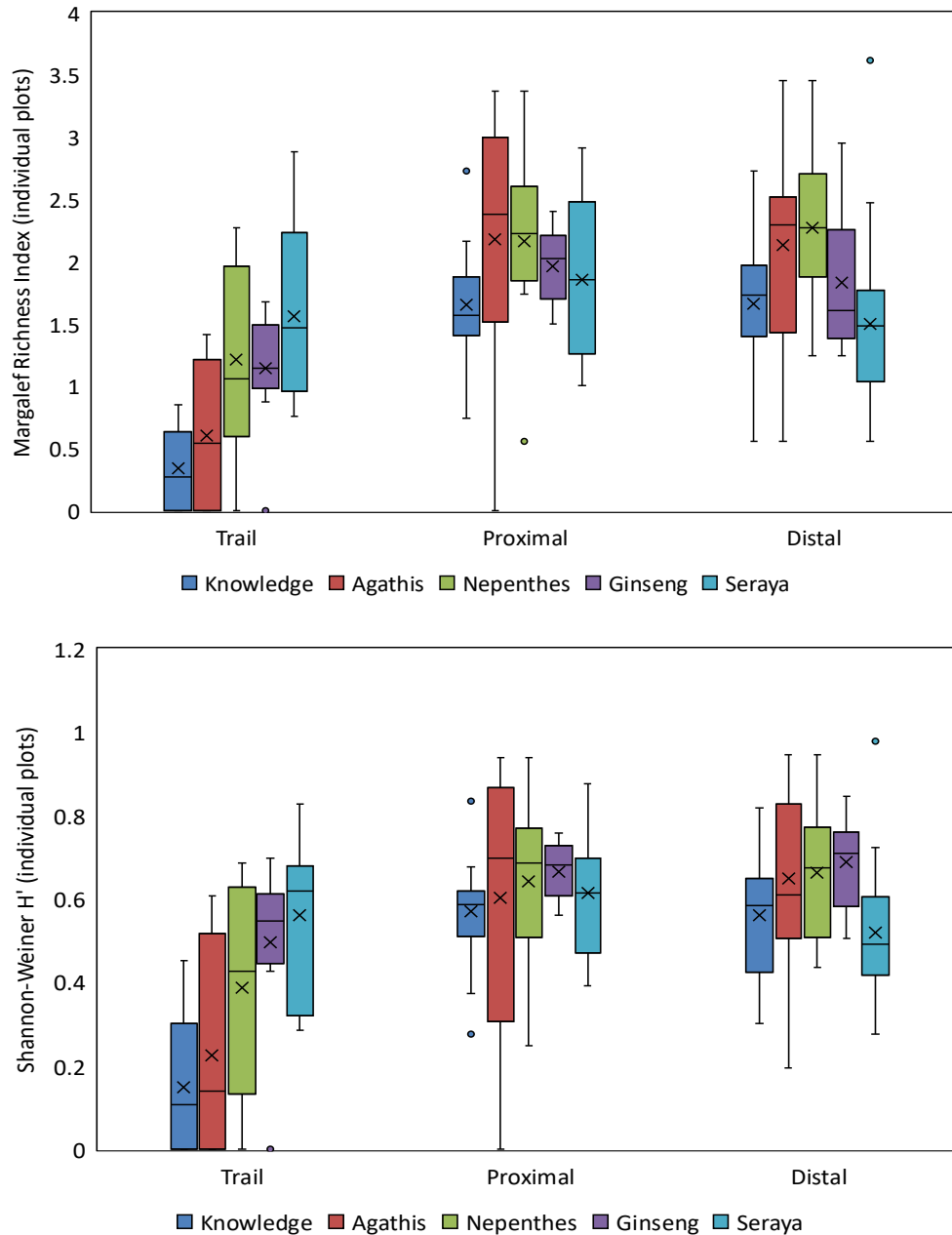


Figure 5.16 Descriptive statistics showing distribution of (top) Margalef richness and (bottom) Shannon-Weiner diversity index calculated per plot (on-trail, $n = 50$, proximal $n = 100$, distal $n = 100$) as a function of distance from trail centre (locations), disaggregated by the five trails. X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

Table 5.5 presents the Jaccard similarity index between observed vegetation species in plots at proximal and distal locations. 200 plots were compared (10 locations on each of 5 trails; 2 proximal and 2 distal plots per location). The mean Jaccard Similarity Index between proximal and distal plots in all trails was 0.258 and the overall index ranged from 0.07 to 0.55. The Ginseng Trail indicated the highest index of plant species similarity (mean 0.326, maximum 0.55), followed by the Knowledge Trail at 0.2801. The lowest similarity index for these plots was for the Nepenthes Trail (0.1662).

Table 5.5: Descriptive statistic for Jaccard Similarity Index between plots in proximal and distal off-trail plot locations, along five trails in the MBCA.

	N	Mean of Similarity Index	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Knowledge	10	0.2801	0.1251	0.0396	0.1906	0.3696	0.08	0.46
Agathis	10	0.2498	0.1666	0.0527	0.1306	0.369	0.07	0.54
Nepenthes	10	*0.1662	0.0857	0.0271	0.1049	0.2275	0.07	0.30
Ginseng	10	**0.326	0.1092	0.0345	0.2479	0.4041	0.21	0.55
Seraya	10	0.2696	0.1385	0.0438	0.1705	0.3687	0.14	0.50
Mean all trails	50	0.2583	0.1336	0.0189	0.2204	0.2963	0.07	0.55

Note:

** indicated highest mean Similarity Index

* Indicated Lowest mean Similarity Index

5.3.3.2 Soil compaction

H2B: Trail usage intensity varies directly with soil compaction among on-trail, proximal and distal plots.

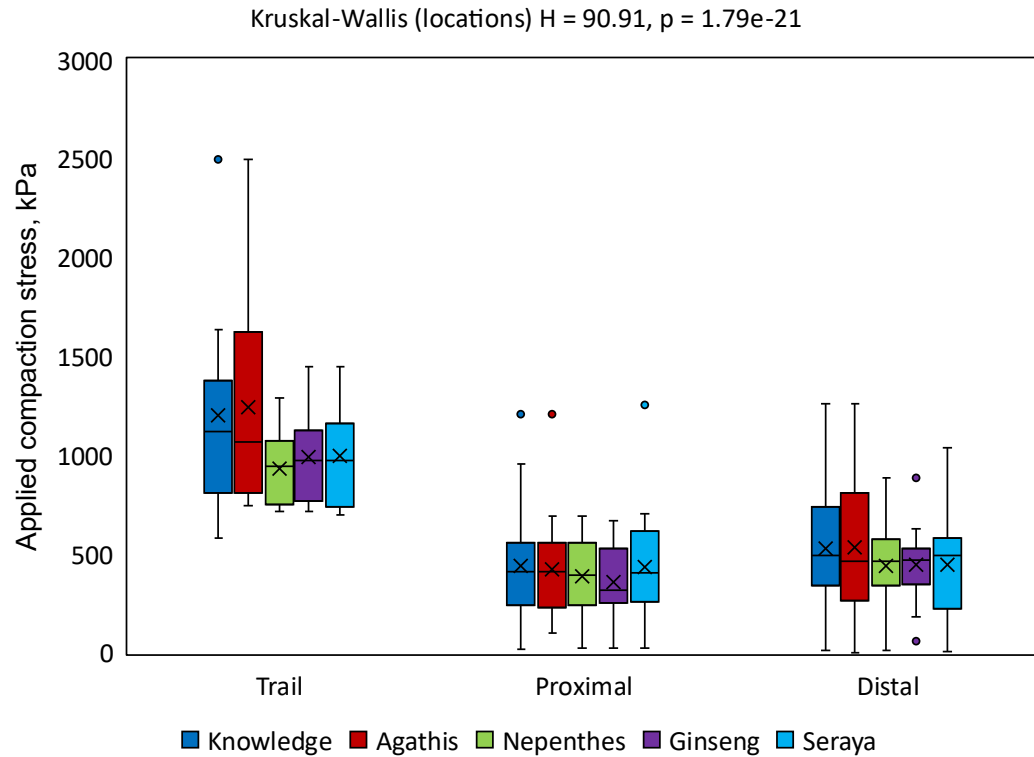


Figure 5.17 Descriptive statistics showing distribution of soil compaction (kPa, mean of 7 depths) observed per plot as a function of distance from trail centre (locations), disaggregated by the five trails. Kruskal-Wallis statistic refers to data aggregated across all trails (on-trail, $n = 50$, proximal $n = 100$, distal $n = 100$). X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

Plots in on-trail locations showed significantly higher (post-hoc Mann-Whitney, $p < 0.05$) soil compaction than plots in off-trail (proximal and distal) locations. There was no significant difference between samples from proximal and distal locations (Mann-Whitney, $p > 0.05$). In contrast to the vegetation parameters (section 5.3.3.1), there is no significant difference between trails with different trail usage intensity at any distance from the trail (on-trail, proximal, distal; Kruskal-Wallis $p > 0.05$).

5.3.3.3 Soil moisture content

H2C: Trail usage intensity varies inversely with soil moisture content among on-trail, proximal and distal plots.

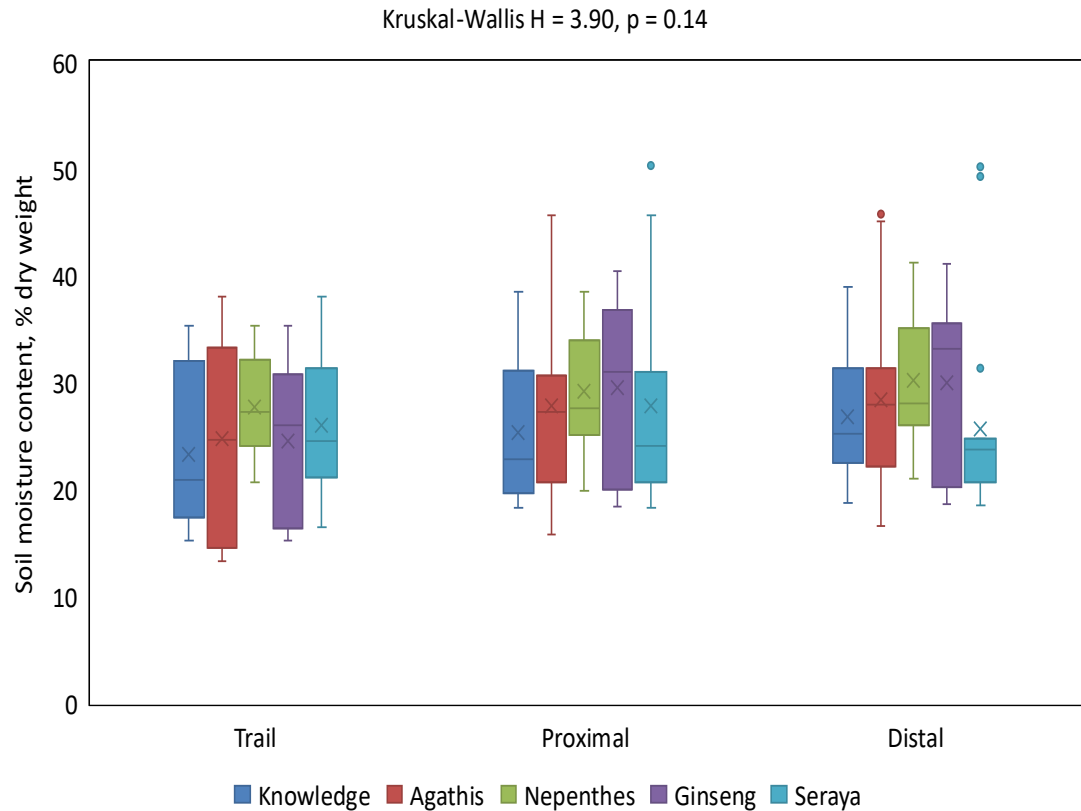


Figure 5.18 Descriptive statistics showing distribution of soil moisture content (% dry weight) observed per plot as a function of distance from trail centre (locations), disaggregated by the five trails. Kruskal-Wallis statistic refers to data aggregated across all trails (on-trail, n = 50, proximal n = 100, distal n = 100). X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

There is no significant difference (Kruskal-Wallis, $p > 0.05$) in soil moisture content among plots in on-trail, proximal or distal locations. Furthermore, there is no significant difference between trails with different trail usage intensity at any distance from the trail (on-trail, proximal, distal; Kruskal-Wallis $p > 0.05$).

5.3.3.4 Soil Organic Matter

H2D: Trail usage intensity varies inversely with soil organic matter content among on-trail, proximal and distal plots.

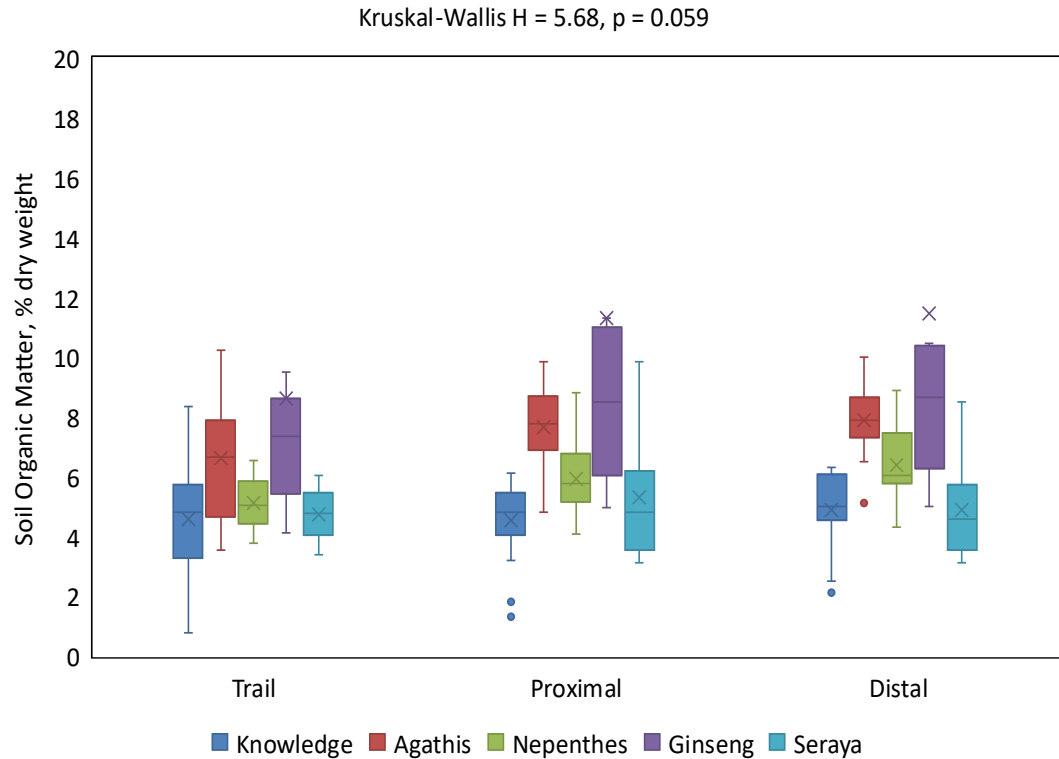


Figure 5.19 Descriptive statistics showing distribution of soil organic matter content (% dry weight) observed per plot as a function of distance from trail centre (locations), disaggregated by the five trails. Kruskal-Wallis statistic refers to data aggregated across all trails (on-trail, n = 50, proximal n = 100, distal n = 100). X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

There is no significant difference (Kruskal-Wallis, $p > 0.05$) in soil organic matter content among plots in on-trail, proximal or distal locations, however post-hoc pairwise Mann-Whitney test indicates a significant difference between on-trail and distal locations ($p = 0.024$). Kruskal-Wallis tests confirm there are significant differences between trails with different trail usage intensity at all

distances from the trail (on-trail, proximal, distal; Kruskal-Wallis $p < 0.05$). Highest mean and maximum soil organic matter was observed at proximal plots along trails with intermediate trail usage levels (Agathis, Ginseng; less markedly Nepenthes).

5.3.3.5 Light intensity

H2E: Trail usage intensity varies directly with light intensity among on-trail, proximal and distal plots.

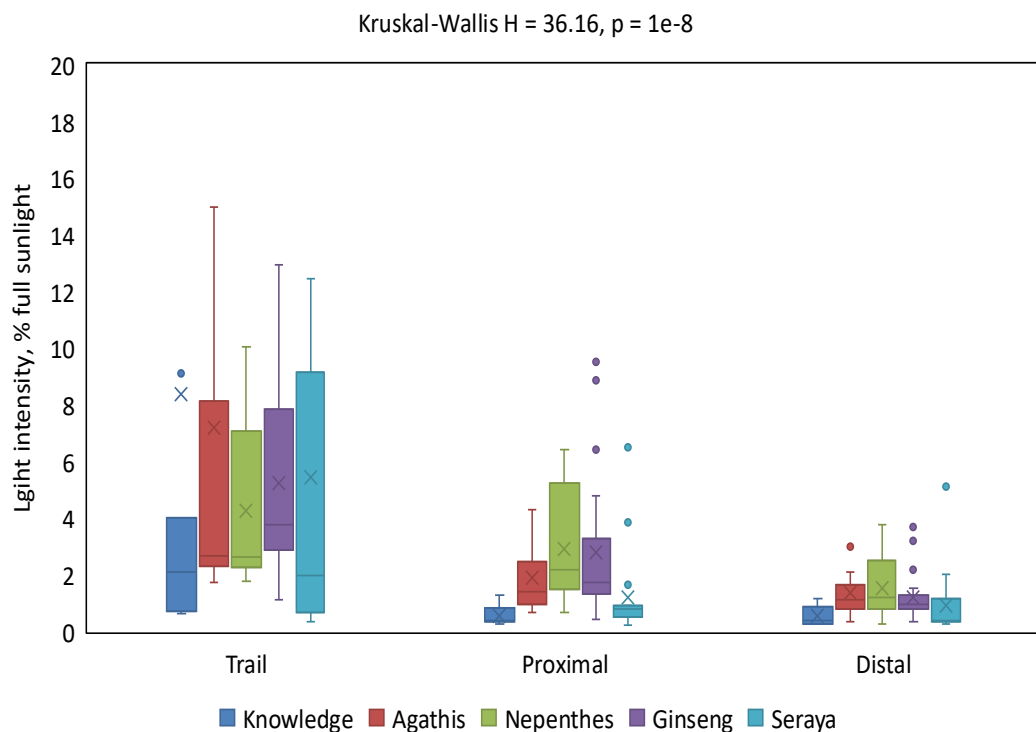


Figure 5.20 Descriptive statistics showing distribution of light intensity (% full sunlight, 670 lux) observed per plot as a function of distance from trail centre (locations), disaggregated by the five trails. Kruskal-Wallis statistic refers to data aggregated across all trails (on-trail, $n = 50$, proximal $n = 100$, distal $n = 100$). X indicates mean, horizontal line indicates median. Box indicates interquartile range and whiskers maximum and minimum values. Dots are outliers.

There are significant pairwise differences between light intensity measured at on-trail plots and at proximal (post-hoc Mann-Whitney, $p < 0.05$) and distal (post-hoc Mann-Whitney, $p < 0.05$) plots, but not between proximal and distal plots (post-hoc Mann-Whitney, $p > 0.05$). The pattern of variation shown in Figure 5.20 is distinctive. On-trail plots along all trails show significantly higher mean and maximum light intensity than proximal and distal off-trail locations, however the light intensity on the highest-use trail (Knowledge) is not distinguishable from that at the lowest-use trail (Seraya). Highest mean and maximum light intensity values occur along trails with intermediate trail usage levels (Agathis, Nepenthes, Ginseng show significant difference from Knowledge and Seraya trails, pairwise Mann-Whitney tests, $p < 0.05$).

5.4 SUMMARY OF ECOLOGICAL FINDINGS

The synthesis of findings shows contrasting patterns in relationship between trail visitation intensity and ecological variables in Maliau Basin Conservation Area (MBCA). Overall, vegetation diversity was high within all trails (Table 5.2). Average (aggregated over 250 plots, all trails, Table 5.2) Simpson Index (0.951) and Shannon-Wiener Index (3.555) indicate a high ecological status of the environment with moderate species distribution rates (Margalef Index = 14.96, evenness = 0.729). But intra-trail comparisons showed variability in these parameters that correlated with trail usage intensity. The highest number of plants were recorded on the Agathis Trail while the Nepenthes Trail showed the highest species richness (Margalef Index = 11.46).

The two hypotheses posed in Chapter 4 drove the design of surveys which aimed to elucidate the impacts of increasing numbers of visitors (trail usage intensities) both between trails with different mean annual visitor numbers, and between points located directly on the trail and up to 7 m distance from it to either side. These two effects (trail usage intensity; proximity to trail centreline) interacted with each other.

H1A: trail usage intensity varies inversely with vegetation biodiversity along trails.

H2A: trail usage intensity varies inversely with vegetation biodiversity among on-trail, proximal and distal plots.

Figures 5.6-5.8 demonstrate that there were significant differences between trails, but this did not vary linearly with trail usage intensity. Knowledge trail (1,380 visitors per annum) showed evidence of lowest ecological richness and diversity but this was not significantly different from Seraya trail with the lowest trail usage intensity (283 visitors per annum). Significantly higher values of plant and species counts and ecological indices were observed for trails with intermediate trail usage intensities. Based on this evidence, while vegetation biodiversity does vary inversely with trail use at the highest visitor numbers, the relationship appears to be non-monotonic and to favour intermediate trail usage intensities **[H1A]**. Figures 5.15 and 5.16 add further insight by disaggregating the plot data into on-trail, proximal and distal location sets. Dramatically different features are observed at on-trail locations compared with off-trail locations. Vegetation biodiversity varied significantly and linearly with trail usage intensity for on-trail plots only, which showed overall significantly lower ecological indicator values than off-trail plots. There were no significant differences between vegetation biodiversity at proximal (3.5 m from trail centreline) and distal (7 m from trail centreline) locations. Therefore, an inverse

relationship between trail usage intensity and vegetation biodiversity is only observed, and hence primarily driven, by impacts at on-trail and possibly very proximal (< 3 m) locations **[H2A]**.

H1B: Trail usage intensity varies directly with soil compaction along trails.

H2B: Trail usage intensity varies directly with soil compaction among on-trail, proximal and distal plots.

Figures 5.9 and 5.17 illustrate that there was no significant variation in soil compaction between trails having different trail usage intensities, but that there was a very significant difference between soil compaction at on-trail plots compared with off-trail plots. There was a slight increase in mean and maximum compaction for plots on the two most visited trails (Knowledge, Agathis) but this was not assessed significant using nonparametric statistical tests. As with the vegetation indices, there was no significant difference between proximal and distal off-trail plots, suggesting that the impacts of trail use on compaction decrease rapidly with distance from the trail. In summary, there is no evidence of a relationship between trail usage intensity and soil compaction among different trails **[H1B]**; and while there is a significant increase in soil compaction on-trail vs off-trail, this does not appear to vary with trail use intensity **[H2B]**.

H1C: Trail usage intensity varies inversely with soil moisture content along trails.

H2C: Trail usage intensity varies inversely with soil moisture content among on-trail, proximal and distal plots.

Figures 5.10 and 5.18 illustrate that there was a small but significant variation in soil moisture content between trails having different trail usage intensities, but that there

was no significant difference between soil moisture content at on-trail plots compared with off-trail plots. At intermediate trail usage intensity, specifically significantly at Nepenthes trail, mean and minimum soil moisture measured was greater compared with Knowledge and Seraya trails. A specific effect at one trail may be due to local variations and/or weather conditions at the time of sampling. In summary, there is no consistent evidence of a relationship between trail usage intensity and soil moisture content among different trails **[H1C]**; nor a significant decrease in soil moisture content on-trail vs off-trail, or with trail use intensity **[H2C]**.

H1D: Trail usage intensity varies inversely with soil organic matter content.

H2D: Trail usage intensity varies inversely with soil organic matter content among on-trail, proximal and distal plots.

Figures 5.11 and 5.19 illustrate that there was a significant variation in soil organic matter content between trails having different trail usage intensities, but that there was no significant difference between soil organic matter content at on-trail plots compared with off-trail plots. At intermediate trail usage intensity, at all plot locations (on-trail, proximal, distal), the mean, minimum and maximum soil organic matter measured was greater compared with Knowledge (high use) and Seraya (low use) trails. In summary, soil organic matter content does not vary inversely with trail usage intensity among different trails **[H1D]**; nor is this relationship seen as a function of distance from the trail **[H2D]**.

H1E: Trail usage intensity varies directly with light intensity along trails.

H2E: Trail usage intensity varies directly with light intensity among on-trail, proximal and distal plots.

Figures 5.112 and 5.20 illustrate that there was a significant variation in light intensity between trails having different trail usage intensities, and that there was a significant difference between soil organic matter content at on-trail plots compared with off-trail plots. At intermediate trail usage intensity, at all plot locations (on-trail, proximal, distal), the mean, minimum and maximum light intensity measured was greater compared with Knowledge (high use) and Seraya (low use) trails. In summary, light intensity varies nonmonotonically with trail usage intensity among different trails [H1E]; light intensity varies directly but abruptly (rather than continuously, over the spatial scales sampled) between on-trail and off-trail plots [H2E].

***H1F:** Trail usage intensity varies inversely with wildlife abundance along trails.*

Table 5.3 and Figure 5.13 indicate that there is no significant difference between observed wildlife, or faunal species richness or diversity indices, among the different trails and therefore no evidence that trail usage intensity varies inversely with wildlife abundance along trails, using the sampling methods applied in this study [H1F].

Overall, results mostly support to Hypotheses 1, indicating trail usage intensity has significant effects on ecological parameters within MBCA. However, these impacts (particularly vegetation and soil parameters) appear largely confined to areas on and very close (< 3 m) to the trail centrelines. Trails with higher usage intensity of (i.e., the Knowledge Trail) showed clear indication of ecological disturbance, soil compaction and increased light intensity although effects were not always significant and observed measures at Knowledge trail (1,380 visitors per annum) were often not significantly different from those at Seraya trail (283 visitors per annum). More notably, substantial and frequently significant increases in ecological

quality indicators were observed at trails with intermediate visitor numbers and at plots proximal (3 m) from the trail centreline.

CHAPTER 6

VISITOR PERCEPTIONS OF NATURAL AREA RECREATION IN MBCA

This chapter presents the results of the study, focusing on visitor perceptions of natural area recreation in Maliau Basin Conservation Area (MBCA). The chapter is structured to systematically address the research question which is “What effects do recreational disturbance impacts along tropical forest trails have on visitor perception, expectation and satisfaction with their visit? and to meet Objective 4 which seeks to evaluate the effectiveness of impact assessment method in such environments. The result is presented in a sequence that first introduces the visitor demographic and trip characteristics, followed by visitor motivation and perceptions of trail condition, their participation in recreation activities and their overall satisfaction. The chapter concludes with visitor preference for trail design, infrastructure and environmental management alongside an inferential statistical analysis to examine the relationship between key variables.

6.1 SURVEY BACKGROUND

Target respondents were the visitors and the tour guides as shown in Figure 6.1. Five hundred (500) printed questionnaires were prepared but only 349 visitors were willing to participate. Out of the 349 respondents, only 327 questionnaires were usable and 22 were invalid due to errors and technical problems. Out of 327 respondents, 301 were visitors and only 26 were tour guides. The survey on visitors' perceptions comprised two parts, the visitor background information, and the visit background itself. Other aspects investigated in the survey were visitor information source and the motivation for the MBCA trip, recreation activities



Figure 6.1: Visitors in MBCA

undertaken, and the perceptions of the nature trail. Finally, Lastly, the visitors gave a rating value and preferences as satisfaction indicators, along with suggestions for improvement.

6.2 VISITOR BACKGROUND AND VISIT CHARACTERISTICS

6.2.1 Demographics

Demographic result for both visitors and tour guides are shown in Table 6.1 below. Most visitors were Malaysian (88%) with more than 60% male. Of the tour guides, 100% were Malaysian and male.

Most respondents, both visitors and tour guides, were single; 50% and 58% respectively. Most (visitors and tour guides) were aged from 21 to 40 years old. However, the percentage of the younger visitors aged less than 20 was high, at 27%. Most tour guide respondents were aged between 21 to 40 years old. Both respondent categories (visitors and tour guides) showed similar patterns of

education with most holding diplomas and bachelor's degrees. Of the visitors, 23% had secondary school education (Table 6.2).

Table 6.1: Gender, nationality, marital status, and age of the respondents

Demographic	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
Gender				
Male	187	62	26	100
Female	114	38	0	0
Nationality				
Malaysian	266	88	26	100
Non-Malaysian	35	12	0	0
Marital status				
Single	152	50	15	58
Married	128	43	11	42
Partner	6	2	0	0
Divorced	15	5	0	0
Age (Years old)				
10 - 20	80	27	0	0
21 - 30	89	30	16	62
31 - 40	88	29	8	31
41 - 50	26	9	2	8
51 - 60	13	4	0	0
Above 60	5	2	0	0

Most visitors and tour guides earned incomes of between 20 and 40 thousand Malaysian Ringgit which is about 3,700 and 7,400 Pounds Sterling per year. Visitor occupations were predominately professional jobs such as teachers, government officers, instructors, and so on. For tour guides, this was their full-time job (see Table 6.2).

6.2.2 Visit Background

All tour guides stated that they had been to MBCA before. However, only 22% of the visitors had previously visited; the rest (78%), were first timers to MBCA. Most visitors who had been before only visited MBCA less than once a year (55%). For the tour guides, the majority had visited more than 4 times a year (Table 6.3). Most of respondents, both visitors and tour guides, were staying in MBCA for 2 to 4 nights (59% and 77% of the overall visitors respectively). Seventeen (17%) of the visitors stayed overnight and 12% stayed 5 to 7 nights. Interestingly, there were some visitors staying more than a week but the percentage was very low. For tour guides, the maximum length of stay in MBCA was 5 to 7 nights.

Table 6.2: Education, yearly income, and occupations of respondent

Demographic	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
Education				
Primary school	3	1	0	0
Secondary School	70	23	0	0
Diploma	105	35	15	58
Bachelor's degree	100	33	11	42
Master's degree	15	5	0	0
Doctorate Degree	8	3	0	0
Other	0	0	0	0
Yearly income (RM)				
Less than 10,000	71	24	0	0
10,000 - 19,999	31	10	0	0
20,000 - 29,999	85	28	12	46
30,000 - 39,999	79	26	11	42
40,000 - 49,999	20	7	3	12
50,000 - 59,999	11	4	0	0
> 60,000	4	1	0	0
Occupations				
Unemployed	3	1	0	0

Self-employed	26	9	0	0
Housewife/husband	4	1	0	0
Professional	35	12	0	0
Others Profession	140	47	0	0
Student	80	27	0	0
Retired	13	4	0	0
Tour Guide	0	0	26	100
Social worker	0	0	0	0
Other	3	1	0	0

Table 6.3: The visit characteristics and the length of stay

Particular	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
Have you been here before?				
Yes	66	22	26	100
No	235	78	0	0
If yes, then how often you come here?				
Less than once a year	36	55	0	0
Once a year	19	29	0	0
2-4 times a year	5	8	7	27
> 4 times a year	6	9	19	73
How long you stay in MBCA?				
Day visit	22	7	0	0
1 night	51	17	2	8
2 - 4 night	178	59	20	77
5 - 7 night	35	12	4	15
8 - 14 night	11	4	0	0
More than 15 nights	4	1	0	0

Table 6.4: Visitor in groups and the size of the groups

Particular	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
Are you traveling in group?				
Yes	298	99	24	92
No	3	1	2	8
If yes, then how many persons in your group?				
2 persons	25	8	1	4
3 - 6 person	83	28	9	38
7 - 12 person	105	35	11	46
13 - 20 person	70	23	3	13
more than 21 persons	15	5	0	0

Table 6.4 indicates the visitor group size. There were 99% of the visitors travelling in groups and only 1% travelling alone. However, the lone travellers were normally accompanied by a tour guide. Most visitors were travelling in a group of 7 to 12 persons (35%). However, 3 to 6 persons in a group were also quite common (28%). More than 90% of the tour guides managed visitor groups, with generally 7 to 12 people.

6.3 VISITOR MOTIVATIONS AND INFLUENCES

6.3.1 Information Sources

The visitors' main information about MBCA was mostly from online sources (Table 6.5). The findings showed 76% of the visitors obtained the information about MBCA from internet via a dedicated search engine or known website. Whereas, for the tour guides, the information obtained was from three different sources namely 1) internet via website that they already knew, 2) tourist information centres and 3) from others

such as from the tour agent companies itself. Surprisingly, newspaper, magazine, television, radio and even tourist information centres were not significant as sources of information about MBCA for visitors.

6.3.2 Motivations for Visiting MBCA

Table 6.6 shows the factors that influenced the visitor to visit MBCA. Most visitors felt that exploring somewhere new was the main motivation that influenced them. The tour guides stated that “other factors” such as recommendation by friends, family and many others were responsible for their motivation to visit MBCA.

Table 6.5: Respondent’s source of information before visit MBCA

Factors	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
How did you find out about MBCA as a place to visit?				
a. Internet via search engine	118	39	0	0
b. Internet via website you already know	111	37	5	19
c. Newspaper/magazine	27	9	0	0
d. TV or radio	10	3	0	0
e. Tourist information centre	30	10	5	19
f. Other (Please specify):	5	2	16	62

Table 6.6: Respondent reasons to visit MBCA

Factors	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
What makes you visited MBCA				
Previous experience	26	9	0	0
Recommendation (friends, family, etc.)	83	28	0	0
Exploring somewhere new	135	45	0	0
I just passing through	22	7	0	0
Other	35	12	26	100

Table 6.7 shows the motives and the natural features that influenced the visitors to MBCA. In this part of questionnaire, respondents were allowed to choose more than one answer as they preferred. The results show that there were three aspects significant to visitors 1) scenery / landscape, 2) wildlife and 3) Outdoor. While tour guides choose almost all of the aspects and only lower a bit in plenty to see as indicated by more than 50% of the tour guides.

Table 6.7: Respondent motive/ factor deciding to MBCA

Particular	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
What aspects were important to you in deciding to visit MBCA?				
a. Scenery / landscape	156	52	26	100
b. Tranquillity/peace & quiet	89	30	20	77
c. Wildlife	251	83	26	100
d. Plenty to see and do	78	26	15	58
e. Outdoor (e.g., hiking, camping Photographing, etc)	264	88	21	81
f. Areas of Outstanding Natural Beauty	45	15	26	100
g. Other, please specify:	43	14	0	0

6.4 VISITOR PERCEPTIONS OF TRAIL CONDITIONS AN ATTRACTIVENESS

6.4.1 Physical Attractiveness

Most visitors agreed that the view of natural landscapes along the trail was fantastic (Figure 6.2). About 70% of the visitors are also agreed on the statement that many unique species can be found and they able to see many wildlife species along the trail during hiking. However, less than 20% agreed that trail alignment itself was very attractive.

The tour guides' perceptions of physical attractiveness are shown in Figure 6.3. In general, all participants expressed strong agreement or agreement with regard to the listed attractiveness attributes. A significant majority (60%) expressed strong agreement with the attribute that natural landscape view was fantastic, many unique fauna and flora along the trail. However, more than 80% of respondents only agreed with the statement that they can observe a significant amount of wildlife and find the trail alignment visually appealing.

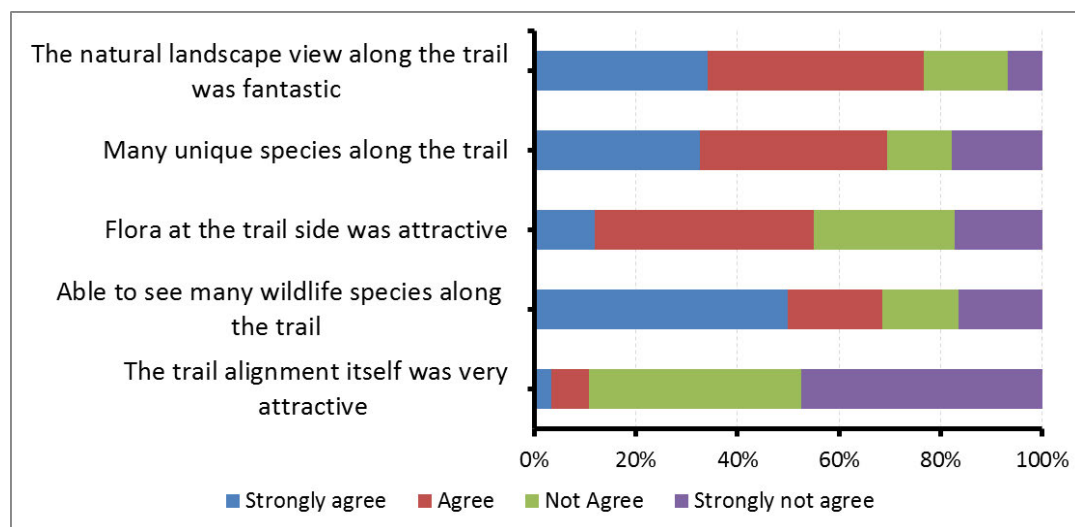


Figure 6.2: Visitor's perceptions of the physical attractiveness along the trails

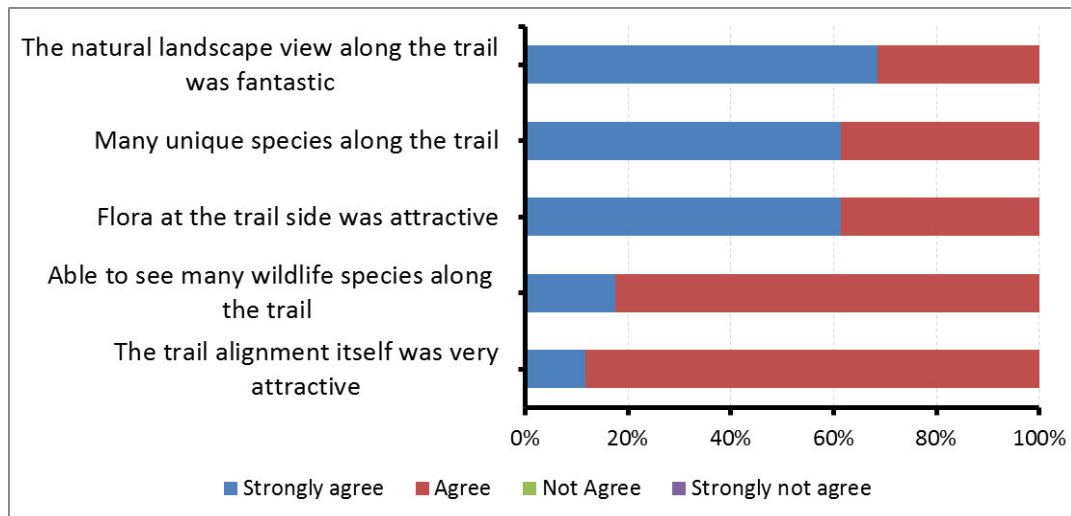


Figure 6.3: Tour guides' perception on physical attractiveness along the trails

6.4.2 Physical Trail Conditions

Their perceptions of the physical conditions of the trails in MBCA are shown in Figures 6.4 and 6.5. Over 60% of visitors agreed in general that trails are steep and slippery with uneven surfaces and were thus considered as challenging. However, about 70% of the visitors did not agree that the trails were scary and dangerous. Most of also rejected idea that the trails were not well maintained.

Figure 6.5 shows the tour guides' perceptions of trail physical conditions. The results were similar to the visitor perceptions. They agreed in general that trails had uneven surfaces and were challenging, but fewer than 60% felt the trails were steep and slippery. Only a small percentage of the tour guides agreed with the statement that the trails were not well-maintained or that trails were scary and dangerous.

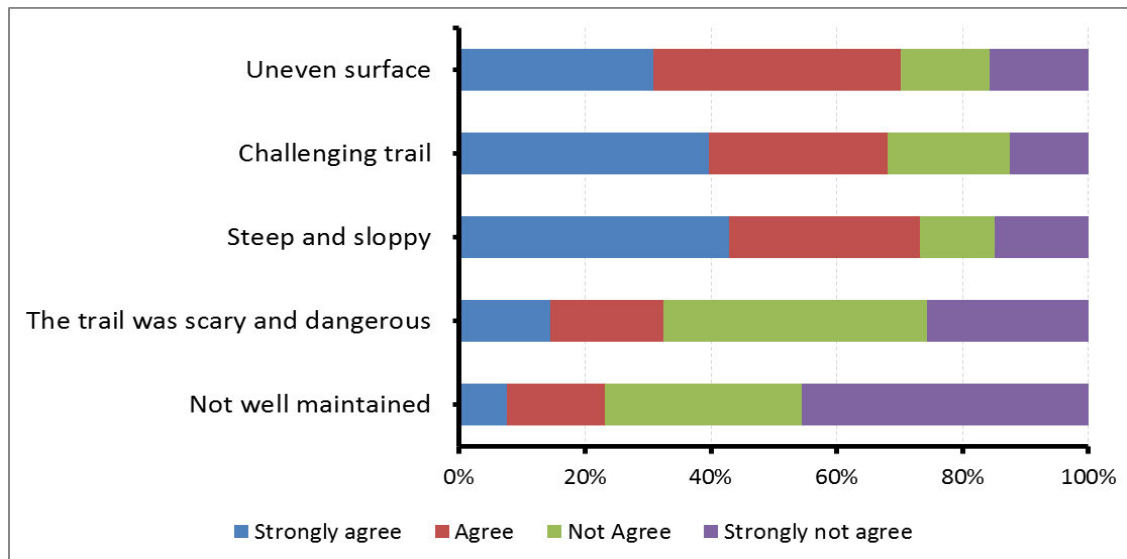


Figure 6.4: Visitors' perceptions of trail physical conditions

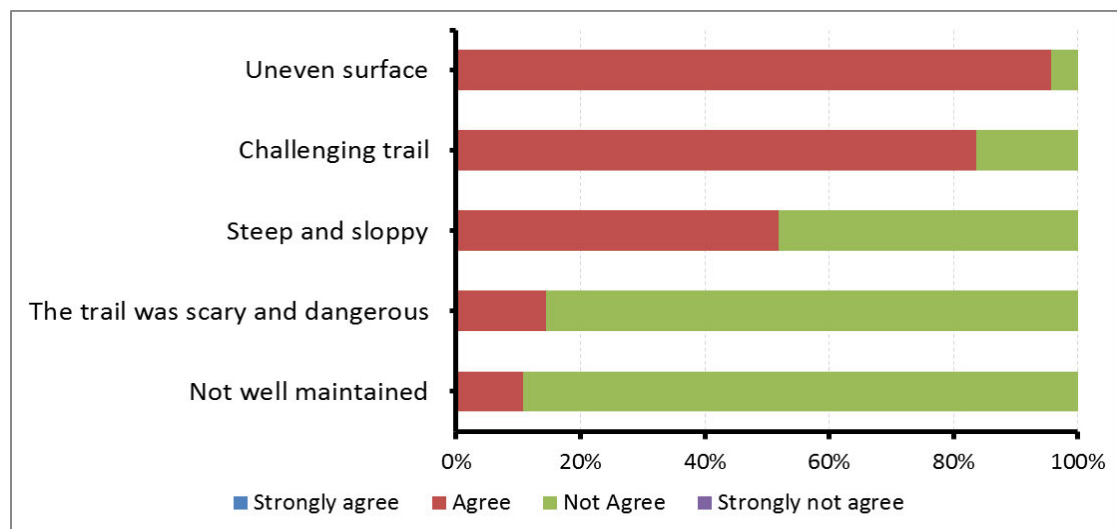


Figure 6.5: Tour guides' perceptions of trail physical conditions

6.5 RECREATION ACTIVITY PARTICIPATION

Most visitors participated in hiking or trekking in groups of 11 to 15 peoples. A similar size pattern was found for the tour guides, which would be expected since they brought the visitors in such groups (Table 6.8).

Table 6.8: The size of hiking group

Factor	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
How many people in your hiking group on a trail?				
a. 1 person	3	1	2	8
b. 2 – 5 persons	31	10	5	19
c. 6 – 10 persons	88	29	7	27
d. 11 – 15 persons	109	36	8	31
e. 16 – 20 persons	70	23	4	15

Figure 6.6 below shows the recreation activities participation by respondents along the trail in MBCA. Both visitors and tour guide share almost similar participation on the activity of hearing nature sound (24%) and watching wildlife (26%). Only 13% to 14% of the visitors and tour guides participated in the activities on studying and experience flora. Again, only 1% of the respondent from both parties doing nothing or just walking through the trails. However, visitors are very keen to do photography, with around 29% involved and this compares to only 13% of tour guides who presumably are there and working.

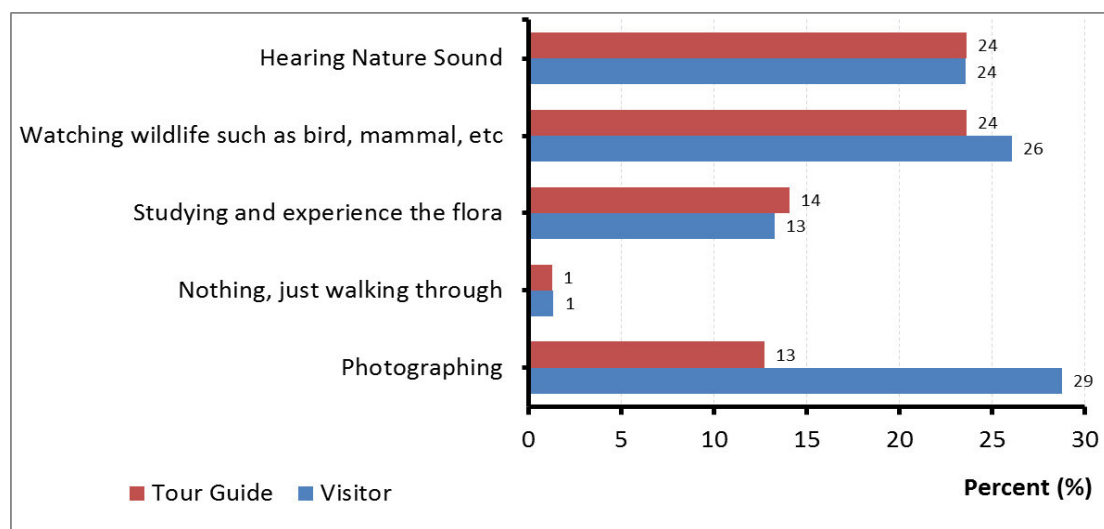
**Figure 6.6: Recreation activities participation during hiking**

Table 6.9 below shows respondent activities at beauty spots. The respondents were allowed to choose more than one answer. The results showed 96% of the visitors did pit stop during hiking to rest, having meal, doing recreation activities and so on. The stop occurred mainly at attractive locations. They generally took photographs at beauty spots (96%) or just stopped there to observe the view and the wildlife for about 10 minutes or so (55%). Others (58%) explored further away and moved off into the forest for up to 5m away from the trail.

Table 6.9: Hiking and other activities at beauty spots

Factors	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
During hiking along trail, do you stop at attractive spot?				
Yes	288	96	26	100
No	13	4	0	0
If your answer is yes, what sort of activities you conducted on that sport?				
a. Stay and just observe it for a while but not more than 5 minutes	123	41	14	54
* b. Stay and just observe it for a while but not more than 10 minutes	165	55	12	46
* c. Find a good spot of photographing	288	96	20	77
* d. Find way off to the forest from the trail to find more as far as 5m away	176	58	11	42
e. Find way off to the forest from the trail to find more as far as 10m away	35	12	6	23
f. Other, please specify:	0	0	0	0

Note: * - indicating high frequency percentage (more than 50%)

However, for the tour guides all stopped at beauty spots, but only 77% took photographs. Most observed the view but generally (54%) stayed less 5 minutes. Fewer than 50% of the tour guides moved off the main trail.

6.6 VISITOR SATISFACTION AND ENJOYMENT

The scoring of respondents' satisfaction and enjoyment in this study were limited to hiking activities along trails and the conditions of the trails. About 90% of the visitors stated that they enjoyed hiking or trekking on nature trails (Table 6.10). They also enjoyed seeing big, old, and diverse tree species (92%), flowering plant (85%), mammals (70%) and birds (58%). While tour guide is enjoying almost every nature element listed in MBCA.

Table 6.10: Respondents' perceptions of enjoying nature

Factors	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
Did you enjoy the Nature trail hiking?				
Yes	271	90	26	100
No	30	10	0	0
What elements you found along the trail that you enjoy most?				
* a. Big old, diversified tree species	249	92	26	100
b. Shrub and palm's	101	37	26	100
c. Lower plant, fungi,	91	34	26	100
* d. Flowering Plant	230	85	26	100
* e. mammal	189	70	26	100
* f. bird	158	58	26	100
g. insect	70	26	26	100
h. Amphibian	51	19	26	100
i. Reptile	52	19	26	100
j. Other (please specify):	5	2	1	4

Note: * indicate higher percentage (more than 50%)

Amphibians and reptiles seemed to be unpopular with visitors and fewer than 20% found them interesting. Only, 2% of the visitors were attracted to other elements such as rocks, soil and terrain. Of the tour guides, 4% chose other elements which they specified as medicinal plants (Table 6.10).

6.7 PREFERENCES AND SUGGESTIONS

The distribution of the respondents' preferences and suggestions are presented in Table 6.11 and Figures 6.7 to 6.11. The preferences and suggestions are divided into three categories which are 1) "preferred length of nature walk", 2) "location or alignment of the trail establishment" and 3) "the trail specification".

6.7.1 Nature Walk Length

Most visitors preferred short and medium distances for the length of their nature walks (Table 6.11). About 44% visitors preferred to have only 2 to 3 hours walks and 33% of them preferred longer walks of 4 to 6 hours. The percentage of visitors became less as the length of the nature walks increased and only 8% were willing to participate in a walk of 2 to 3 days. Almost none wanted to spend more than 3 days on a nature walk.

Table 6.11: respondent's preference on nature walks

Factor	Visitor (n = 301)		Tour Guide/Agent (n = 26)	
	Frequency	Percent	Frequency	Percent
Preferred length of nature walks				
* 2 – 3 hours walk	131	44	1	4
# 4 – 6 hours walk	98	33	21	81
7 – 9 hours walk	44	15	2	8
All day walk	19	6	0	0
2 – 3 days walk	8	3	1	4
Longer than 2/3 days	1	0	1	4

Note:

- * - Indicating higher percentage of visitor's preference
- # - Indicating higher percentage of tour guides preference

However, for the tour guides most were willing to participate in a 4 to 6 hour walk. This preference again decreased for longer walks.

6.7.2 Trail Establishment

Figures 6.7 to 6.11 below showed the preferences and suggestions from the respondents on the establishment of trails especially on the locations and alignments. Most of the visitors fell between strongly agree and agree for the trails to be built on the top of the ridge in order to avoid muddy trails (Figure 6.7). On the other hand, all the tour guides agreed with this suggestion.

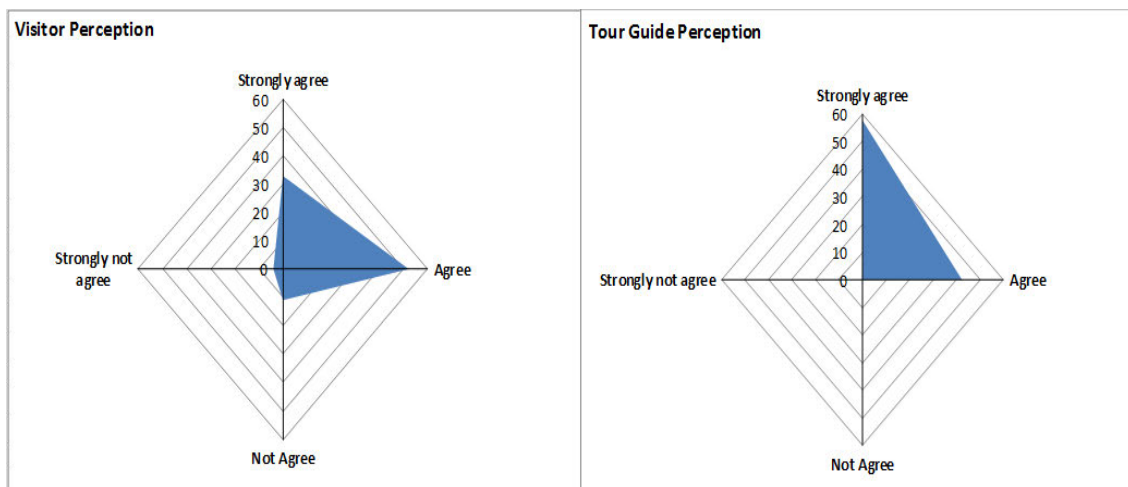


Figure 6.7: Always on the top of the ridge to avoid muddy trail

Figure 6.8 showed the response to the statement that trails built on slippery areas shown be better drained. It is not favoured by the visitors where most of them fall between agree and not agree. However, for the tour guides it is 100% agreeable. Figure 6.9 shows that both visitors and tour guides had responses divided between not agree and agree for the suggestion that “the trail should be built on a flat area for better accessibility”.

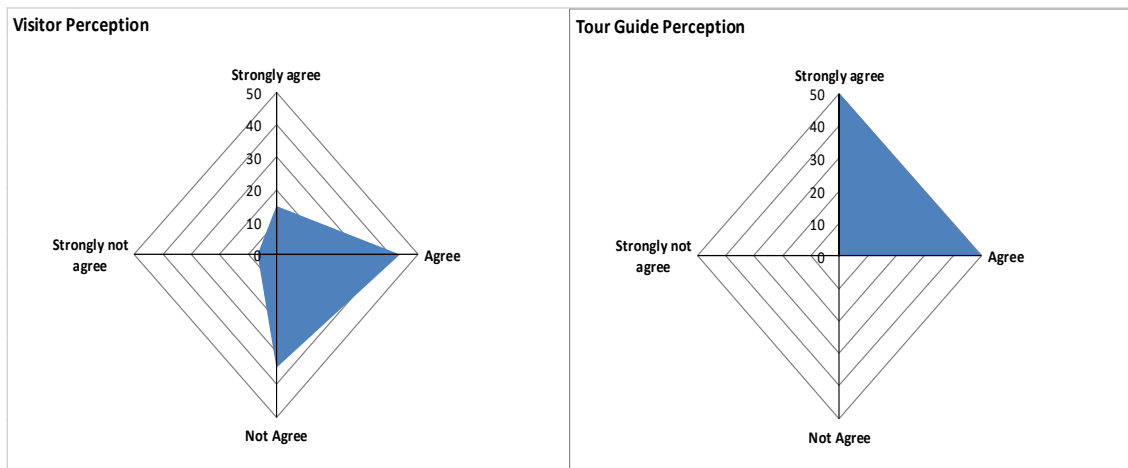


Figure 6.8: The trails built on slippery areas should be better drained

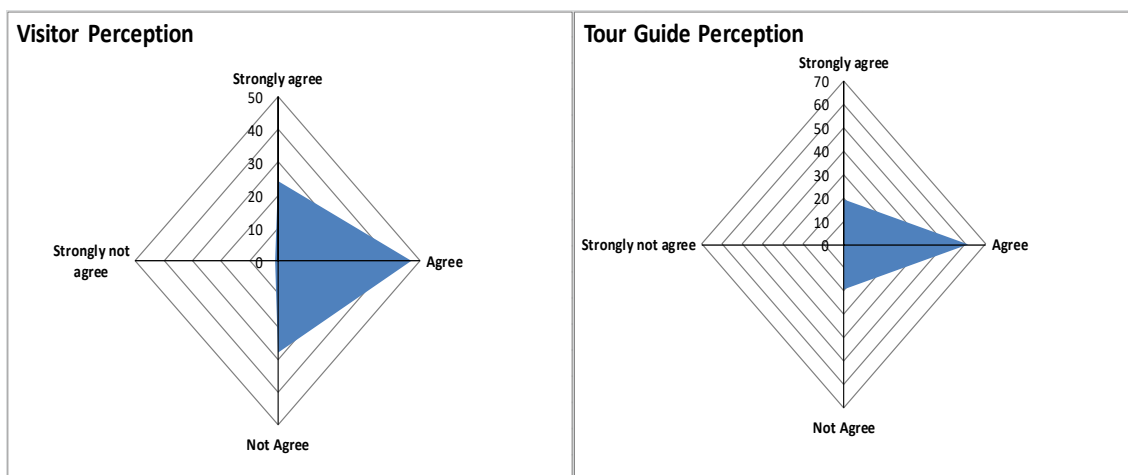


Figure 6.9: Should be built on flat area for better accessibility

Most of the visitors did not agree with the suggestion that the trail should be built near riverside (Figure 6.10). Even though some of the tour guides agreed, but the responses were more for “not agree” to this statement. Most visitors agreed that trails should be built through areas rich in flora and fauna; with only small percentage disagreeing. However, all the tour guides fell between agree and strongly agree on this suggestion (Figure 6.11).

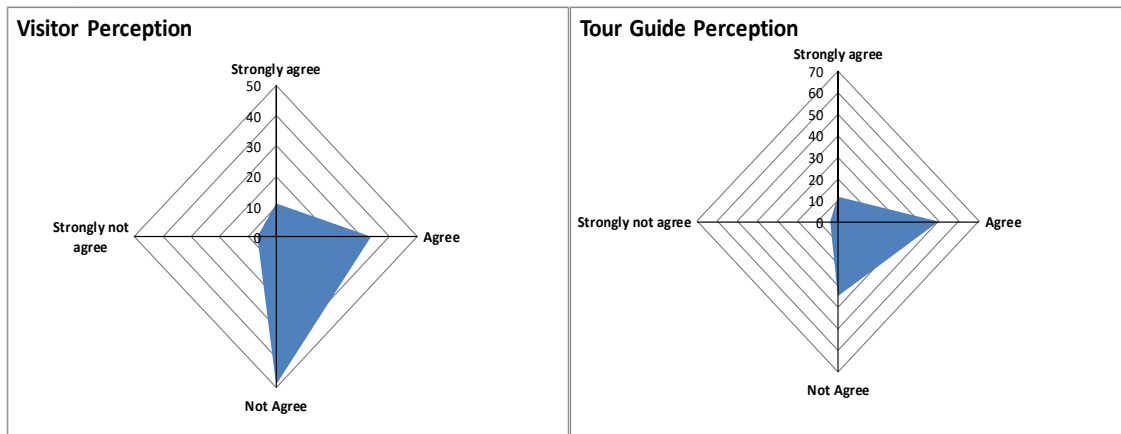


Figure 6.10: Should be built on areas near a river

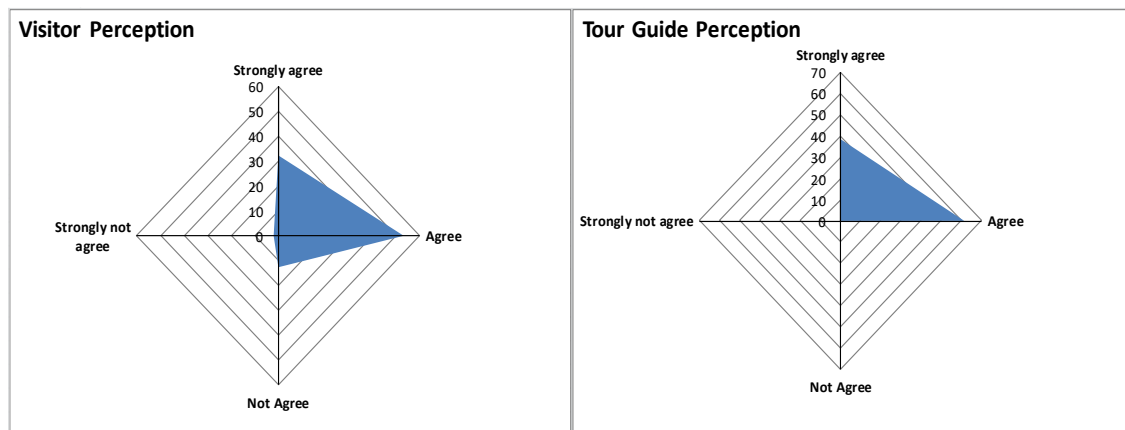


Figure 6.11: Should be built on rich of flora and fauna area

6.7.3 Trail Specifications

The preference and suggestion of trail specifications by visitors and tour guides on nature trail are shown in Figures 6.12 and 6.13 below. There were four nature trail specifications listed for the respondents to choose. Obviously, more than 60% of the visitors agreed in general to all the trail specifications listed. There was less agreement on the suggestions that “width must accommodate more than 1 person” but this was still over 50% in overall agreement.

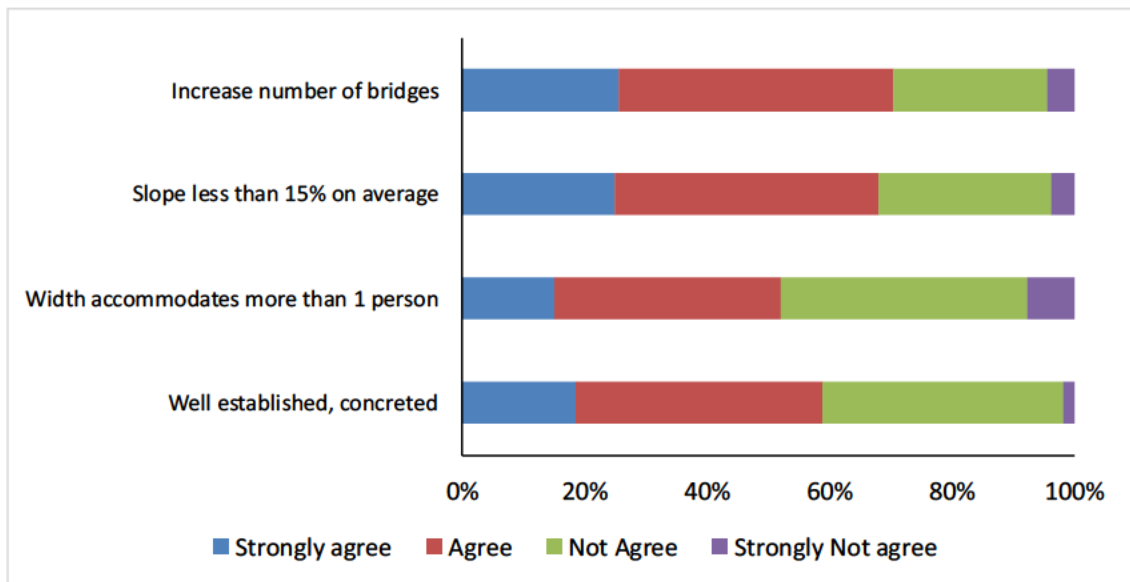


Figure 6.12: Nature trail specification (visitor suggestion)

Figure 6.13 below shows that all tour guides strongly agreed that management should increase the number of bridges along the trails. They also agreed in general that trails need to be wide enough to accommodate more than one person in a row. The other two trail specifications were also supported by most with over 50% agreeing with suggestions.

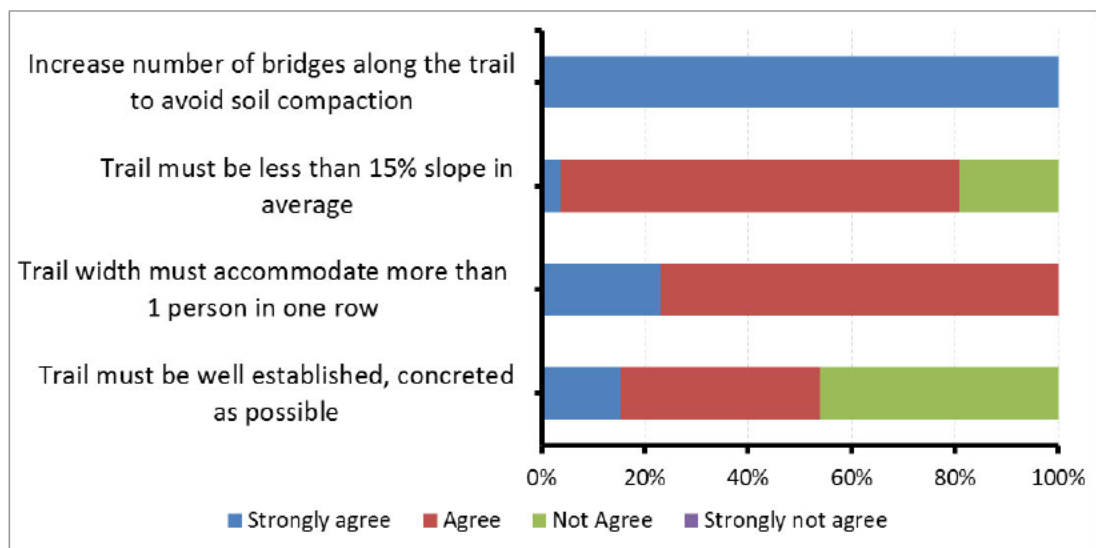


Figure 6.13: Nature trail specification (Tour Guide Suggestion)

6.8 TOUR GUIDE RATINGS

Figure 6.14 below indicates the visitor evaluation and rating for tour guides in MBCA. More than 80% of the visitors agreed in general that tour guides have knowledge on local history, local culture relation to environment, and on the natural environment in general. The visitors rating on tour guides decreased for their knowledge on scientific aspects as vegetation, wildlife, soil and hydrology.

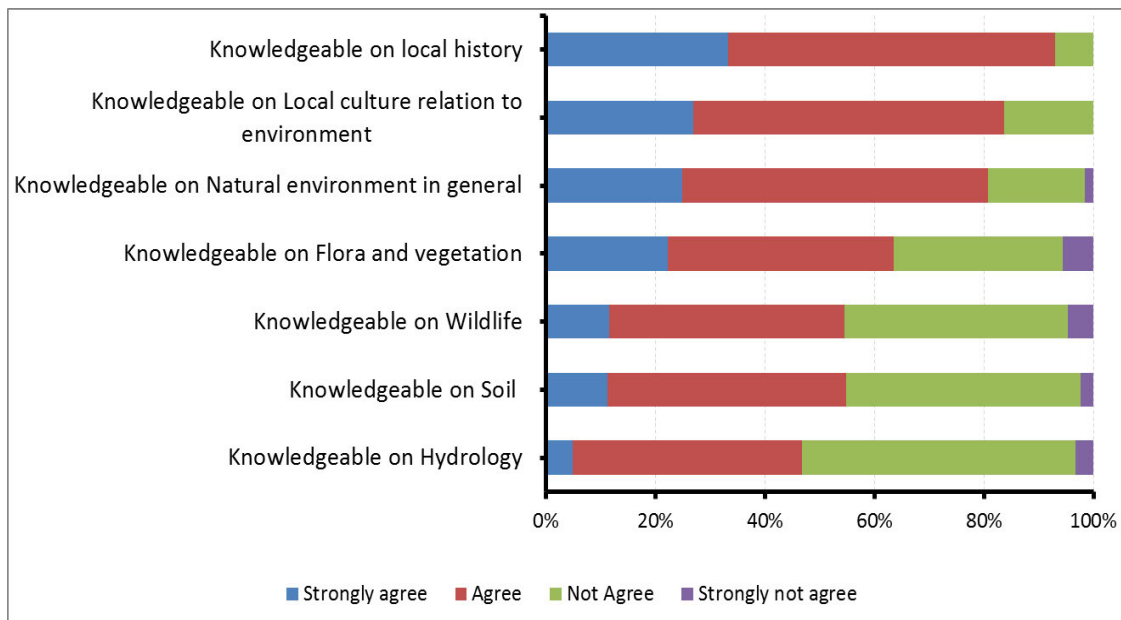


Figure 6.14: Visitor rating of tour guides' knowledge

6.9 STATISTICAL ANALYSIS

As noted in the methods chapter (Chapter 4), *a priori* hypotheses were not used to drive the visitor perceptions analysis. Two distinct features observed in the survey data presented above were explored in more detail using inferential statistics. The first feature explored is the relationship between prior expectations of the visit (motivation for visit, Table 6.7) and the reported quality of experience as judged by the five 'physical attractiveness' parameters. The second feature explored is the

extent to which the overall quality of experience is correlated with each individual factor in the set of five 'physical attractiveness' parameters (Figure 6.2).

6.9.1 Expectation and experience

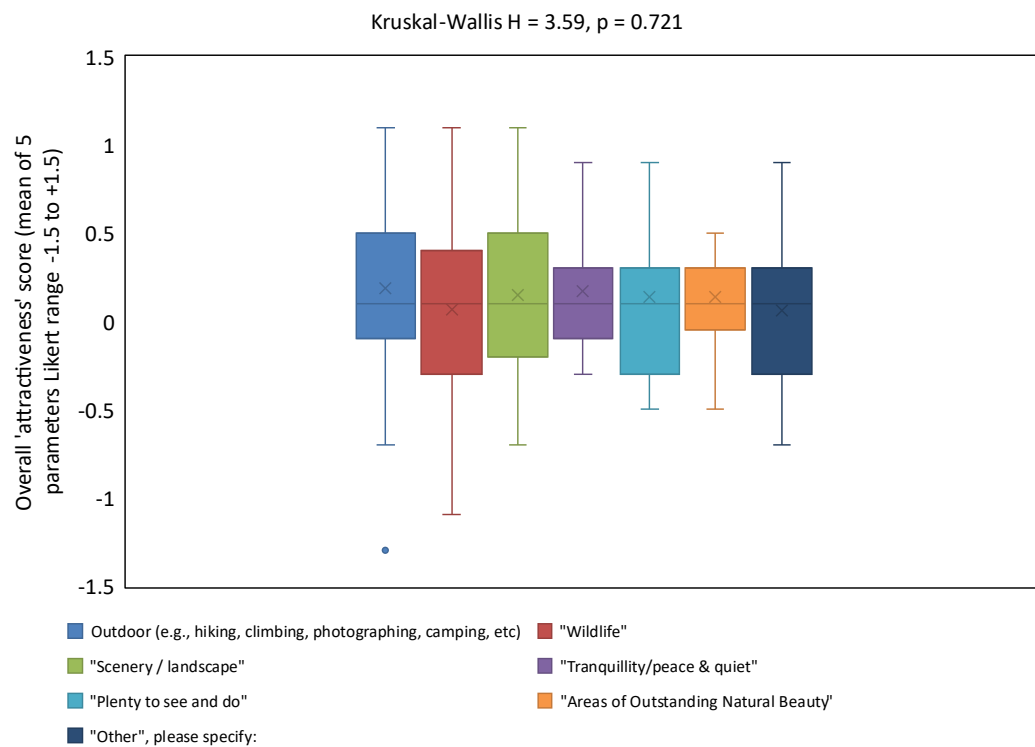


Figure 6.15 Descriptive statistics showing attractiveness score (mean of scores for five survey parameters, Likert scale -1.5 strongly disagree to + 1.5 strongly agree) as a measure of overall positive experience, disaggregated by stated primary motivation for visit. X shows mean, horizontal line is median, box indicates interquartile range and whiskers show maxima and minima. Dots are outliers.

Since Table 6.7 indicated a strong separation between three principal motivations (outdoor, wildlife, scenery) and other motivations, a Kruskal-Wallis test was performed to explore whether different stated motivations led to different perceptions of 'attractiveness' of the trail environments visited. Conjecturally, a person preconditioned to expect high quality wildlife experiences would be more sensitive

to variations in this quality, and/or react with stronger opinions in relation to these measures. Figure 6.15 demonstrates that although there was no significant difference between attractiveness scores among the different groups, responses from those who had stated one of the ‘principal’ motivations were more widely spread across the range of possible scores (-1.5 to +1.5) which might indicate a greater degree of sensitivity or reaction to the trail ecological experience.

6.9.2 Drivers of overall experience of ‘attractiveness’

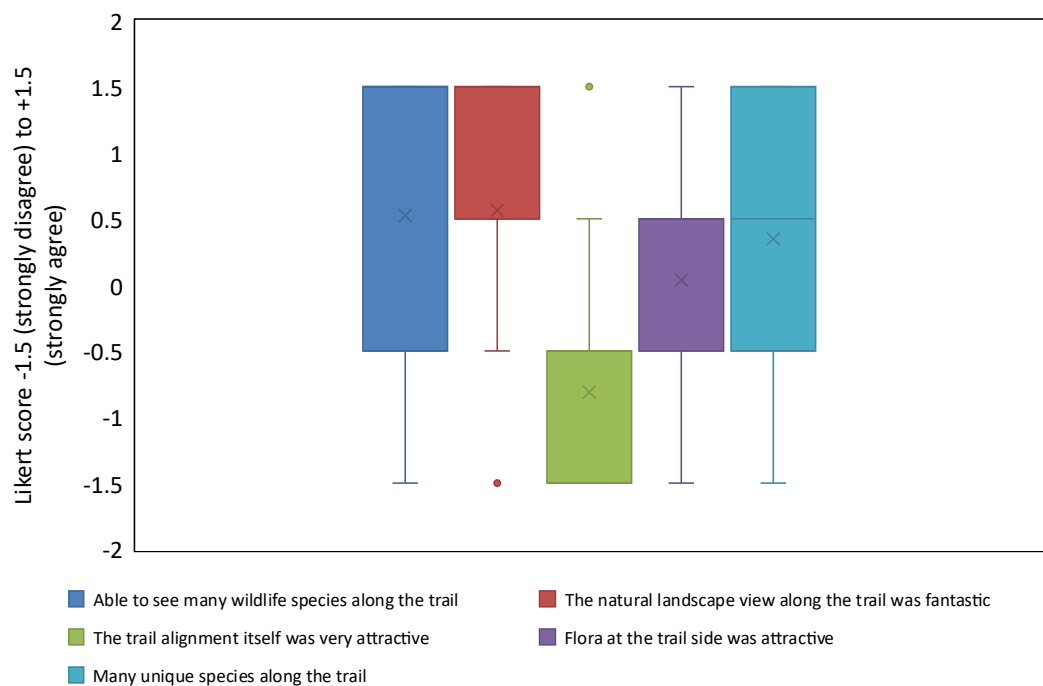


Figure 6.16 Descriptive statistics showing survey score (Likert scale -1.5 strongly disagree to + 1.5 strongly agree) for five factors contributing to ‘physical attractiveness’ of the trail environment. X shows mean, horizontal line is median, box indicates interquartile range and whiskers show maxima and minima. Dots are outliers.

Table 6.12 Linear regression ($y = mx + c$) statistics for relationships between overall attractiveness score and the five factors whose average it is. SSE is the sum of squared errors between observed and modelled value of Attractiveness score over 301 individual samples.

'Physical attractiveness' factor	m	c	SSE (n = 301)
Wildlife abundance	0.2015	0.0298	38.52
Landscape / scenery	0.1684	0.0393	47.88
Trail alignment	0.1881	0.2874	48.59
Trail-side flora	0.2294	0.1257	41.31
Unique species	0.1992	0.0650	41.21

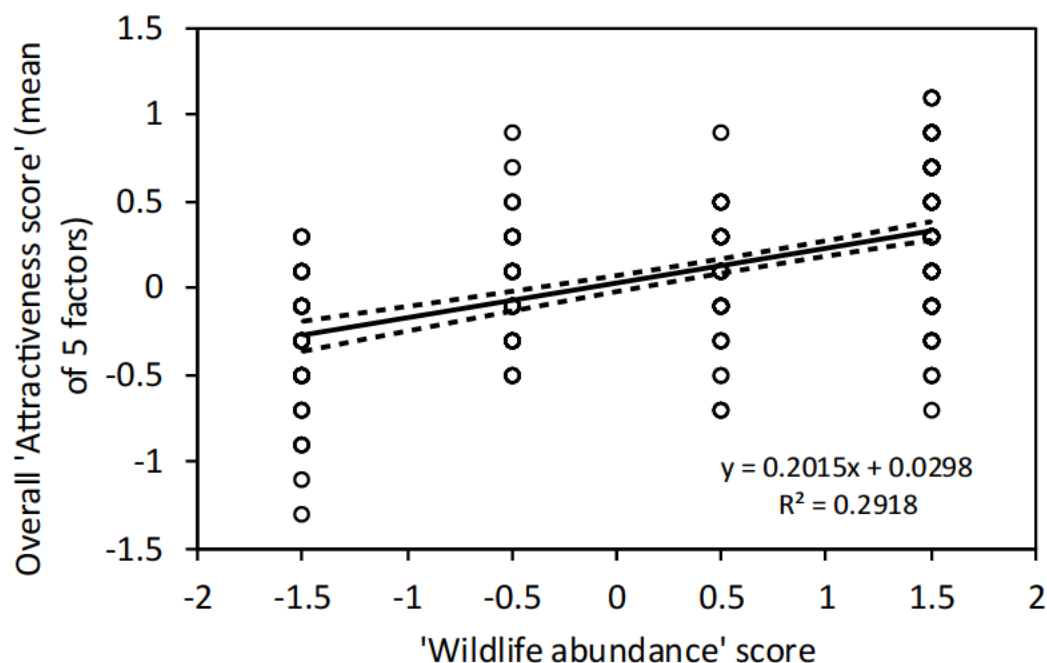


Figure 6.17 Linear regression between observed (survey responses) Likert score (-1.5 strongly disagree to +1.5 strongly agree) for the statement 'Able to see many wildlife species along the trail', and overall 'Attractiveness' score calculated as the mean of five surveyed factors shown in Table 6.12. Dashed lines are 95% confidence intervals.

Figures 6.16 and 6.17, and Table 6.12, present results of an exploration of survey responses relating to the physical attractiveness of the trail. An overall 'attractiveness score' was calculated as the mean, per individual survey respondent, to the five statements shown in Figure 6.16 scored on a four-point Likert [-1.5, -0.5, +0.5, +1.5] from strongly disagree to strongly agree. Linear least squares regression was used to explore which of these surveyed factors most closely predicted the overall attractiveness; in other words, which of the five factors (if any) was the strongest driver of positive nature experience for visitors to the MBCA. Table 6.12 shows best-fit straight line regression coefficients for each factor, illustrated for 'wildlife abundance' in Figure 6.15. The regression equation was then used to calculate a model Attractiveness Score from observed factor score, and the sum of squared errors (SSE) between this model and the true Attractiveness Score (calculated from observed factor scores over all 301 survey respondents) was evaluated as a measure of predictive accuracy. Table 6.12 shows that the factor with the lowest SSE (38.52) was 'wildlife abundance' (statement 'Able to see many wildlife species along the trail'). Unique species (statement 'many unique species along the trail') and trail-side flora (statement 'flora at the trail-side was attractive') had SSEs 41.21 and 41.31, respectively.

6.10 SUMMARY

The chapter explores visitor perceptions of recreation in the Maliau Basin Conservation Area (MBCA) and presents findings from a structured survey conducted with both visitors and tour guides. The study evaluates visitor demographics, motivations for visiting MBCA, perceptions of trail conditions,

participation in recreational activities, satisfaction levels, and preferences for trail design and infrastructure.

The study revealed a diverse demographic composition among visitors to the Maliau Basin Conservation Area (MBCA). The majority of visitors were Malaysian, with a higher proportion of male respondents. A significant percentage of visitors were young, particularly within the 21–40 age range, and most had tertiary education qualifications. Visitors largely travelled in groups, with most staying in the area for two to four nights. Tour guides were exclusively male, all of whom were Malaysian and had extensive familiarity with the site.

Visitor motivations for visiting MBCA primarily centred on expectations of rich wildlife encounters, opportunities for outdoor activities such as hiking and photography, and the appeal of the scenic landscape. Wildlife was a particularly strong attraction, with a high percentage of visitors expressing interest in observing diverse species. The unique flora and fauna, tranquillity, and the pristine natural beauty of the site further contributed to their decision to visit. Many visitors also relied on online sources for information about MBCA, demonstrating the importance of digital platforms in promoting ecotourism destinations.

The study found that visitor motivations were not directly linked to their expressed quality of experience. However, there was some evidence that prior expectations regarding the ecology and scenery of MBCA influenced the level of agreement or disagreement with statements about the overall experience. This was reflected in the variation in attractiveness scores, where respondents exhibited a wider range of

opinions based on their initial expectations. This suggests that those with strong preconceived notions of MBCA's ecological richness and scenic beauty were more likely to respond with either high levels of satisfaction or notable dissatisfaction, depending on how their expectations were met.

The most significant predictor of visitors' overall quality of experience, as measured by the attractiveness score, was the abundance of wildlife encountered during their visit. The presence of diverse fauna along the trails played a crucial role in shaping visitor perceptions of the area's appeal. Trail-side flora and the diversity of species were also strong contributors to the overall experience, further underscoring the importance of biodiversity in enhancing the recreational value of MBCA. Visitors who encountered a greater variety of species tended to report higher satisfaction levels, reinforcing the notion that biodiversity is a key factor in ecotourism enjoyment.

Visitors exhibited a clear preference for trails that provided access to ecologically rich and biodiverse areas. This aligns with the finding that wildlife encounters and flora diversity were critical drivers of positive visitor experiences. Trails that offered immersive encounters with the natural environment were particularly favoured, highlighting the importance of maintaining and promoting these routes within MBCA to enhance visitor satisfaction.

Additionally, the study found a significant preference among visitors for increased use of bridges and boardwalks, particularly over difficult terrain. The presence of well-constructed infrastructure was seen as an important factor in improving accessibility and safety along the trails. Many visitors supported the idea of building

trails that avoid muddy or slippery areas, and they expressed interest in improved drainage systems to enhance trail conditions. The use of boardwalks and bridges was perceived as a practical solution for making trails more navigable, reducing the physical challenges posed by steep, uneven, or wet terrain.

Overall, the study underscores the importance of balancing ecological preservation with visitor experience enhancements. Wildlife abundance, scenic landscapes, and the diversity of plant and animal species emerged as the most influential factors in shaping visitor satisfaction. Preferences for well-maintained trails and infrastructural improvements highlight the need for sustainable trail management practices that enhance accessibility while minimizing environmental impact. By addressing these preferences, MBCA can continue to offer high-quality nature-based experiences that align with visitor expectations while conserving the area's ecological integrity.

CHAPTER 7

DISCUSSION

This chapter examines the meaning, importance, and relevance of the results presented in Chapters 5 and 6. The discussions also focus on explaining and evaluating the findings and showing how they relate to the research questions and previous literature introduced in Chapters 1 and 2.

7.1 SUMMARY OF FINDINGS

The results showed that recreational use by visitors along selected trail in Maliau Basin Conservation Area (MBCA) has affected core ecological parameters particularly the understory vegetation, light intensity and soil condition. The species composition and abundance of the understory vegetation along trails were influenced by the number of recreation users and the intensity of disturbance by visitors. Soil compaction, soil moisture content and soil organic matter were also affected. In contrast, changes in trail usage intensity (mean annual visitor numbers) had no significant effect on number or diversity of wildlife (fauna) species encountered along trails in MBCA. Visitor surveys confirmed that ecological richness (both fauna and flora, and both abundance and diversity) were key drivers of motivation for visit, perceptions of quality of experience, and desires for future trail development.

7.2 EFFECTS OF VISITORS AND RECREATION USE ON VEGETATION

The number of visitors (trail usage intensity) reflect the recreational pressure placed on understorey vegetation. Assuming a simple linear effect relationship, a greater

number of visitors per trail was expected to decrease ecological quality indicators both on-trail and at locations proximal to the trail on either side. Over five years, more than 17,000 visitors came and used these five trails in MBCA. Most visitors were local Malaysians and mainly came in groups ranging in size from small (2-6 people) to quite large, with, in extreme, up to 50 participants.

Findings from the five studied trails in the Maliau Basin Conservation Area (MBCA) confirmed that underlying ecological richness and biodiversity levels are generally very high in this protected tropical rainforest. Across the 250 study plots, 5,941 individual plants were recorded, representing 63 families and 131 species, this represents a remarkably high level of plant diversity for a sampled area of just 250 m². The biodiversity indices and species richness were relatively high, suggesting robust ecological integrity in the study area. These findings align with earlier observations by Whitmore (1995), who noted that small plots within Borneo's tropical forests often contain 100 to 200 plant species, underscoring the region's inherent biodiversity.

7.2.1 Trail usage and vegetation

While comparison of vegetation species similarity between disturbed and undisturbed plots revealed low similarity indices across all selected trails, suggesting localized shifts in species composition (Jaccard Similarity Index), the overall ecological quality of understory or ground vegetation was not negatively impacted by disturbance on a trail-by-trail basis. Typically, there was no significant difference between plots sampled on the Knowledge trail (1,380 visitors per annum, high trail usage intensity) and on the Seraya Trail (213 visitors per annum, low trail usage

intensity), although when calculated from data aggregated over all plots at each trail, ecological indices at Knowledge were consistently lower than at Seraya (Table 5.2). However, whether calculated at plot (50 per trail), location (10 per trail), or whole trail basis, the highest individual and mean values of ecological richness and diversity were observed at the intermediate trail usage intensity trails (Agathis, Nepenthes, Ginseng) likely due to increased light penetration to the forest floor which was also observed higher on average in plots from on these trails (Figure 5.12). This phenomenon aligns with the Intermediate Disturbance Hypothesis (IDH), which posits that moderate levels of disturbance can enhance biodiversity by creating niches for light-demanding or disturbance-tolerant species, while preventing competitive exclusion by dominant species (Connell, 1978; Haddad et al., 2021).

Recent studies further support this interpretation. For example, Pereira et al. (2020) examined the impacts of recreational activities on tropical forest ecosystems and found that low to moderate disturbances often promote species heterogeneity without compromising overall biodiversity. Similarly, Zhang et al. (2019) highlighted that light gaps created by human activity can facilitate the growth of pioneer and secondary species, thereby enriching local biodiversity. This could explain the vigorous growth observed in disturbed areas within MBCA.

The findings suggest that MBCA's vegetation is rather resilient to visitor-related disturbances, while also highlighting the complex ecological processes at work. The maintenance of high biodiversity levels, despite localized changes in species composition, suggests that small-scale disturbances may play a role in shaping the ecosystem without causing significant harm. The greater numbers of visitors and

higher trail usage caused increased disturbance along the trails. Such conditions in effect create a linear forest gap that allows sunshine to penetrate to the forest floor. In this situation, the ground-floor vegetation is normally of light-demanding species and with higher light levels they become bushier. Every plant and seedling species competes with each other. However, in certain circumstances, some species will dominate in particular areas due the timing of the plant fruiting season. The domination of certain species along a trail is very obvious when, for example, only one or two species predominantly occupy an extensive area along a particular trail. For example, in Ginseng Trail, out of 1,299 plants found, there were only 48 species from 28 families. This was due to the dominance by *Heritiera borneensis* along the trail. The fruiting season of this species and existence of many 'mother trees' close to the trail contributed to the dominance. The seeds had been dispersed intensively during the season and germination encouraged by the increased sunlight intensity along the trail route.

However, these results underscore the importance of further research to understand the balance between disturbance and stability in maintaining ecological health. Future studies should focus on long-term trends in species composition and identify the ecological thresholds at which disturbances shift from being neutral or beneficial to becoming detrimental. In the suite of trails considered in this study, the 'positive' effects of intermediate disturbance at trail usage intensities around 500 – 800 visitors per annum appear to disappear at trail usage intensities above c. 1,000 visitors per annum, suggesting that growth in visitors to this level more widely across MBCA, or increases above this level, may cause more significant ecological degradation.

7.2.2 non-recreational factors impacting on vegetation biodiversity

The comparison of species biodiversity and evenness indices for vegetation among the trails showed similar trends. Nepenthes Trail consistently had the highest indices in species richness and biodiversity; while it was the trail with the median mean annual visitors, it was also the trail with the most varied environmental factors. There were many different terrains and slopes along the trail which result in different associated species and vegetation. The situation agrees with the finding by Clark and Clark (2000) where stem number per plot and plot basal area were significantly higher on slopes than on flat plots. The uneven and sloping conditions of the Nepenthes Trail made it vulnerable to visitors which potentially led to more soil erosion and lower rates of retention of humus. Figure 5.19 notes anomalously low levels of soil organic matter at Nepenthes compared with other intermediate-usage trails, and although species richness and diversity indices were very high, overall plant counts at Nepenthes were significantly lower than on other trails.

7.2.3 Visitors' disturbance impacts on vegetation on- and off-trail

Research by Coppes and Braunisch (2013) and Rowe et al. (2018) suggests that visitor disturbances along trails predominantly affect areas within approximately 5 meters from the trail edge. These studies emphasize that beyond this immediate buffer zone, areas remain largely undisturbed by visitor activities. Such findings align with earlier observations by Cole (1976, 1995), Marion and Cole (1996), and Marion et al. (2006), who similarly noted that visitor impacts were most pronounced within this narrow trail-side zone. Other recent studies (Leung & Marion, 2019; Pickering et al., 2020) confirm that intensive trail use remains a primary source of recreation-induced impacts in natural areas, with vegetation damage being one of the most

common effects. Marion et al. (2021) emphasized that recreational foot traffic can significantly alter vegetation cover, composition, and structure along trails.

In this study, findings from on-trail plots corroborated this prior research, with vegetation damage being severe compared to off-trail (proximal and distal plots at 3.5 and 7 m distance from the trail centre line). Plots in proximal locations showed no significant difference in species diversity and biodiversity indices than distal plots, which suggests that if they are experiencing disturbance (being within 5 m of the trail as noted above) then they are at least not being negatively affected. Highest mean and maximum values of ecological indicators tended to occur in proximal plots on intermediate-usage-intensity trails, aligning with the Intermediate Disturbance Hypothesis (IDH) (Connell, 1978; Zhang et al., 2019). According to IDH, moderate disturbances can promote biodiversity by preventing competitive exclusion and enabling the coexistence of pioneer and established species.

These findings contrast with the trends reported in earlier studies, such as Hendee et al. (1990) and Whitmore (1989), which associated recreation impacts primarily with trail widening and forest gap creation. While these gaps often result in dynamic growth under the rainforest canopy, they were typically viewed as deviations from ecological norms (Zhang et al., 2019). Recent research (Pickering & Barros, 2021; Jiang et al., 2022) supports this observation, emphasizing that while forest gaps from recreational activities can lead to increased biodiversity, they also represent a departure from natural ecological processes. In the MBCA, however, forest gaps created by visitor footfall appeared to increase species richness by allowing greater light penetration and enabling more species to establish. This suggests a shift in

biodiversity patterns, which mimics natural processes of canopy opening and competitive succession in the tropical rainforest, rather than degradation or deviation from a natural ecosystem. The findings highlight the need for further research to understand how such disturbances influence long-term ecosystem health, particularly in highly biodiverse regions like MBCA.

7.3 RECREATIONAL USE IMPACTS ON FOREST SOIL

The relationship between soils and vegetation is reciprocal, with fertile soil promoting plant growth and providing nutrients. Similar to tree cover and forests, vegetation prevents soil degradation and desertification by stabilizing soil, sustaining water and nutrient cycling, and reducing erosion. On the basis of the preceding information, it is evident that outdoor recreation activities can harm vegetation cover, expose soil to wind and water erosion, and cause soil compaction and bulk density.

7.3.1 Changes in soil compaction as a result of trampling

Soil compaction occurs when pore space is reduced, and bulk density increases (Cambi et. Al 2015; Fu *et al.* 2019). Therefore, any process such as trampling that reduces pore-space will cause soil compaction. The study results indicate a similar trend of soil compaction highly correlated with trampling intensity. Knowledge and Agathis Trails demonstrated elevated mean and maximum soil compaction compared to the other lower-usage-intensity trails. Kruskal-Wallis tests did not indicate any significant differences between sample populations across any of the trails, but very significant increase in soil compaction was observed on-trails compared with off-trail plots. (Figure 5.17).

In summary, significant soil compaction is observed on MBCA trails at even low visitor numbers, but the effects in this study appear confined to the trail itself and are not observed even 3 m away from the trail centre line. This finding contrasts with previous studies suggest that low to moderate recreational use often results in minimal soil compaction. For example, Marion et al. (2019) found that well-designed trails, such as those with appropriate trail grades and alignments, significantly mitigate soil compaction even under substantial use. Similarly, Kutiel et al. (2000) reported that significant soil compaction occurred mainly under high pedestrian use, whereas trails with lower use showed negligible impacts. The finding that soil compaction was limited to < 3 m from the trail again contradicted past studies (Marion et al 2006) which found visitor damage occurred up to 5m beyond trail centre. The visitor survey data indicated that around two-thirds of visitors explored up to 10 m off-trail, often to find a good spot for photographs (Table 6.9); on the evidence in this study, these off-trail behaviours at the levels of usage reported here do not have negative impacts on soil compaction or ecology, in this environment.

7.3.1 Changes in soil moisture content (SMC) and organic matter

The effects of recreational use and visitor trampling on Soil Moisture Content (SMC) are complex and unpredictable. SMC normally being related to factors such as soil compaction, texture, organic content, density of forest cover, and ground exposure (Hammit and Cole 1987). Compared to other related factors in general, the effects of recreation on SMC are probably less important. In MBCA, SMC is probably only significant when available moisture declines in soils that are inherently droughty under undisturbed area. SMC usually decreases as soil compaction increases since compaction reduces infiltration and the amount of water available to the soil (Hammit

and Cole 1987). This study found no significant differences in SMC either between trails or at different distances from the trail centre (Figure 5.18). In MBCA, despite the soil in general being classified as within the Maliau category which is sandstone (Tongkul 2002), most of the ground area is covered by an organic layer that acts like a sponge to protect the soil from direct trampling effects. It showed that recreation trails in a rainforest protected area, SMC was not a very good indicator for trampling effects.

There were no significant differences in soil organic matter (SOM) with distance from trail centres, but significantly higher mean and maximum SOM at trails with intermediate trail usage intensity (except at Nepenthes, Figure 5.19). The results are broadly in agreement with the findings of Chappell *et al.* (1971), where there were no significant differences of SOM between used and unused. In tropical rainforest, the accumulation of SOM is very thin on the surface layer and only consists of 2 to 3 percent of the total biomass (Ross 1993). In MBCA, the soil surface layer is rather thin under the part-decayed leafy litter, and through erosion small amounts of disturbance may rapidly affect the SOM content. The report by the Missouri Botanical Garden (2002) stated that only 48 percent SOM or nutrients found in tropical rainforest soil compared to 69 percent in temperate forest. However, the general percentage of SOM along trails in MBCA is much lower and only up to 10.4 percent in the lowest use trails (Seraya Trail). This finding is consistent with the study reported by Hazebroek *et al.* (2004) that virtually all of the MBCA soils are extremely poor in nutrients. Most of the soils of MBCA have been derived from both the mudstone and the sandstones that comprise the bulk of its subsurface. The parent rocks making up the MBCA subsurface determine which soil are produced

(Hazebroek *et al.* 2004). The result is similar to the past study conducted in Temperate Forest as reported by Liddle (1997) and Hammit and Cole (1987).

7.4 LIGHT INTENSITY RELATIONSHIP TO RECREATION ECOLOGY

Light intensity is one of the important factors in the tropical rainforest primarily due to plant life and associated photosynthesis. The relationship between light intensity and recreation ecology is very difficult and complicated due to its interrelation with other factors such as forest gaps (Ritter *et. al.*, 2005). The evaluation of light intensity as an important ecological factor in recreation impacts has to answer questions concerning the forest profile and tree structure along the trails in MBCA. Tree structure and profile in ideal virgin forest is normally very dense and light penetration to the ground is less than 1% (Longman and Jenik 1987).

However, the opening of the forest canopy along the trails in MBCA created forest gaps or forest openings that allow sunlight to reach the forest floor directly. Thus, the light reaching the floor in all trails increased in general ranged from 1.5 to 8.1 percent. The 3- to 5-metre-wide opening in the heavily used trails of Knowledge and Agathis contributed to a high percentage of light intensity reaching the forest floor. However, it is slightly less in the Agathis Trail due to the occurrence of many massive *Agathis* sp trees. Light intensity on on-trail plots is relatively high and dropped sharply across proximal and distal plots. The high intensity of light reaching the forest floor provides good conditions for many species of vegetation to grow. This situation then creates high biodiversity along the disturbed areas.

7.5 WILDLIFE AS INDICATOR FOR WILDLIFE TOLERANCE TO DISTURBANCE

Assessment and evaluation of visitor and recreation impact on wildlife gained less popularity and attention by forest managers except for those poaching and illegal fishing. These circumstances are mainly due to assumption that wildlife is not stagnant as plants and the impact would not immediately obvious or easily evaluated (Ream 1980). While in MBCA, as a conservation forest area, the management placed great emphasis on conducting studies on wildlife and gathering as much information as possible on wildlife populations, distributions and so on (Hazebroek *et al.* 2004). However, other than this current study, there has not yet been any research undertaken on recreation impact on wildlife in MBCA. This research is therefore a pioneer study on recreation impact on wildlife in MBCA.

The researcher conducted surveys along the trails during normal visiting times and behaving like a visitor trying to encounter fauna, resulting in 245 encounters of wildlife of various categories along the trails. There were 326 animals found during the survey made up of 87 species. The number of species found is far less than 563 species of wildlife recorded throughout the whole MBCA. This preliminary result suggests a typical trail visitor is likely to encounter only around 15 % of total faunal biodiversity during a visit to the MBCA trails. Further analysis of the results from this study showed the visitors' use of the trails could create disturbance to wildlife and change animal behaviour towards humans.

In general, total wildlife encountered in every trail does not indicate much difference between them (Figure 5.13). The visitors' perspective survey along the trails in MBCA found out eight categories of wildlife. The most common categories of wildlife

to be seen when hiking on the selected trails were birds, mammals, and insects. Some birds and mammals seem to have a high tolerance of visitor disturbance while others may be displaced from an area of concentrated recreational use. In general, wildlife with less tolerance of recreational disturbance will be replaced by those better adapted to the new environment conditions with increased disturbance (Kuss, Graefe and Vaske 1984). The animal tolerance level is very complex and varies with factors such as habitat type. The high-usage trails such as Knowledge and Agathis obviously have more changes in habitat type and so the animal species encountered are slightly different (although species richness and diversity indicators were not significantly different between trails).

7.6 RECREATIONAL DISTURBANCE, VISITORS AND TOURIST GUIDE PERCEPTION

Beyond ecological factors, visitor behaviour, perception, participation, and satisfaction serve as critical parameters in assessing the impact of recreational disturbance. Visitor numbers are pivotal, as they underpin the promotion of nature tourism aimed at generating economic returns for protected areas. Consequently, understanding and fostering positive perceptions toward natural areas can significantly enhance visitor engagement and contribute to the sustainability of destinations such as the Maliau Basin Conservation Area (MBCA).

Recent studies emphasize that visitor perceptions are not only shaped by their experiences but also by how effectively information about the area's ecological and cultural significance is conveyed (Deng et al., 2020; Li et al., 2021). In comparison to visitors, the perceptions of tourist guides warrant closer examination. Tourist

guides often possess a deeper understanding of the area's ecological and recreational dynamics, which may lead to differing perceptions compared to the general public (Yuen et al., 2022). Their insights can provide valuable perspectives for managing visitor expectations and minimizing recreational disturbances.

While perception and preference are sometimes used interchangeably in research literature (Pigram & Jenkins, 1999), contemporary studies underscore the need for nuanced approaches to these constructs, particularly in the context of diverse demographic factors such as gender, age, education, occupation, income, and marital status (Chiu & Lee, 2019; Wu et al., 2021). For instance, demographic influences on visitor motives, anticipations, and levels of satisfaction play a significant role in recreation impact management. Recognizing these factors can aid in tailoring strategies to enhance visitor experiences while safeguarding biodiversity.

Ultimately, the integration of visitor and guide perceptions into the management framework for MBCA offers a robust pathway to address the dual objectives of conservation and tourism development. By leveraging these insights, recreation managers can implement evidence-based practices that align visitor expectations with conservation priorities, ensuring long-term sustainability.

7.6.1 Demographic and visitation background

Findings from this study revealed that typical visitors at MBCA can be characterized as dominated by male Malaysians between the ages of 10 and 40 years old, moderate income, with tertiary levels of education such as college graduates and other profession such as teacher, government officer and so on (Table 6.21 and

6.22). This demographic pattern has a close relationship with the “the nature of activities itself”, in other words, young tourists or visitors have a high interest in adventure recreation activities which requires a strong mental and physical endurance. Other factors include the high level of trekking difficulty at the MBCA which is only suitable for those who are fit and healthy. In Malaysia, active hikers above 50 years’ old are infrequent. The tourist guides are all male Malaysian and mostly single aged 21 to 30 years old. Tourist guides in MBCA have tertiary level of education and so are well-educated.

7.6.2 Respondents Motivation and Anticipation in MBCA

The popularity of MBCA as a conservation area that offered a challenging outdoor experience was the main reason why it was became a dream site to visit. For nature lovers in the region, it is a must-see destination. The connotation “Lost World of Borneo” has always attracted eco-tourists to experience pristine nature. This phrase has been published worldwide on internet, and most of the visitors reveal that their source of information is from online search engines. Furthermore, visitors were motivated to visit MBCA because they want to explore somewhere new, and it was also recommended by friends and families. Motivation is a dynamic process, intangible and difficult to measure directly. In a travel process, motivations mount up when an individual imagines having a vacation. This then stimulates the individual to be focused and willing to commit to a trip in order to achieve their objective. According to Torkildsen (1999), visitor motivation does not happen by chance or coincidence, but the need is an element that leads to motive. Mill & Morrison (1985) stated that a need becomes the basis for an individual to be motivated.

For example, a person has a need to take a vacation in a nature-based area. The area would offer benefits to her such as relief, retreat, and tranquillity; otherwise, the area will be of no interest to such an individual. In the case of visitor in MBCA, most of them motivated to visit based on the environment attraction that being offered by MBCA. Most of the visitors are interested in visiting MBCA because of the scenery, natural landscape, wildlife, and the outdoor activities. These aspects can fulfil some of their needs as explained by previous researchers as far back as Maslow (1943). By contrast, most of the tour guides are individuals who want to be close to nature but also to be employed in the process. Almost the entire natural attribute of MBCA becomes their deciding factors to visit. This kind of motivation by both visitors and tour guides to visit the natural area and to experience the natural attractions is likely to produce fewer impacts than the individual who simply desires to visit in order to escape the home and work environment (Hammit & Cole 1987).

7.6.3 Perception, satisfaction and recreational disturbance in MBCA

Some researchers like Chawla (1999) and Ewert *et al.* (2005) stated that participation in outdoor and environmental education activities might lead to the enhancement of environmental attitudes. Since the 1970s, several studies (e.g., Dunlap & Heffernan, 1975; Jackson, 1986; Tarrant & Green, 1999) were conducted to examine this hypothesis. Most of the studies recorded positive findings as the majority of the participants indicated significant improvement in their environmental attitudes after participating in recreational activities. In addition, these studies also found a strong correlation between participation in appreciative outdoor recreational activities and positive environmental attitudes. Although the participants' attitude

towards a good environment, group size can affect the environment as larger group sizes will increase the amount of use in a particular environment.

Grigoroudis and Siskos (2019) stated that satisfaction was more a judgment or evaluation than an attitude and is a complex construct with numerous associated measurement issues. Past researchers operationalized satisfaction at both the overall satisfaction and attribute satisfaction levels (Naidoo *et al.* 2011). Attribute and attractions satisfaction have been defined as consumer subjective satisfaction judgment resulting from observation of attribute performance (Marzuki *et. al.*, 2017). Trekking and hiking are very important attributes in MBCA. This attribute influences visitors and is a major reason for the visits. Thus, the importance and performance of this attribute in MBCA needs clarifying by measuring tourists' perceptions as suggested by Chen *et. al.*, (2019), This is that identification of the destination attributes "that influence on tourists' choice of a destination is important in developing marketing strategies". Moreover, tourists' perceptions about the performance of destination attributes may determine their re-visit intentions or positive, word-of-mouth recommendations (Li *et. al.*, 2019).

The study results found no significant link between visitor motivations for visit and the quality of experience as indicated by the mean of five 'physical attractiveness' factors ('attractiveness score'). However, this overall attractiveness was most strongly predicted by perceptions of wildlife and floral abundance and diversity, indicating that recreational impacts which degrade these factors may strongly impact future visitor experience and reputation of the MBCA and other similar ecosystems. This reflexive relationship between motivation, experience, impact and satisfaction

exemplifies the Wilderness Paradox (Shogan, 2013) and is intensified by the stated desires of visitors in relation to future trail establishment, focusing on areas richest in flora and fauna, and infrastructure including the provision of more bridges over rough or boggy areas.

The evidence collected and presented in this study indicates that such developments, as long as visitor numbers are controlled at approximately current levels, will not significantly degrade floral or faunal biodiversity and may even enhance it through the opening of the canopy. Construction of more extensive boardwalks and bridges may reduce on-trail soil compaction and trampling, perhaps mitigating the negative ecological impacts for on-trail biodiversity and, by encouraging visitors to stay on the 'bridge', may minimise the already-minor impacts of off-trail trampling. However, it is obvious from the data presented here that any level of trail development results in 'disturbed' ecology, and additional trail infrastructure such as bridges places further barrier between the visitor and their 'perception of wildness' (Baker, 2022).

7.7 WIDER SIGNIFICANCE OF THE FINDINGS

MBCA research results are applicable beyond the site and have transferable insights within different local, regional and tropical ecosystems. As such, the research results lead to a better understanding of the influence of recreation on biodiversity, soils, and visitor experiences and further establish key concepts concerning recreation ecology. The insights gained from this study will help to develop sustainable management plans across similar protected area globally,

balancing the goals of conservation whilst allowing for responsible ecotourism practices to take place.

7.7.1 Key Findings and Their Transferability

The table below summarizes how the key findings from MBCA relate to wider ecosystems and recreational ecology research:

Table 7.1: Transferability of Key Findings from MBCA to Other Ecosystems and Recreation Ecology Research

Key Finding	Application to Other Local/ Regional/Tropical Ecosystems	Relevance to Recreation Ecology Research
Recreational use affects vegetation composition and abundance, but intermediate disturbance can promote biodiversity	Supports the Intermediate Disturbance Hypothesis (IDH), suggesting that low-to-moderate recreational use may enhance biodiversity in other tropical rainforests, particularly where forest gaps form naturally.	Reinforces findings in temperate and tropical recreation ecology that controlled levels of disturbance can increase species heterogeneity (Pereira et al., 2020).
Soil compaction is a significant impact of recreational use, but effects remain localized to trails	Indicates that well-planned trails in other tropical protected areas can minimize off trail soil compaction. Guides sustainable trail design for regions with fragile soils, such as protected area in Southeast Asia and the Amazon.	Aligns with global recreation ecology studies emphasizing the importance of trail management in minimizing soil degradation (Marion et al., 2019).
Light gaps created by trails influence vegetation growth and biodiversity	Similar effects likely in other dense tropical forests where controlled canopy openings enhance species diversity. Supports adaptive management approaches that balance forest integrity and visitor access.	Expands on recreation ecology research by demonstrating that recreation disturbance can mimic natural succession dynamics.
Wildlife encounters along trails show tolerance thresholds to recreational disturbance	Provides insights for other tropical conservation areas on how different species respond to recreational use. Suggests that moderate levels of tourism can be maintained without significantly reducing faunal biodiversity.	Contributes to the emerging body of research on wildlife behaviour in response to recreation activity in conservation areas (Pickering & Hill, 2019).
Visitor motivations and perceptions are shaped by ecological richness and trail infrastructure	Highlights the importance of ecological integrity in visitor satisfaction, reinforcing the need for biodiversity-focused tourism management in other tropical ecotourism destinations.	Supports previous studies linking visitor satisfaction to biodiversity quality and wilderness perception, informing sustainable tourism planning (Deng et al., 2020).

7.7.2 Reflections on Recreation Ecology Research

This study strengthens the use of MBCA as a model for recreation ecology research in tropical ecosystems by revealing that the ecological response to recreation activity in MBCA. Investigations on light penetration under access trails, species diversity inside and outside trails, and localized soil compaction inform the development of recreation ecology models in the tropical environment. The study also contributes to the ongoing debate worldwide about how best to balance access to nature with the need for protection, and highlights the value of data-led management in addressing this.

Overall, MBCA serves as both a unique case study and a transferable model for sustainable recreation management in tropical conservation areas. The insights gained can support evidence-based policies and conservation efforts in ecologically sensitive regions worldwide, ensuring that nature-based tourism remains both viable and sustainable.

CHAPTER 8

CONCLUSIONS

8.1 INTRODUCTION

This chapter will conclude the study by summarising the key research findings in relation to the research aims and questions and discussing the findings and contribution thereof. It will also review the limitations of the study and propose opportunities for future research.

8.2 AIM AND OBJECTIVES OF THE RESEARCH

This study aimed to evaluate the ecological impacts of recreational use on five trails in MBCA using selected parameters namely vegetation, soil compaction, soil moisture and organic matter content. The results indicate that recreation impacts on vegetation is strongly correlated to some factors, particularly the effects of trampling and soil compactions. Moreover, the vegetation biodiversity is somehow influenced by the occurrence of forest gap due to disturbance. Further findings show that the soil compaction initiate the impact of soil moisture and organic matter content. The varying visitor intensity in the study area indicate differences in the effects of recreational use on these soil parameters studied. The findings also showed that there is no clear evidence of animal species diversity affected by the amount of visitation and recreation disturbance in every trail. The heavily used and moderately visited trails indicated no significant differences.

The objective of determining the nature and degree of ecological impacts of recreational use of five permanent trails in MBCA on visitor perceptions using

questionnaires distributed to designated visitors and guides indicated that ecological impacts is related with the nature attributes and attractions. These attributes influence the recreation experience in a particular trail. For the aim of comparing the findings of the two different approaches to reach a coherent conclusion, emphasizing that the two approaches cannot be compared but complement each other. In rainforests, natural features and attractions influence visitor behaviour and perception and vice versa where physical characteristics and human behavioural effects will act in both directions.

8.3 KEY FINDINGS

The overall findings in this research can be briefly summarised as follows and in the table 8.1 below. This study aimed to explore what impact recreational disturbance have along tropical forest trails (RQ1). Specifically, it evaluated ecotourism impacts on fauna and flora on five trails in MBCA using selected parameters namely vegetation, wildlife, soil and light intensity (Objective 4). The study highlighted that there is an indication that an increase in the number of visitors to MBCA is a threat, but, to this date, the amount of use remains within manageable limit. Furthermore, the study highlighted how wildlife impact is currently not priority for many managers if compared with other pressing issues such as poaching and squatting.

In relation to the aim to explore what effects recreational disturbance impacts along tropical forest trails have on visitor perceptions, expectations, and satisfaction with their visit (RQ2), this study highlights that the background of the visitor shapes their perception, with first timer visitors having a different perception and satisfaction compared to experienced tourist guide. With regards to the development of criteria

to identify fundamental ecology impact indicators for the tropical rainforest trails of MBCA based on the perceptions of visitors and guides (Objective 4), the findings of this research highlighted two key categories of ecology impact indicators that are appropriate for the MBCA trail: a) the number of trail use (amount of use determined by background, source of information, motive, participation, and satisfaction of visitors) and b) impact on trail physical features (e.g. muddy, slippery, slopes). These indicators would be useful in managing the trail resources and trekking experiences in MBCA and could be applied to determine the carrying capacity and other visitor management strategies for the tropical rainforest trails in Malaysia.

With regards to research methodology this study set out to develop appropriate methodologies for impacts assessment on fauna, flora, and soils (Objective 2) and to use and apply the developed methodologies to assess impact on fauna, flora, and soils (Objective 3). A novel methodological approach was adopted to quantify recreation impacts in MBCA that used both ecological and human perception data. The recreation impact on ecology along trails in MBCA was assessed used a modified methodology developed by Cole (1995) with pairing transect both side of the trail giving equal pairing measurement of ecological parameters. This methodology proved effective and appropriate, thanks to the effective establishment of plot arrangements along transects, which yielded favourable outcomes for the assessment and computation of biodiversity. A critical appraisal of the literature related to conservation, tourism, and recreational ecology (Objective 1) highlighted the relatively low number of studies conducted in tropical Rain Forests. This modified research approach from temperate forest demonstrates transferability to tropical

rainforest, at least with regards to the selected ecological parameters and protected natural areas.

Table 8.1: Summary of the critical assessment and analysis of the research finding

Summary of the critical assessment and analysis of the research findings				
Key Research Questions and Research Objectives	Evidence from the Literature review	Evidence from the research survey & Findings	Comparative analysis of research findings supported by literature	Overall Findings
Recreation disturbance impact along tropical rainforest trail effects on visitors' perception in MBCA (RQ2)	-Recreation disturbances have minor impact on recreation perceptions -Lucas (1990) had established that some studies of visitor perception of wilderness impact showed little relationship between visitor satisfaction and amount of impact. -Many visitors do not notice the ecological change, and those who do, may not conceive of change as damage or as undesirable. -seems clear that recreational impacts are not critical, prominent factors in the perceptions of recreationists. -Which types of impacts visitor is most aware of is still unclear.	Visitor Perception indicated by their background such as education, age, experience. -There are significant different of perception and satisfaction between visitor and tourist guide. -The physical impact along trail especially uneven surface, muddy, steep and slopy trail effect the perception and satisfaction of visitor. However, they perceive that the disturbance along trail causes the trails more challenging.	-Forest trekking is not a common activity for many visitors in Malaysia. Many cases where MBCA is their first experience. However, their background has high influence on their perception in general. -The findings indicated similar to past research where recreation impact is not a critical prominent factor in their perception. The visitor more concern toward the scenery of natural landscape and species uniqueness of flora and fauna.	Background of visitors is linked to their perceptions. First-time visitors have different perceptions and satisfaction levels, compared to experienced tourist guides.
Critically appraise literature related to conservation, tourism and recreational ecology (Objective 1)	To conduct this research, gathering of published literature must be done and analysed as follow: -Nature conservation - philosophy of natural area tourism (NAT) in general - Tourism and environment - Trends and prime objectives of natural area tourism	- Rio summit 1992 - Ecological impacts due to NAT.	-No baseline data on recreation impact in MBCA - - Many aspects of impact on ecology are less known	Relatively low number of research studies have previously been conducted in tropical rain forest

	- Natural attractions and features of natural area designated for tourism -An introduction to Recreation ecology - Recreational activities in natural area tourism destinations - Ecological impacts of recreational activities - Nature trails in Tropical Forest - Method or approach of Recreation Ecology Assessments - Ecological Impact Indicators - Effects of Trampling, Impacts on Vegetation, Wildlife and Soil - Visitor perceptions			
Develop appropriate methodologies for impacts assessment on fauna, flora, and soils (Objective 2)	- Recreation Ecology research begun in 1930s in UK, but active research only began in 1970s. - Many Rapid assessment methods has been developed that normally classified into 3: i. Reconnaissance approach ii. Sampling based approach. iii. Census based approach	Assessing recreation impact on ecology along trails in MBCA using modified methodology developed by Cole (1995).	-Pairing transect both side of the trail gives equal pairing measurement of ecological parameter	The development of the methodology derived from Cole's approach exhibits commendable progress unencumbered by any hindrances. This is primarily due to the effective establishment of plot arrangements along transects, which yields favourable outcomes for the assessment and computation of biodiversity.
Use and apply the developed methodologies to assess impact on fauna, flora and	From my research methodology, the chosen one used for assessing and monitoring the conditions of visitor-concentrated site particularly along trails and camp site.	The key data for disturbance impact on ecology: - Vegetation biodiversity and plant population	The Chosen Methodology to gather key findings on specific ecological parameter which is Vegetation, Soil and Wildlife.	The approach to quantify recreation impacts in MBCA using both ecological and human perception

soils (Objective 3)		- Soil compaction, Soil Moisture Content and Soil Organic matter content - Wildlife biodiversity, density, and frequency to encounter along trails.	- Other than that, the visitor perception is another method used in this study.	
Evaluate ecotourism impacts on fauna and flora on five trails in MBCA using selected parameters namely vegetation, wildlife, soil and light intensity. (RQ1, Objective 4)	- Trails is normally where disturbance is concentrated. - The recreation impact along trails determined by frequency and amount of use. -The visitor curiosity and behaviour also determine this impact. -Ecological parameters for physical impact indicator are vegetation, soil and wildlife. - The light intensity is the extra parameter. -Visitor disturbance along trail mainly occurred within 5m from the trail.	- Selected five trails in MBCA has been categorised to high, medium, and low use trails based on visitor frequency and amount of use for clear comparison. - Ecological parameter assessment along trails using Systematic plot sampling and placed in 3 different zone which are heavy disturbed, disturbed, and undisturbed. - finding comparison using ecological parameters indicated that trails with different amount of use show significant different in recreation impact. - Finding: ecological parameters assessment in difference plot zone shows different particularly in heavy disturbed, while disturbed and undisturbed plot zone sometimes show no different of rec. impact. -Light intensity influence the growth of new seedling in forest gap. This will inverse the disturbance impact to vegetation	- Past research stated that intensive trail-use considered the most prominent causes for recreation impact. - The finding was similar to this literature where the	There is an indication that an increase in the number of visitors to MBCA is a threat. However, to date, the rate of use remains within a manageable limit. For many managers, wildlife impact is not regarded as such a high priority compared to poaching and squatters.

8.4 SIGNIFICANCE OF THE RESEARCH AND CONTRIBUTION TO KNOWLEDGE

This research has contributed to the field of recreation ecology particularly in tropical rain forest both theoretical and practice. Several paper outputs have been released and presented in various seminar and conference as shown in the appendix 19.

This research has clearly addressed the research questions and problems related to recreational ecology in tropical rainforests. This study found that the methodology used in temperate forests works well in the tropics with some modifications to suit local conditions and requirements.

The increasing popularity of outdoor recreation has shot up the amount of use in the natural environment. This leads to the problem of recreational ecological impacts especially plant and soil damage as well as disturbance to wildlife. Due to the increasing number of visitors, recreationist protected areas like MBCA pose a real and significant threat to the resources they value so much. This is especially true at inland attraction sites, campsites and along trails, where tours and impacts are concentrated.

Based on literature and current practice in the tropical forest, there were less emphasize and priority on visitor impacts by the managers compared to other management concerns such as poaching and squatters. Most of the research in tropical forest including MBCA focused on resources, flora, fauna, geology, and landscape ecology. Thus, this study in this field has been conducted to fulfil the research gap from a basic baseline. Many aspects in this gap of specific impacts

of recreational activities on ecology can be addressed for example how recreation influences the ecology especially in relation to vegetation and soil, with different slopes, elevations, topography, and contours.

The basic current relevant theories in recreation ecology impact are that the disturbance impact will eliminate many vegetations species and subsequently it will lower the plant biodiversity index on affected area. The theory is very well suited to the finding on soil impacts, however, it a bit contrast when deal with plants, where some findings indicated that biodiversity of vegetation is much higher in disturbed areas due to the forest gap or forest openings that allow penetration of sun light.

The significance of this study is discussed from two perspectives: (1) practical contributions for the management of recreation resources in Malaysia's protected areas and national park, and (2) its contribution to the body of knowledge about recreation ecology in tropical environment. The main output of this research is the identification and development of the physical impact approaches of recreation impact for tropical rainforest areas, with specific reference to MBCA.

The development of a methodology for studying recreation impact that suits tropical environments will enhance the management of recreational resources. Additionally, this study has produced a baseline guideline and standard for the measurement of recreation and tourism impacts in protected areas. This is very important especially to the agencies that are directly involved in managing the national park and protected areas such as The Forestry Department and Sabah Park, Malaysia. The findings will

assist the MBCA to set up guidelines, which may for example be used to limit recreation resource usage at the areas and to determine carrying capacity of the recreation resource along the trail in future.

8.5 LIMITATIONS OF THE RESEARCH

In appraising the findings of this study, it is important to interpret the results in the light of the following limitations.

8.5.1 Data Collection limitation

When performing data collection, each plant or vegetation counted in the plot needs to be identified down to the species level. Identifying tropical plant species is not an easy task. Researchers are not fully trained as plant botanists and are only able to identify some of the plants in the field. In that case, it will be quite difficult because plant samples have to be taken from the field and have to be taken to the herbarium for identification purposes.

8.5.2 Lack of access to research equipment's and facilities

The study area is located far from the laboratory facilities, which is about 6 hours away while the soil sample must be processed in the laboratory quickly. This causes researchers to have to commute frequently to carry out laboratory work. Moreover, the soil compactor meter equipment is only one, and this slows down a bit the field data acquisition work.

8.5.3 Time limitation

Time constraints were experienced while gathering data in the field and also questionnaire for the respondents. Local rain in the interior forest area always delays the time for data measurement. Overall, the length of the study greatly exceeded its original intended duration. The research design was crystallised in 2013. Research with the same aims and objectives today would acknowledge recent developments, such as the policies of local authorities promoting the establishment of protected areas for nature tourism and the Sustainable Development Goal of Tourism in the 2030 Agenda by the United Nations World Tourism Organisation (UNWTO), which aims to enhance nature tourism. The COVID-19 pandemic had a significant impact on the tourism industry, but it also led to the recovery of ecologically affected areas. These developments will reflex and be indicative of the forthcoming research design.

8.5.4 Financial limitation

Financial resources for both the PhD and fieldwork were limited. A better and bigger fund would have enabled a more conducive environment to carry out the field and PhD work.

8.6 RECOMMENDATIONS FOR FURTHER RESEARCH

This study is a first step in measuring recreation ecology impact in MBCA tropical rain forest. Using the results of this study, the findings should be able to facilitate further research such as follow:

a. Data collection repeated yearly

Since the recreation impact should be carried out as long-term monitoring research, data collection should be repeated on the similar plot every year. This will allow the trend of impact over time with amount of use.

b. Includes more ecological parameter for impact measurement

Ecological element basically consists of vegetation, soil, wildlife, and water. It is good in further study to include more of these parameters under those elements for more holistic finding on ecological impact.

8.7 CONCLUDING REMARKS

The researcher encourages the practical application of the impact monitoring method that have been developed in this thesis. It is envisaged that the work from this thesis can be used not only in assessing the physical measurement of recreation impact on ecology but also the human perceptions toward the activity and disturbance. Furthermore, it is important to acknowledge that the visitor motivation, participation, and satisfaction in nature-tourism sites influence the respondent perceptions on ecological impact in specific sites.

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Appendix 1.0: Application letter for Research Site in Maliau Basin Conservation Area (MBCA)

Wilter Azwal Malandi
Unit 9, Science Park
University of Sheffield Hallam
S1 1WB
United Kingdom

Dr. Waidi Sinun
Group Manager
Conservation & Environmental Management Division
Yayasan Sabah Group
12th Floor, Menara Tun Mustapha
P.O Box 11623
88817 Kota Kinabalu
Sabah, MALAYSIA.

29 JAN 2009

Sir,

APPLICATION FOR PHD RESEARCH SITE AT MALIAU BASIN CONSERVATION AREA (MBCA)

The matter above is referred.

For your information, currently I am attached to University of Sheffield Hallam in United Kingdom for my PhD program under supervision by **Dr Ian D. Rotherham**, and very interested to possess my PhD research site at MBCA due to relevancy of my field interest. For your further info of my research interest, the rough proposal of the research is as attachment.

Your Considerations for this matter is much appreciated.

Thank You



WILTER AZWAL BIN MALANDI

Appendix 2.0: Approval letter from Maliau Basin Conservation Area (MBCA) management

Y/S/MB/RC/2009/16
11th November, 2009

Mr. Wilter Azwal Ma'andi
Unit 9, Science park,
Sheffield Hallam University,
Sheffield S11WB,
England United Kingdom



Maliau Basin Management Committee
P.O. Box 1167
88017 Kuala Lumpur, Sabah, Malaysia
Phone: (088) 4413012 ext. 111
Fax: (088) 242246-4306111

Dear Sir,

Application to Do Research in Maliau Basin Conservation Area

We refer to your application to conduct research in Maliau Basin Conservation Area entitled **"Assessing Ecological Impacts of Recreation Use of Trails in Protected Area"**, beginning 2010.

On behalf of the Maliau Basin Management Committee (MBMC), we have no objection to your research application and welcome you to Maliau Basin, and we take this opportunity to remind you of the following terms and conditions in relation to your research, whereby you are:

- 1) To report to Maliau Basin Management Committee Secretary before proceeding to Maliau Basin Studies Centre.
- 2) To report to Manager MBCA upon your arrival in Maliau Basin Studies Centre.
- 3) To comply with the research guideline and procedures, especially those related to appointment of Research Assistants, collection and distribution of specimen and submission of research progress reports.
- 4) To pay all costs incurred during your stay at Maliau Basin Studies Centre.
- 5) To submit final thesis/research report.
- 6) To obtain approval from MBMC before submitting manuscripts for publication and submit to us copy of any publication arising out from your research.

I thank you.

Yours sincerely,

DR. WAIDI SINUN
Secretary
Maliau Basin Management Committee

c.c. - Chairman, MBMC

Manager, MBCA.... *Please ensure procedures/guidelines to do research in MBCA are comply with, and all payments are in order*

Appendix 3.0: Maliau Basin Conservation Area (MBCA) research proposal form.

Secretary
Maliau Basin Management Committee
P.O. Box 11622
88817 Kota Kinabalu
Sabah, Malaysia



MBRP PROJECT REF. NO.
(For official use only)

MALIAU BASIN RAINFOREST RESEARCH AND TRAINING PROGRAMME RESEARCH PROPOSAL FORM

1. APPLICANT

- 1.1 Name of Principal Investigator(s): WILTER AZWAL B. MALANDI
- 1.2 Position: STUDENT
- 1.3 Name of Institution: SHEFFIELD HALLAM UNIVERSITY
- 1.4 Address: UNIT 9, SCIENCE PARK, SHEFFIELD HALLAM UNIVERSITY, SHEFFIELD S1 1WB, ENGLAND UNITED KINGDOM.

2. MALAYSIAN COLLABORATOR

- 2.1 Name of Malaysian Collaborator(s): HAMZAH TANGKI
- 2.2 Position: PROJECT MANAGER
- 2.3 Name of Institution: INOPRISE, YAYASAN SABAH
- 2.4 Address: MBCA, INNOPRISE, YAYASN SABAH

3. OVERSEAS COLLABORATOR

- 3.1 Name of Overseas Collaborator(s): DR IAN D. ROTHERHAM.
- 3.2 Position: READER AND DIRECTOR OF THE TOURISM AND ENVIRONMENTAL
CHANGE RESEARCH UNIT
- 3.3 Name of Institution: SHEFFIELD HALLAM UNIVERSITY
- 3.4 Address: FACULTY OF DEVELOPMENT AND SOCIETY, SHEFFIELD HALLAM
UNIVERSITY, CITY CAMPUS, S1 1WB, UNITED KINGDOM

4. RESEARCH PROJECT

- 4.1 What is the title of your research project?
"Assessing ecological impacts of recreation use of trails in protected area"
- 4.2 Are you a candidate for a degree (please specify)?
- YES; (PhD)
- 4.3 When do you propose to commence your research in Maliau Basin?
- Year 2010
- 4.4 What is the proposed duration of your research in Maliau Basin?
3 years
- 4.5 Give a brief statement of your research project with regard to the followings:

Appendix 3.0 (Cont.): Maliau Basin Conservation Area (MBCA) research proposal form.

a) Objectives and scope

The overall aim(s) of this study is to provide a *robust insight* into the impacts of recreational disturbance along tourism trail in tropical forests. The objectives of the research will be to:

1. Gather and critically analysis published literature
2. Develop appropriate methodologies to assess impacts on fauna, flora and soils.
3. Apply the chosen methodologies to gather key data
4. Evaluate impacts on fauna and flora important in ecotourism and wildlife tourism visitors
5. Assess perception and attitudes by visitor, managers and trail guides.

b) Research design

The study is designed to measure the effect of recreational use of trail to the ecology in the forest. Among the factors to be considered are disturbance to the vegetation particularly trampling, Soil compaction and erosion, regeneration rate of vegetation, the durability of the vegetation to the trampling effect and light influence to the recreational effects. The targets of potentially affected by recreation activities are the ecological communities, plant species and structure and soil structure. The detailed field methodology is in the proposal. It is also intended to undertake an interview and questionnaires survey of visitor and manager perceptions.

c) General techniques to be used

Generally the site-study will be sub-divided into five distinct phases, each designed need to investigate a specific, yet related, aspect of the impact of recreation use of trails on the forest ecology. These Phases are:

A. An initial study and familiarization plus transect setting.

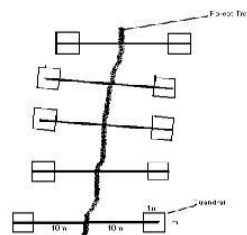


Figure: Plots and quadrates along the trail.
(NTS)

B. Preliminary assessment of the impact of the main trail through the forest

In this case, the Shannon-Weiner biodiversity index ($H' = -\sum p_i \ln p_i$) and Margalef abundance index ($D_{Mg} = (S-1)/\ln N$) will be used to calculate the bio-diversity and abundance index of vegetation.

C. Comparison of different trails

Appendix 3.0 (Cont.): Maliau Basin Conservation Area (MBCA) research proposal form.

This stage is based on the observation in the initial study. Different trails will be examined for both physical and biological. The differences of trail are in terms of heavy visited and the abandoned trail.

D. Experimental trail for human trampling measurement

The experimental design for trampling treatments as shown in Figure 2 follows standard protocols described by Cole and Bayfield (1993a).

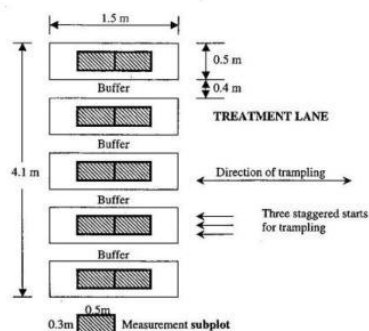


Figure 2: Layout of treatment lanes, buffers and measurement of subplot within treatment lanes (Cole and Bayfield, 1993a)

E. Rapid examination of the whole trail network

Assessment of the impact of the main trail through the forest will be initiated by measurements of the trail parameters, both physical and biological (e.g. soil compaction and erosion).

d) Overall budget

- No specific budget allocation or funding for this research as this a PhD study and given only study allowance

5. RESEARCH FUNDING/BUDGET

5.1 What agency is supporting you and your research in Maliau Basin? (Please attach Letter of Financial Support from your agency)

- MINISTRY OF HIGER EDUCATION

5.2 What form of contribution do you have for your collaborator(s), or do you have a budget allocation for funding your local collaborator(s) for your research work at Maliau Basin?

- Paper and publication

5.3 How much additional budget allocation do you have for funding a local counterpart for post-graduate study at a local or foreign university? (Applicable to researchers who are doing a Ph.D or post-doctoral degree)

(Ringgit Malaysia)..... - NONE.....

Appendix 3.0 (Cont.): Maliau Basin Conservation Area (MBCA) research proposal form.

5.4 Will your research result in a thesis, dissertation, report and publication?

- THESIS

5.5 What are the implications of your research for the followings?

a) Sustainable management of Malaysian forests

Forest is part of the environment in which tourism and recreation take place. Yet recreation activities in forest are not usually considered on their own but as part of outdoor recreation, because few visitors go to observe the forest itself but to carry out recreational activities in it. In Malaysian context, the forest has been divided into several categories to implement the concept of Sustainable Forest Management. Thus the protected area like MBCA is one of the above mention strategy.

Many researcher believe that eco-tourism and recreation is a strategic tool to implement the sustainable management of a forest area. However, must bear in mind that recreation if unchecked, also cause massive destruction to the forest area in form of soil compaction, vegetation destruction, wildlife harassment and so on particularly along the forest recreation trail. Thus this research will try to find out the significant impact of the recreation activities in the forest as well as the perception of the managers and visitors to the area.

Ultimately and hopefully the finding of this research will give some basic references to the forest manager to implement the concept of sustainable forest management (SFM) in a protected area, specifically on the visitation impact, Recreation Carrying capacity, and so on.

b) Improved awareness of environmental conservation in Malaysia

Recent research suggests that ecotourism and recreation can both promote and maintain protected areas and environmental conservation. ***This is*** especially where owners or managers have a vested interest in environmental conservation due to their capital investment (Wesche, 1993). Despite **some truth in** the statement a certain degree of disturbance and impact still occurred along the way. ***This was*** especially in natural areas with high usage by people, however, the impact might be minimized by not only a good management but also by increasing the awareness of conservation by both visitor and manager.

Some expected finding in this research such as trampling, soil compaction, and others will be able to find out the environmental impact of the recreation activities in such area. The questionnaire will be distribute to managers and visitor to gain their perception toward the recreation and conservation of the area.

At the end of this study, several simple recommendation of the fact of visitation in protected area will be produce mainly for public awareness purposes.

c) Technology or skills transfer

Conservation in developed Countries has been started much more earlier than in undeveloped and developing countries. The standard and public awarness is very significant in such country. Many research and study on recreation as well as the conservation has been carried out with many method had been developed. These research method mainly visitor impact assessment method was proven working in temperate environment but not yet in rain forest, thus, it's a venue to transfer the skill and knowledge to this country.

Appendix 3.0 (Cont.): Maliau Basin Conservation Area (MBCA) research proposal form.

5.6 What assistance will you need from MBMC other than the approval?

Require several assistances particularly during my stay in MBCA for research setting dan data collection. Generally that's in terms of basic daily requirements, Computer for data entry, analysis or internet and also a lab for sample collection.

APPLICANT SHOULD NOTE THAT AFTER ARRIVAL IN MALAYSIA, NO CHANGE OF RESEARCH PROPOSAL/PROJECT CAN BE MADE WITHOUT PRIOR APPROVAL OF THE MALIAU BASIN MANAGEMENT COMMITTEE (MBMC) AND THE ECONOMIC PLANNING UNIT OF THE PRIME MINISTER'S DEPARTMENT IN PUTRAJAYA

- I have read the "Procedures and Guidelines for Conducting Research in MBCA" and agree to abide by the guidelines given, including the stipulation not to submit a manuscript for publication without the approval of the Maliau Basin Management Committee.
- I also accept that I shall be living at the Maliau Basin Studies Centre entirely at my own risk, and neither the Maliau Basin Management Committee nor Yayasan Sabah shall be held responsible for any accident, thief or other misfortune suffered.
- I hereby agree to submit at no cost to the Maliau Basin Management Committee the followings:
 - ♦ 7 (seven) hardcopies and 1 (one) in digital form (*Microsoft word format or Acrobat pdf format Version 7*) of summary of research findings before leaving Sabah;
 - ♦ 2 (two) copies of thesis/dissertation;
 - ♦ 7 (seven) copies of reports and publications based on the research finding.

SIGNED:



Principal Investigator

27 OCT 2009

Date



Appendix 4.0: Likert style and open ended Questionnaire on visitors and tour guide perception



Sheffield Hallam University

Dear respondents,

I am a Postgraduate student in Faculty of Development and Society, Sheffield Hallam University, Sheffield United Kingdom; I am presently conducting a research entitled "Ecological impact of recreation use of trails in a protected area".

I would be very grateful if you could offer a moment of your time to complete the attached questionnaires. The overall aim of this study is to provide a robust insight into the impact of recreational disturbance along tourism trail in Maliau Basin Conservation Area (MBCA).

Your participation and cooperation in providing the relevant information's are vital to make this research study possible. You are rest assured that all information given will be tested with strict confidentiality. Your feedback is highly appreciated.

Thank You,

Wilter Azwal Malandi

SECTION A - RESPONDENT PROFILE

1. Gender

a. Male

b. Female

☐
☐

2. Nationality

Malaysian

Non-Malaysian (Please specify):

☐
☐

3. Marital status

a. Single

b. Married

c. Partner

d. Divorced

☐
☐
☐
☐

4. Age

a. 10 – 20 years old

b. 21 – 30 Years old

c. 31 – 40 Years old

d. 41 – 50 years old

e. 51 – 60 years old

f. Above 60 years old

☐
☐
☐
☐
☐
☐

5. Education

a. Primary School

b. Lower Secondary School

c. Higher Secondary School

d. Diploma

e. Bachelor degree

f. Master degree

g. Doctorate degree

h. Other: _____

☐
☐
☐
☐
☐
☐
☐

6. Yearly income (US Dollar)

a. Less than 10,000

b. 10,000 – 19,999

c. 20,000 – 29,999

d. 30,000 – 39,999

e. 40,000 – 49,999

f. 50,000 – 59,999

g. More than 60,000

h. Other

☐
☐
☐
☐
☐
☐
☐
☐

7. Occupations

a. Unemployed

b. Self-employed

c. House wife/husband

d. Professional (doctor, engineer, lawyer etc)

e. Other professional (teacher, technician, etc)

☐
☐
☐
☐
☐

f. Student

g. Retired

h. Tour guide

i. Social worker

j. Other: _____

☐
☐
☐
☐
☐

Appendix 4.0 (Cont.): Likert style and open ended Questionnaire on visitors and tour guide perception

SECTION B - THE VISIT AND SOURCE OF INFORMATION

Yes No

1. Have you been here before?

2. If you answer 'Yes' above, then how often you come here?

a. less than once a year	
b. once a year	
c. 2 - 4 times a year	
d. More than 4 times a year	

3. How long you will stay here?

a. day visit	
b. 1 night	
c. 2 - 4 night	
d. 5 - 7 night	
e. 8 - 14 night	
f. more than 15 night	

4. What influenced you to come and visit MBCA?

	Yes
a. Previous experience	
b. Recommendation (Friends, family, etc)	
c. Exploring somewhere new	
d. I just passing through or on the way to...	
e. Other:	

5. How did you find out about the MBCA as a place to visit?

a. Internet via search engine	
b. Internet via website you already know	
c. Newspaper/magazine	
d. TV or radio	
e. Tourist information centre	
f. Other (Please specify):	

SECTION C: MOTIVATION AND ANTICIPATION

1. What aspects were important to you in deciding to visit MBCA?

a. Scenery / landscape	
b. Tranquillity/peace & quiet	
c. Wildlife	
d. Plenty to see and do	
e. Outdoor (e.g., hiking, climbing, Photographing, camping, etc)	
f. Areas of Outstanding Natural Beauty	
g. Other, please specify:	

2. What activities you expect to undertake prior arrive in MBCA?

a. Short walk (under 2 hours)	
b. Long walk (over 2 hours)	
c. Night Walking	
d. Swimming	
e. Wildlife watching	
f. Sightseeing by car	
g. Educational activity (Zoology, botany, etc)	
h. Relaxing (doing nothing)	
i. Other, please specify:	

Appendix 4.0 (Cont.): Likert style and open ended Questionnaire on visitors and tour guide perception

SECTION D: HIKING AND PARTICIPATION

1.	How many people in your hiking group on a trail?	
	a. 1 person	
	b. 2 – 5 persons	
	c. 6 – 10 persons	
	d. 11 – 15 persons	
	e. 16 – 20 persons	
	f. More than 20 persons	

2.	Attractions along nature trail during hiking	Strongly agree	Agree	Not Agree	Strongly not agree
	a. Able to see many wildlife species along the trail				
	b. Natural landscape view along the trail was fantastic				
	c. The trail alignment itself was very attractive				
	d. Flora at the trail side was attractive				
	e. Many unique species along the trail				
	f. Other, please specify:				

3.	What activities have you done along nature trail	Strongly agree	Agree	Not Agree	Strongly not agree
	a. Nothing, just walking through				
	b. Photographing				
	c. Watching wildlife such as bird, mammal, etc				
	d. Studying and experience the flora				
	e. Hearing Nature Sound				
	F. Other, please specify:				

		yes	No
4.	During hiking along trail, do you stop at attractive spot?		

5.	If your answer is yes, what sort of activities you conducted on that sport?	
	a. Stay and just observe it for a while but not more than 5 minute	
	b. Stay and just observe it for a while but not more than 10 minute	
	c. Find a good spot of photographing	
	d. Find way off to the forest from the trail to find more as far as 5m away	
	e. Find way off to the forest from the trail to find more as far as 10m away	
	f. Other, please specify:	

SECTION E: RESPONDENT SATISFACTION

3.	What your opinion on current condition of Nature Trail in MBCA	Strongly agree	Agree	Not Agree	Strongly not agree
	a. Challenging trail				
	b. Not Well maintained				
	c. Steep and sloppy				
	d. Uneven surface				
	e. the trail was scary and dangerous				
	f. Other, please specify				

Appendix 4.0 (Cont.): Likert style and open ended Questionnaire on visitors and tour guide perception

	yes	No
1. Did you enjoy the Nature trail hiking?		

2. What elements you found along the trail that you enjoy most?	
a. Big old diversified Tree species	
b. Shrub and palm's	
c. Lower plant, fungi,	
d. Flowering Plant	
e. mammal	
f. bird	
g. insect	
h. Amphibian	
i. Reptile	
j. Micro-organism	
k. Rare wildlife	
l. Rare flora	
m. Geology, Land form, Mountain, etc	
n. Hydrology and waterfall	
o. Medicinal plants	
p. Other please specify	

SECTION E: RESPONDENT PERCEPTION, RATING AND PREFERENCES

1. Preferred length of nature walk	
a. 2 – 3 hour walk	
b. 4 – 6 hour walk	
c. 7 – 9 hour walk	
d. All day walk	
e. 2 – 3 days walk	
f. Longer than 2/3 days	

2. Where should nature trail being establish	Strongly agree	Agree	Not Agree	Strongly not agree
a. Always on the top of the ridge to avoid muddy trail				
b. Should be built on the sloppy area for better irrigation				
c. Should be built on flat area for better accessibility				
d. Should be built on area near river				
e. Should be built on rich of flora and fauna area				

3. Nature trail specification (visitor Suggestion)	Strongly agree	Agree	Not Agree	Strongly not agree
a. Trail must be well established, concreted as possible				
b. Trail width must accommodate more than 1 person in one row				
c. Trail must be less than 15% slope in average				
d. Increase number of bridges along the trail to avoid soil compaction				
e. Other, Please specify:				

4. Visitor rating on tour guide knowledge	Strongly agree	Agree	Not Agree	Strongly not agree
a. Knowledgeable on Flora and vegetation				
b. Knowledgeable on Wildlife				
c. Knowledgeable on Hydrology				
d. Knowledgeable on Soil				
e. Knowledgeable on Micro-organism				
f. Knowledgeable on Natural environment in general				
g. Knowledgeable on Local culture relation to environment				
h. Knowledgeable on local history				

THANK YOU FOR YOUR COOPERATION.

Appendix 5.0: Application letter to distribute questionnaires in Maliau Basin Conservation Area (MBCA)

Wilter Azwal Malandi

School of International Tropical Forestry
Universiti Malaysia Sabah



Mr. Hamzah Tangki

Manager
Maliau Basin Conservation Area (MBCA)
Conservation & Environmental Management Division
Yayasan Sabah Group
12th Floor, Menara Tun Mustapha
P.O Box 11623
88817 Kota Kinabalu
Sabah, MALAYSIA.

23 SEPTEMBER 2010

Dear Sir,

APPLICATION FOR APROVAL TO DISTRIBUTE QUESTIONNAIRES IN MALIAU BASIN CONSERVATION CENTRE (MBCA)

Kindly refer to the matter above.

For you information, that visitor is an important part of my research and is intended to gather their perception toward their visit in MBCA. This part is very important in correlation to recreation and impact study on ground that currently I am doing.

Your Considerations for this matter is very appreciated.

Thank You

WILTER AZWAL MALANDI
Researcher

Appendix 6.0: List of plant species surveyed on plots area along all five (5) trails in Maliau Basin Conservation Area (MBCA)

Species	vernacular name	Family
<i>Agathis sp.</i>	Agathis	Araucariaceae
<i>Aglaia sp</i>	lotupak	Meliaceae
<i>Agrostistachys sp.</i>	Kayu garang	Euphorbiaceae
<i>Alangium javanicum</i>	Kendolon	Alangiaceae
<i>Alstonia spatulata</i>	Pulai	Apocynaceae
<i>Amydrium medium</i>	Lianas	Araceae
<i>Aporusa grandistipula</i>	Galang-galang	Euphorbiaceae
<i>Aporussa elmeri</i>	panatan	Euphorbiaceae
<i>Ardisia elliptica</i>	mata pelanduk	Myrsinaceae
<i>Artabotry sp.</i>	Lianas	Annonaceae
<i>Artocarpus anisphyllus</i>	Terap ikal	Moraceae
<i>Artocarpus integer</i>	Pulutan/Cempedak	Moraceae
<i>Artocarpus sp.</i>	Terap	Moraceae
<i>Baccauria macrocarpa</i>	Tampoi merah	Euphorbiaceae
<i>Baccurea angulata</i>	Belimbing hutan	Euphorbiaceae
<i>Baccurea latifolia</i>	Tampoi kuning	Euphorbiaceae
<i>Baccurea paviflora</i>	kunau-kunau	Euphorbiaceae
<i>Bambusa sp</i>	bambu	Graminae
<i>Barringtonia macrostachya</i>	Tampalang	Lecythidaceae
<i>Bauhinia sp</i>	Lianas	Fabaceae
<i>Blumeodendron tokbrai</i>	Gangulang	Euphorbiaceae
<i>Caladium sp</i>	keladi	Araceae
<i>Calamus sp.</i>	rattan	Acoraceae
<i>Callicarpa sp.</i>	Lianas	Verbenaceae
<i>Calophyllum obliquinerium</i>	Bintangor	Guttiferae
<i>Canarium sp.</i>	kedondong	Burseraceae
<i>Castanopsis motlenyana</i>	Berangan	Fagaceae
<i>Combretum nigrescens</i>	Lianas	Annonaceae
<i>Curculigo sp.</i>	Curculigo	Hypoxidaceae
<i>Davallia sp.</i>	fern	Davalliaceae
<i>Decaspermum fruticosum</i>	Obah merah	Myrtaceae
<i>Dehasia sp</i>	medang	Lauraceae
<i>Dialium indum</i>	keranji	Leguminosae
<i>Dillenia borneensis</i>	Simpoh gajah	Dilleniaceae
<i>Dillenia excelsa</i>	Simpoh laki	Dilleniaceae
<i>Diospyros sp</i>	kayu malam	Ebenaceae
<i>Dryobalanops lanceolata</i>	kapur paji	Dipterocarpaceae
<i>Dryobalanops sp.</i>	kapur	Dipterocarpaceae

<i>Drypetes longifolia</i>	Odapon putih	Euphorbiaceae
<i>Durio graveolens</i>	Durian merah	Bombacaceae
<i>Durio zibethinus</i>	Durian	Bombacaceae
<i>Elaeocarpus sp.</i>	Kungkurad	Elaeocarpaceae
<i>Elisian laciniata</i>	Elisia	Solanaceae
<i>Elmerrillia mollis</i>	Cempaka bulu	Magnoliaceae
<i>Erycibe sp</i>	Lianas	Convolvulaceae
<i>Eugenia sp.</i>	Oba	Myrtaceae
<i>Eurycoma longifolia</i>	tongkat ali	Simaroubaceae
<i>Eusideraxylon zawageri</i>	belian	Lauraceae
<i>Ficus deltoidea</i>	Sempit-sempit	Moraceae
<i>Ficus sp</i>	ara	Moraceae
<i>Friesodielsia sp.</i>	Lianas	Annonaceae
<i>Fungi</i>	Kulat	Lycoperdaceae
<i>Ganua sp.</i>	Nyatoh	Sapotaceae
<i>Garcinia parvifolia</i>	Kandis	Guttiferae
<i>Gironniera narvosa</i>	Impas tebu	Ulmaceae
<i>Gnetum sp.</i>	Lianas	Gnetaceae
<i>Goniothalamus sp.</i>	Pisang-pisang	Annonanceae
<i>Heritiera borneensis</i>	mengkulang	Malvaceae
<i>Hopea ferruginea</i>	Selangan mata kucing	Dipterocarpaceae
<i>Hydnocarpus borneonsis</i>	Karpus tulang sai	Flacourtiaceae
<i>Ixora grandiflora</i>	Kiam	rubiceae
<i>Knema oblongifolia</i>	darah-darah	Myristicaceae
<i>Koompassia excelsa</i>	Mangaris	Leguminosae
<i>Koompassia malaccensis</i>	Kempas	Caesalpiniaceae
<i>Labisia pumila</i>	Kacip fatimah	Myrsinaceae
<i>Lansium domesticum</i>	Langsat	Meliaceae
<i>Leea indica</i>	Mali-mali	Leeaceae
<i>Lithocarpus sp</i>	mempening	Fagaceae
<i>Luvunga minutiflora tone</i>	Lianas	Rutaceae
<i>Mallotus penangensis</i>	molatus kemanyan	Euphorbiaceae
<i>Mallotus stipularis</i>	Molatus	Euphorbiaceae
<i>Mangifera pajang</i>	Bambangan	Anacardiaceae
<i>Mangifera sp.</i>	Mangga	Anacardiaceae
<i>Melastoma sp.</i>	Senduduk	Melastomataceae
<i>Mezzetia sp.</i>	Karai	Annonaceae
<i>Milletia sp.</i>	Taroi-taroi	Leguminosae
<i>Moultonianthus leembruggianus</i>	telinga-telinga	Euphorbiaceae
<i>Neonauciea bernardoi</i>	Bangkal merah	Rubiaceae
<i>Nephelium mutabile</i>	Meritam	Sapindaceae
<i>Nephelium sp.</i>	Rambutan	Sapindaceae
<i>Orchid</i>	Orkid	orchidaceae
<i>Palm</i>	Palma	Palmaceae

<i>Pandanus sp.</i>	pandan	Pandanaceae
<i>Parashorea macrophylla</i>	urat mata	Dipterocarpaceae
<i>Parashorea tomentella</i>	urat mata beludu	Dipterocarpaceae
<i>Paspalum conjugatum</i>	Grass	Poaceae
<i>Peantace adenophora</i>	Takalis daun bulat	Tiliaceae
<i>Peantace laxiflora</i>	Takalis daun halus	Tiliaceae
<i>Phytocrene anomala Merrill</i>	Lianas	Icacinceae
<i>Piper sarmentosum</i>	Sireh-sireh	Piperaceae
<i>Pleocarpidia sp.</i>	Buluh-buluh	Rubiaceae
<i>Podocarpus rumphii</i>	Kayu cina	Podocarpaceae
<i>polyalthia sp.</i>	mempisang	Annonaceae
<i>Polyalthia sumatrana</i>	karai putih	Annonaceae
<i>Popowia pisocarpa</i>	Binitan	Annonaceae
<i>Psychotria sp.</i>	Kopi	Rubiaceae
<i>Pternandra coerulescens</i>	Sireh-sireh	Melastomaceae
<i>Pterospermum javanicum</i>	bayur	Sterculiaceae
<i>Rubus sp</i>	rumpot duri	Rosaceae
<i>Sarcostigma sp.</i>	Lianas	Icacinceae
<i>Sarcotheca direvsifolia</i>	Tabarus	Oxalidaceae
<i>Scaphium macropodum</i>	kembang semangkuk	Sterculiaceae
<i>Selaginella sp.</i>	Lumut	selaginellaceae
<i>Shorea acuminata</i>	seraya kuning	Dipterocarpaceae
<i>Shorea argentifolia</i>	seraya daun mas	Dipterocarpaceae
<i>Shorea assamica</i>	Melapi bunga	Dipterocarpaceae
<i>Shorea fallax</i>	Seraya daun kasar	Dipterocarpaceae
<i>Shorea gibbosa</i>	Seraya kuning gajah	Dipterocarpaceae
<i>Shorea glauca</i>	Selangan batu	Dipterocarpaceae
<i>Shorea hopeifolia</i>	Seraya kuning jantan	Dipterocarpaceae
<i>Shorea johorensis</i>	Seraya majau	Dipterocarpaceae
<i>Shorea kunstleri</i>	Seraya sirap	Dipterocarpaceae
<i>Shorea leprosula</i>	seraya tembaga	Dipterocarpaceae
<i>Shorea ovalis</i>	seraya kepong	Dipterocarpaceae
<i>Shorea parvifolia</i>	Seraya punai	Dipterocarpaceae
<i>Shorea pounciflora</i>	Oba suluk	Dipterocarpaceae
<i>Shorea symingtonii</i>	Melapi kuning	Dipterocarpaceae
<i>Sindora beccarina</i>	sepetir	Fabaceae
<i>Spatholobus sp.</i>	Lianas	Fabaceae
<i>Syzygium sp.</i>	Obah	Myrtaceae
<i>Tetramerista glabra</i>	Tuyut	Tetrameristicaceae
<i>Tetracera indica</i>	palas	Dilleniaceae
<i>Trichomanes sp.</i>	Ferns	Hymenophyllaceae
<i>Trigonabalanus verticillata</i>	Mempening babi	Fagaceae
<i>Vatica dulitensis</i>	Resak bukit	Dipterocarpaceae
<i>Vatica heteroptera</i>	Resak	Dipterocarpaceae
<i>Veitchia sp.</i>	Palm	Areaceae/palmae

<i>Ventilago dichotoma</i> Merrill	Lianas	Ilacaceae
<i>Wild ginger</i>	Halia	Zingiberaceae
<i>Willughbeia</i> sp.	Lianas	Apocynaceae
<i>Zizyphus angustifolius</i>	Monsit	Rhamnaceae

Appendix 7.0: List of Wildlife surveyed along all five (5) selected trails in Maliau Basin Conservation Area (MBCA)

Nama Tempatan	Scientific Name	Category
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian
<i>Tree frog</i>	<i>Polypedates colletti</i>	Amphibian
<i>Lowland Litter Frog</i>	<i>Leptobrachium abbotti</i>	Amphibian
<i>Cricket Frog</i>	<i>Rana nicobariensis</i>	Amphibian
<i>Emerald dove</i>	<i>Chacophaps indica</i>	Birds
<i>Lesser coucal</i>	<i>Centropus bengalensis</i>	Birds
<i>owl</i>	<i>otus spilocephalus</i>	Birds
<i>Whiskered Treeswift</i>	<i>Hemiprocne comata</i>	Birds
<i>Woodpeckers</i>	<i>Sasia abnormis</i>	Birds
<i>Black white Bulbuls</i>	<i>Pycnonotus melanoleucos</i>	Birds
<i>Frogmouth sp.</i>	<i>Batrachostomus sp.</i>	Birds
<i>Brown Barbet</i>	<i>Calorhamphus fuliginosus</i>	Birds
<i>Common Kingfisher</i>	<i>Alcedo atthis</i>	Birds
<i>Red-crowned Barbet</i>	<i>Megalaima rafflesii</i>	Birds
<i>Nymphalid butterfly</i>	<i>Athyma larymna</i>	Butterfly
<i>Emperor moth</i>	<i>Antheraea helperi</i>	Butterfly
<i>Forest nymf butterflies</i>	<i>Idea sp.</i>	Butterfly
<i>Camponatus</i>	<i>Gigas sp</i>	Insects
<i>Darkling beetles</i>	<i>Setenis sp.</i>	Insects
<i>long-horned beetle</i>	<i>Anoplophora glabripennis</i>	Insects
<i>Stick insect</i>	<i>Caraucius chani</i>	Insects
<i>Song cicada</i>	<i>Tosena fasciata</i>	Insects
<i>Wildboar</i>	<i>Sus barbatus</i>	Mammals
<i>Giant squirrel</i>	<i>Ratufa affinis</i>	Mammals
<i>Palm Civet</i>	<i>Paradoxurus hermaphroditus</i>	Mammals
<i>White head's pygmy squirell</i>	<i>Exilisciurius whitehead</i>	Mammals
<i>Milipede</i>	<i>Eurymerodesmus spp</i>	Arthropods
<i>Brown spiny rat</i>	<i>Maxomys rajah</i>	Mammals
<i>Land snail</i>	<i>Everettia spp</i>	Molusca
<i>Monitor Lizard</i>	<i>Varanus spp</i>	Reptiles
<i>Flying lizard</i>	<i>Draco maximus</i>	Reptiles
<i>Aphan lizard</i>	<i>Aphaniotis sp.</i>	Reptiles
<i>lizard</i>	<i>Mabuya indepressa</i>	Reptiles
<i>Milipede</i>	<i>Eurymerodesmus spp</i>	Arthropods
<i>Mountain tree shrew</i>	<i>Tupaia montana</i>	Mammals
<i>Wildboar</i>	<i>Sus barbatus</i>	Mammals
<i>Nymphalid butterfly</i>	<i>Athyma larymna</i>	Butterfly
<i>Borneon mormon</i>	<i>Papilio acheron</i>	Butterfly
<i>Ashy Drongo</i>	<i>Dicrurus leucophaeus</i>	Birds
<i>Common Kingfisher</i>	<i>Alcedo atthis</i>	Birds
<i>Blue-eared Barbet</i>	<i>Megalaima australis</i>	Birds
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian

<i>Scally crowned babbler</i>	<i>Malacopteron cinereum</i>	Birds
<i>Common Kingfisher</i>	<i>Alcedo atthis</i>	Birds
<i>Woodpecker (Speckled Piculet)</i>	<i>Picumnus innominatus</i>	Birds
<i>Brown Barbet</i>	<i>Calorhamphus fuliginosus</i>	Birds
<i>Bee Eater</i>	<i>Nyctynornis amictus</i>	Birds
<i>Oriental Pied Hornbills</i>	<i>Anthracosceros albirostris</i>	Birds
<i>Finch's bulbul</i>	<i>criniger finschii</i>	Birds
<i>Borneon blue flycatcher</i>	<i>cyornis superbus</i>	Birds
<i>Borneon treepie</i>	<i>Dendrocitta cinerascens</i>	Birds
<i>Spiderhunter</i>	<i>Arachnothera crassirostris</i>	Birds
<i>Ashy Drongo</i>	<i>Dicrurus leucophaeus</i>	Birds
<i>owl</i>	<i>otus spilocephalus</i>	Birds
<i>Emperor moth</i>	<i>Antheraea helferi</i>	Butterfly
<i>Forest nymf butterflies</i>	<i>Idea sp.</i>	Butterfly
<i>Stick insect</i>	<i>Caraucius chani</i>	Insects
<i>Bush Cricket</i>	<i>Mecopoda sp.</i>	Insects
<i>Bush Cricket</i>	<i>Mecopoda sp.</i>	Insects
<i>Giant forest ant</i>	<i>Camponotus gigas</i>	Insects
<i>Darkling beetles</i>	<i>Setenis sp.</i>	Insects
<i>preying mantid</i>	<i>Deroplatys dessicata</i>	Insects
<i>Wildboar</i>	<i>Sus barbatus</i>	Mammals
<i>Red leaf monkeys</i>	<i>Presbytis rubicunda</i>	Mammals
<i>Pig-tailed macaque</i>	<i>Macaca nemestrina</i>	Mammals
<i>Palm Civet</i>	<i>Paradoxurus hermaphroditus</i>	Mammals
<i>Porcupine</i>	<i>Hystrix brachyura</i>	Mammals
<i>Giant squirrel</i>	<i>Ratufa affinis</i>	Mammals
<i>Pig-tailed macaque</i>	<i>Macaca nemestrina</i>	Mammals
<i>Pit-viper</i>	<i>Trmeresurus sumatranus</i>	Reptiles
<i>Flying lizard</i>	<i>Draco maximus</i>	Reptiles
<i>Turtoise</i>	<i>Dogania subplana</i>	Reptiles
<i>HemiFren lizard</i>	<i>Hemidactylus frenatus</i>	Reptiles
<i>lizard</i>	<i>Mabuya indepressa</i>	Reptiles
<i>Milipede</i>	<i>Eurymerodesmus spp</i>	Arthropods
<i>Land snail</i>	<i>Everettia spp</i>	Molusca
<i>Spiderhunter</i>	<i>Arachnothera crassirostris</i>	Birds
<i>long-horned beetle</i>	<i>Anoplophora glabripennis</i>	Insects
<i>Marbled cat</i>	<i>Pardofelis marmorata</i>	Mammals
<i>Red spiny rat</i>	<i>Maxomys surifer</i>	Mammals
<i>Borneon blue flycatcher</i>	<i>cyornis superbus</i>	Birds
<i>Stick insect</i>	<i>Caraucius chani</i>	Insects
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian
<i>White lipped frog</i>	<i>Rana chalconata</i>	Amphibian
<i>Common Kingfisher</i>	<i>Alcedo atthis</i>	Birds
<i>Pheasants</i>	<i>Arborophila hyperythra</i>	Birds
<i>Black crested bulbul</i>	<i>Pycnonotus melaicterus</i>	Birds
<i>Checker throated woodpecker</i>	<i>Meiglyptes tristis</i>	Birds

<i>Plain sunbird</i>	<i>Anthreptes simplex</i>	Birds
<i>Crimson winged woodpecker</i>	<i>Picus puniceus</i>	Birds
<i>Borneon blue flycatcher</i>	<i>cyornis superbus</i>	Birds
<i>Borneon treepie</i>	<i>Dendrocitta cinerascens</i>	Birds
<i>Sanpiper</i>	<i>Tringa hypoleucos</i>	Birds
<i>Orange albatross</i>	<i>Appias nero</i>	Butterfly
<i>Stick insect</i>	<i>Caraucius chani</i>	Insects
<i>Termites</i>	<i>Hospitalitermes</i>	Insects
<i>Giant forest ant</i>	<i>Camponotus gigas</i>	Insects
<i>long-horned beetle</i>	<i>Anoplophora glabripennis</i>	Insects
<i>Bush Cricket</i>	<i>Mecopoda sp.</i>	Insects
<i>Darkling beetles</i>	<i>Setenis sp.</i>	Insects
<i>Song cicada</i>	<i>Tosena fasciata</i>	Insects
<i>Barking deer</i>	<i>Muntiacus sp.</i>	Mammals
<i>Malay civet</i>	<i>Viverra zangara</i>	Mammals
<i>Giant squirrel</i>	<i>Ratufa affinis</i>	Mammals
<i>Red spiny rat</i>	<i>Maxomys surifer</i>	Mammals
<i>Porcupine</i>	<i>Hystrix brachyura</i>	Mammals
<i>Wildboar</i>	<i>Sus barbatus</i>	Mammals
<i>Spotted flying squirrel</i>	<i>Petaurista elegans</i>	Mammals
<i>Marbled cat</i>	<i>Pardofelis marmorata</i>	Mammals
<i>Red spiny rat</i>	<i>Maxomys surifer</i>	Mammals
<i>Pig-tailed macaque</i>	<i>Macaca nemestrina</i>	Mammals
<i>Flying lizard</i>	<i>Draco maximus</i>	Reptiles
<i>Monitor Lizard</i>	<i>Varanus spp</i>	Reptiles
<i>CyrtPub lizard</i>	<i>Cyrtodactylus pubisulcus</i>	Reptiles
<i>HemiFren lizard</i>	<i>Hemidactylus frenatus</i>	Reptiles
<i>preying mantid</i>	<i>Deroplatys dessicata</i>	Insects
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian
<i>Cross toad</i>	<i>Leptophryne borbonica</i>	Amphibian
<i>Lowland Litter Frog</i>	<i>Leptobrachium abbotti</i>	Amphibian
<i>Pig-tailed macaque</i>	<i>Macaca nemestrina</i>	Mammals
<i>Spectacled spiderhunter</i>	<i>Arachnothera flavigaster</i>	Birds
<i>Scally crowned babbler</i>	<i>Malacopteron cinereum</i>	Birds
<i>Black crested bulbul</i>	<i>Pycnonotus melaicterus</i>	Birds
<i>Plain sunbird</i>	<i>Anthreptes simplex</i>	Birds
<i>Stick insect</i>	<i>Caraucius chani</i>	Insects
<i>Song cicada</i>	<i>Tosena fasciata</i>	Insects
<i>Friiled Tree Frog</i>	<i>Rhacophorus appendiculatus</i>	Amphibian
<i>Poisonous Rock Frog</i>	<i>Rana hosii</i>	Amphibian
<i>Monitor Lizard</i>	<i>Varanus spp</i>	Reptiles
<i>Giant forest ant</i>	<i>Camponotus gigas</i>	Insects
<i>Woodpeckers</i>	<i>Sasia abnormis</i>	Birds
<i>Bee Eater</i>	<i>Nyctynornis amictus</i>	Birds
<i>Monitor Lizard</i>	<i>Varanus spp</i>	Reptiles
<i>Cross toad</i>	<i>Leptophryne borbonica</i>	Amphibian
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian

<i>Lowland Litter Frog</i>	<i>Leptobrachium abbotti</i>	Amphibian
<i>Plain sunbird</i>	<i>Anthreptes simplex</i>	Birds
<i>Common Kingfisher</i>	<i>Alcedo atthis</i>	Birds
<i>Bee Eater</i>	<i>Nyctynornis amictus</i>	Birds
<i>Asian paradise flycatcher</i>	<i>Terpsiphone paradisii</i>	Birds
<i>Long billed spiderhunters</i>	<i>Arachnothera robusta</i>	Birds
<i>Plain sunbird</i>	<i>Anthreptes simplex</i>	Birds
<i>Finch's bulbul</i>	<i>criniger finschii</i>	Birds
<i>Sanpiper</i>	<i>Tringa hypoleucos</i>	Birds
<i>Emperor moth</i>	<i>Antheraea helferi</i>	Butterfly
<i>Stick insect</i>	<i>Caraucius chani</i>	Insects
<i>long-horned beetle</i>	<i>Anoplophora glabripennis</i>	Insects
<i>Termites</i>	<i>Hospitalitermes</i>	Insects
<i>Giant forest ant</i>	<i>Camponotus gigas</i>	Insects
<i>Wildboar</i>	<i>Sus barbatus</i>	Mammals
<i>Pig-tailed macaque</i>	<i>Macaca nemestrina</i>	Mammals
<i>Porcupine</i>	<i>Hystrix brachyura</i>	Mammals
<i>Spotted flying squirrel</i>	<i>Petaurista elegans</i>	Mammals
<i>Marbled cat</i>	<i>Pardofelis marmorata</i>	Mammals
<i>Red spiny rat</i>	<i>Maxomys surifer</i>	Mammals
<i>Pig-tailed macaque</i>	<i>Macaca nemestrina</i>	Mammals
<i>Brown spiny rat</i>	<i>Maxomys rajah</i>	Mammals
<i>Red spiny rat</i>	<i>Maxomys surifer</i>	Mammals
<i>Slender-toed Gecko</i>	<i>Cyrtodactylus consobrinus</i>	Reptiles
<i>Flying lizard</i>	<i>Draco maximus</i>	Reptiles
<i>Aphan lizard</i>	<i>Aphaniotis sp.</i>	Reptiles
<i>HemiFren lizard</i>	<i>Hemidactylus frenatus</i>	Reptiles
<i>Scally crowned babbler</i>	<i>Malacopteron cinereum</i>	Birds
<i>Black white Bulbuls</i>	<i>Pycnonotus melanoleucos</i>	Birds
<i>Emperor moth</i>	<i>Antheraea helferi</i>	Butterfly
<i>preying mantid</i>	<i>Deroplatys dessicata</i>	Insects
<i>Porcupine</i>	<i>Hystrix brachyura</i>	Mammals
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian
<i>Bush Cricket</i>	<i>Mecopoda sp.</i>	Insects
<i>Song cicada</i>	<i>Tosena fasciata</i>	Insects
<i>Flying lizard</i>	<i>Draco maximus</i>	Reptiles
<i>Finch's bulbul</i>	<i>criniger finschii</i>	Birds
<i>Sanpiper</i>	<i>Tringa hypoleucos</i>	Birds
<i>White crowned hornbill</i>	<i>Berenicornis comatus</i>	Birds
<i>Black crested bulbul</i>	<i>Pycnonotus melaicterus</i>	Birds
<i>Red spiny rat</i>	<i>Maxomys surifer</i>	Mammals
<i>Palm Civet</i>	<i>Paradoxurus hermaphroditus</i>	Mammals
<i>Pig-tailed macaque</i>	<i>Macaca nemestrina</i>	Mammals
<i>Lowland Litter Frog</i>	<i>Leptobrachium abbotti</i>	Amphibian
<i>Low squirrel</i>	<i>Sundasciurus arestes</i>	Mammals
<i>Song cicada</i>	<i>Tosena fasciata</i>	Insects
<i>Common Kingfisher</i>	<i>Alcedo atthis</i>	Birds

<i>White lipped frog</i>	<i>Rana chalconata</i>	Amphibian
<i>Tree frog</i>	<i>Polypedates colletti</i>	Amphibian
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian
<i>Scally crowned babbler</i>	<i>Malacopteron cinereum</i>	Birds
<i>White crowned hornbill</i>	<i>Berenicornis comatus</i>	Birds
<i>Common Kingfisher</i>	<i>Alcedo atthis</i>	Birds
<i>Plain sunbird</i>	<i>Anthreptes simplex</i>	Birds
<i>Finch's bulbul</i>	<i>criniger finschii</i>	Birds
<i>Spectacled spiderhunter</i>	<i>Arachnothera flavigaster</i>	Birds
<i>Sanpiper</i>	<i>Tringa hypoleucos</i>	Birds
<i>Crimson winged woodpecker</i>	<i>Picus puniceus</i>	Birds
<i>Black crested bulbul</i>	<i>Pycnonotus melaicterus</i>	Birds
<i>Sanpiper</i>	<i>Tringa hypoleucos</i>	Birds
<i>Woodpeckers</i>	<i>Sasia abnormis</i>	Birds
<i>Black white Bulbuls</i>	<i>Pycnonotus melanoleucos</i>	Birds
<i>Emperor moth</i>	<i>Antheraea helferi</i>	Butterfly
<i>Forest nymf butterflies</i>	<i>Idea sp.</i>	Butterfly
<i>Stick insect</i>	<i>Caraucius chani</i>	Insects
<i>Bush Cricket</i>	<i>Mecopoda sp.</i>	Insects
<i>Giant forest ant</i>	<i>Camponotus gigas</i>	Insects
<i>Darkling beetles</i>	<i>Setenis sp.</i>	Insects
<i>preying mantid</i>	<i>Deroplatys dessicata</i>	Insects
<i>Wildboar</i>	<i>Sus barbatus</i>	Mammals
<i>Marbled cat</i>	<i>Pardofelis marmorata</i>	Mammals
<i>Mouse deer</i>	<i>Trangulus sp.</i>	Mammals
<i>Cross toad</i>	<i>Leptophryne borbonica</i>	Amphibian
<i>Low squirrel</i>	<i>Sundasciurus arestes</i>	Mammals
<i>Red leaf monkeys</i>	<i>Presbytis rubicunda</i>	Mammals
<i>Brown spiny rat</i>	<i>Maxomys rajah</i>	Mammals
<i>CyrtPub lizard</i>	<i>Cyrtodactylus pubisulcus</i>	Reptiles
<i>Wildboar</i>	<i>Sus barbatus</i>	Mammals
<i>Spotted flying squirrel</i>	<i>Petaurista elegans</i>	Mammals
<i>Red spiny rat</i>	<i>Maxomys surifer</i>	Mammals
<i>Palm Civet</i>	<i>Paradoxurus hermaphroditus</i>	Mammals
<i>Flying lizard</i>	<i>Draco maximus</i>	Reptiles
<i>HemiFren lizard</i>	<i>Hemidactylus frenatus</i>	Reptiles
<i>lizard</i>	<i>Mabuya indepressa</i>	Reptiles
<i>Malay Badger (Teledu)</i>	<i>Mydaus javanensis</i>	Mammals
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian
<i>Poisonous Rock Frog</i>	<i>Rana hosii</i>	Amphibian
<i>Dark-eared Tree Frog</i>	<i>Polypedates macrotis</i>	Amphibian
<i>Frilled Tree Frog</i>	<i>Rhacophorus appendiculatus</i>	Amphibian
<i>Oriental Bay Owl</i>	<i>Pholdilus badius</i>	Birds
<i>Wildboar</i>	<i>Sus barbatus</i>	Mammals
<i>Brightly coloured Geometrid moth</i>	<i>Millionia basalis</i>	Butterfly
<i>Great Argus Pheasant</i>	<i>Argusianus argus</i>	Birds
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian

<i>Hornbill</i>	<i>Anthracosceros sp.</i>	Birds
<i>Little heron</i>	<i>Butorides striatus</i>	Birds
<i>Black-capped Babbler</i>	<i>Pellorneum capistratum</i>	Birds
<i>Malay civet</i>	<i>Viverra zangalunga</i>	Mammals
<i>CyrtPub lizard</i>	<i>Cyrtodactylus pubisulcus</i>	Reptiles
<i>Low squirrel</i>	<i>Sundasciurus arestes</i>	Mammals
<i>Borneon horned frog</i>	<i>Megaphrys nasuta</i>	Amphibian
<i>Bee Eater</i>	<i>Nyctynornis amictus</i>	Birds
<i>Oriental Pied Hornbills</i>	<i>Anthracosceros albirostris</i>	Birds
<i>Woodpeckers</i>	<i>Sasia abnormis</i>	Birds
<i>Spectacled spiderhunter</i>	<i>Arachnothera flavigaster</i>	Birds
<i>Plain sunbird</i>	<i>Anthreptes simplex</i>	Birds
<i>Black crested bulbul</i>	<i>Pycnonotus melaicterus</i>	Birds
<i>Barking deer</i>	<i>Muntiacus sp.</i>	Mammals
<i>lizard</i>	<i>Mabuya indepressa</i>	Reptiles

Appendix 8.0: SPSS Output of Normality Test between location with respect to trail in Maliau Basin Conservation Area (MBCA)

Tests of Normality ^a							
	LOCATI	Kolmogorov-Smirnov ^b			Shapiro-Wilk		
	ON	Statistic	df	Sig.	Statistic	df	Sig.
LIGHT_INTENSITY	1	.423	10	.000	.454	10	.000
	2	.370	20	.000	.763	20	.000
	3	.261	20	.001	.783	20	.000
SOIL_COMPACTION	1	.238	10	.115	.875	10	.116
	2	.180	20	.089	.929	20	.150
	3	.101	20	.200*	.969	20	.737
SOM	1	.181	10	.200*	.952	10	.695
	2	.143	20	.200*	.903	20	.046
	3	.176	20	.105	.888	20	.025
SOIL_MC	1	.264	10	.047	.843	10	.048
	2	.214	20	.017	.864	20	.009
	3	.190	20	.057	.901	20	.044
SPECIES_RICHNESS	1	.207	10	.200*	.924	10	.392
	2	.162	20	.178	.894	20	.032
	3	.154	20	.200*	.964	20	.617

*. This is a lower bound of the true significance.

a. TRAIL = Knowledge

b. Lilliefors Significance Correction

Tests of Normality ^a							
	LOCATI	Kolmogorov-Smirnov ^b			Shapiro-Wilk		
	ON	Statistic	df	Sig.	Statistic	df	Sig.
LIGHT_INTENSITY	1	.356	10	.001	.613	10	.000
	2	.205	20	.027	.883	20	.020
	3	.200	20	.035	.864	20	.009
SOIL_COMPACTION	1	.200	10	.200*	.849	10	.056
	2	.175	20	.110	.882	20	.019
	3	.119	20	.200*	.946	20	.314
SOM	1	.167	10	.200*	.959	10	.774
	2	.151	20	.200*	.948	20	.335
	3	.153	20	.200*	.948	20	.341
SOIL_MC	1	.170	10	.200*	.919	10	.348
	2	.167	20	.148	.931	20	.161
	3	.178	20	.096	.927	20	.136
SPECIES_RICHNESS	1	.172	10	.200*	.969	10	.883
	2	.112	20	.200*	.964	20	.622
	3	.150	20	.200*	.931	20	.158

*. This is a lower bound of the true significance.

a. TRAIL = Agathis

b. Lilliefors Significance Correction

Appendix 8.0 (Cont.): SPSS Output of Normality Test between location with respect to trail in Maliau Basin Conservation Area (MBCA)

Tests of Normality^a

	LOCATIO N	Kolmogorov-Smirnov ^b			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
LIGHT_INTENSITY	1	.300	9	.019	.785	9	.014
	2	.225	20	.009	.845	20	.004
	3	.219	20	.013	.903	20	.046
SOIL_COMPACTION	1	.162	9	.200*	.947	9	.660
	2	.120	20	.200*	.964	20	.626
	3	.118	20	.200*	.980	20	.939
SOM	1	.165	9	.200*	.961	9	.806
	2	.074	20	.200*	.970	20	.749
	3	.144	20	.200*	.972	20	.788
SOIL_MC	1	.167	9	.200*	.964	9	.837
	2	.145	20	.200*	.937	20	.206
	3	.173	20	.120	.928	20	.139
SPECIES_RICHNESS	1	.192	9	.200*	.917	9	.364
	2	.130	20	.200*	.934	20	.184
	3	.168	20	.143	.927	20	.134

*. This is a lower bound of the true significance.

a. TRAIL = Ginseng

b. Lilliefors Significance Correction

Tests of Normality^a

	LOCATIO N	Kolmogorov-Smirnov ^b			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
LIGHT_INTENSITY	1	.242	10	.098	.861	10	.079
	2	.241	20	.004	.764	20	.000
	3	.281	20	.000	.768	20	.000
SOIL_COMPACTION	1	.159	10	.200*	.930	10	.449
	2	.127	20	.200*	.968	20	.703
	3	.110	20	.200*	.971	20	.773
SOM	1	.345	10	.001	.632	10	.000
	2	.312	20	.000	.730	20	.000
	3	.352	20	.000	.714	20	.000
SOIL_MC	1	.257	10	.061	.864	10	.086
	2	.180	20	.088	.881	20	.019
	3	.204	20	.029	.866	20	.010
SPECIES_RICHNESS	1	.162	10	.200*	.951	10	.684
	2	.236	20	.005	.915	20	.080
	3	.156	20	.200*	.940	20	.240

*. This is a lower bound of the true significance.

a. TRAIL = Nepenthes

b. Lilliefors Significance Correction

Appendix 8.0 (Cont.): SPSS Output of Normality Test between location with respect to trail in Maliau Basin Conservation Area (MBCA)

Tests of Normality^a

	LOCATIO N	Kolmogorov-Smirnov ^b			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
LIGHT_INTENSITY	1	.254	10	.068	.745	10	.003
	2	.368	20	.000	.576	20	.000
	3	.296	20	.000	.610	20	.000
SOIL_COMPACTION	1	.152	10	.200*	.938	10	.526
	2	.136	20	.200*	.898	20	.038
	3	.148	20	.200*	.947	20	.319
SOM	1	.102	10	.200*	.987	10	.991
	2	.147	20	.200*	.897	20	.036
	3	.172	20	.124	.869	20	.011
SOIL_MC	1	.162	10	.200*	.962	10	.812
	2	.193	20	.050	.832	20	.003
	3	.337	20	.000	.685	20	.000
SPECIES_RICHNESS	1	.308	10	.008	.756	10	.004
	2	.219	20	.013	.895	20	.033
	3	.226	20	.009	.901	20	.043

*. This is a lower bound of the true significance.

a. TRAIL = Seraya

b. Lilliefors Significance Correction

Appendix 9.0: SPSS Output of Tests of Equality of Variances in Maliau Basin Conservation Area (MBCA)

Test of Homogeneity of Variances^a

	Levene Statistic	df1	df2	Sig.
LIGHT INTENSITY	10.204	2	47	.000
SOIL COMPACTION	1.760	2	47	.183
SOM	1.433	2	47	.249
SOIL MC	.612	2	47	.547
SPECIES RICHNESS	2.388	2	47	.103

a. TRAIL = Knowledge

Test of Homogeneity of Variances^a

	Levene Statistic	df1	df2	Sig.
LIGHT INTENSITY	15.122	2	47	.000
SOIL COMPACTION	3.312	2	47	.045
SOM	2.101	2	47	.134
SOIL MC	.146	2	47	.864
SPECIES RICHNESS	.973	2	47	.385

a. TRAIL = Agathis

Test of Homogeneity of Variances^a

	Levene Statistic	df1	df2	Sig.
LIGHT INTENSITY	10.517	2	47	.000
SOIL COMPACTION	.058	2	47	.944
SOM	.440	2	47	.646
SOIL MC	.521	2	47	.597
SPECIES RICHNESS	1.154	2	46	.324

a. TRAIL = Ginseng

Test of Homogeneity of Variances^a

	Levene Statistic	df1	df2	Sig.
LIGHT INTENSITY	2.712	2	47	.081
SOIL COMPACTION	.204	2	47	.739
SOM	.774	2	47	.467
SOIL MC	.004	2	47	.999
SPECIES RICHNESS	1.099	2	47	.342

a. TRAIL = Nepenthes

Test of Homogeneity of Variances^a

	Levene Statistic	df1	df2	Sig.
LIGHT INTENSITY	47.475	2	47	.000
SOIL COMPACTION	.014	2	47	.986
SOM	3.295	2	47	.046
SOIL MC	.413	2	47	.664
SPECIES RICHNESS	1.157	2	47	.323

a. TRAIL = Seraya

Appendix 10.0: Some photo of recreation trails in Maliau Basin Conservation Area (MBCA)



Appendix 11.0: Some photo of vegetations along trails in Maliau Basin Conservation Area (MBCA)



Appendix 11.0 (Cont.): Some photo of vegetations along trails in Maliau Basin Conservation Area (MBCA)



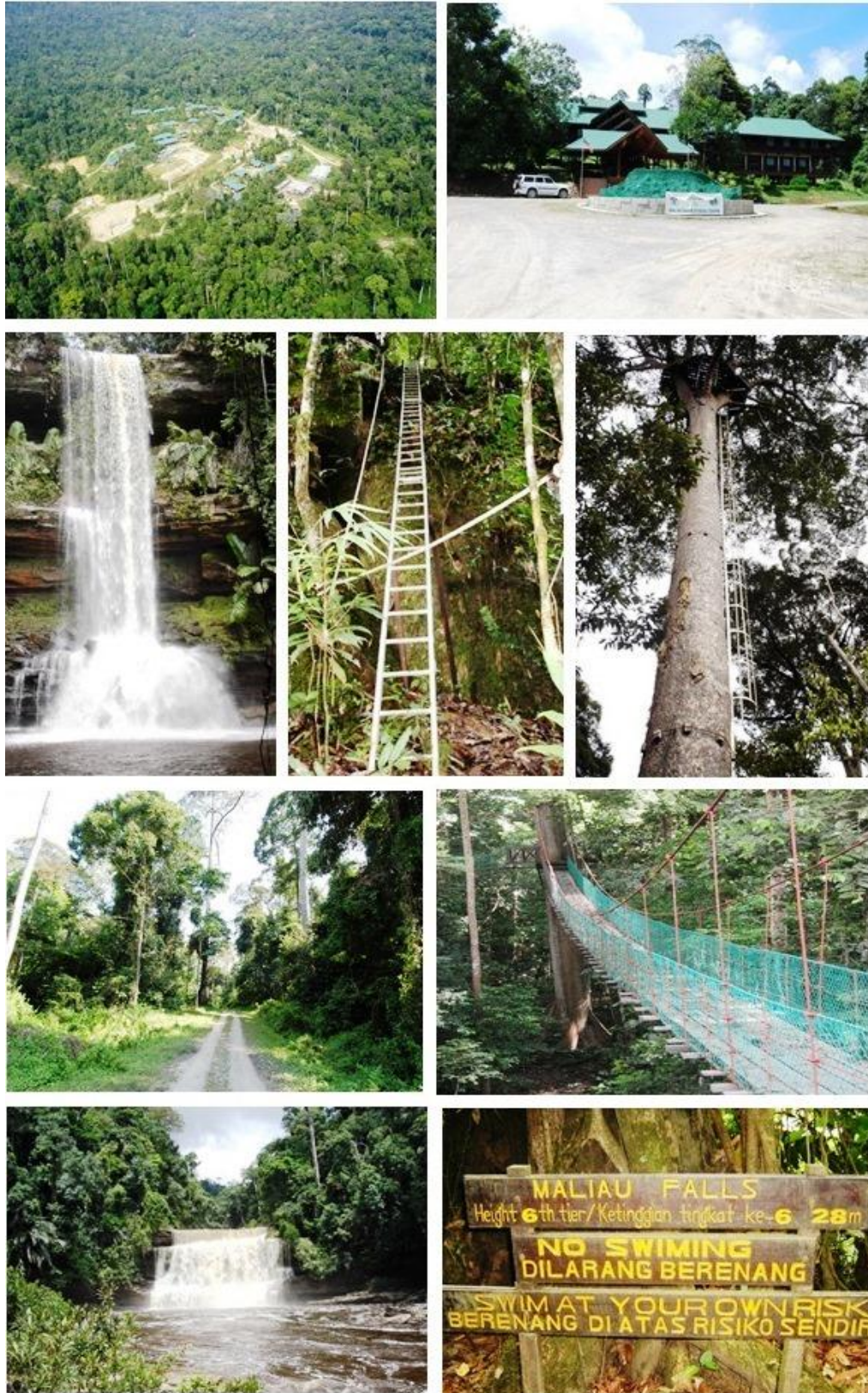
Appendix 12.0: Some photo of Wildlife along trails in Maliau Basin Conservation Area (MBCA)



Appendix 13.0: Some photo of Insect along trails in Maliau Basin Conservation Area (MBCA)



Appendix 14.0: Some photo of Maliau Basin Conservation Area (MBCA) and attractions



Appendix 15.0: Infrastructure and Facilities in Maliau Basin Conservation Area

Among the infrastructure and facilities available in the MBCA Study Centre include the following: -

- **VIP House/Chalet**

This consists of 3 luxury bedrooms with attached bathroom and coffee-making facilities. It also has a separate sitting room.

- **Rest House**

The rest house offers a choice of queen-size bed (Deluxe) or standard twin-sharing. Both with attached bathroom and coffee-making facilities with a separate sitting room.

- **Hostel**

Tourists coming in groups are recommended to stay in the hostel. There are two blocks of dormitory-style accommodation with two common toilets cum showers at each block. Other than that, one common kitchen and dining area are also available.

- **Annex Room**

Annex room is mainly for the purpose of long term researcher and student accommodation. There are 6 rooms available with one common kitchen, living room and toilet cum showers. A Separate sitting room is also available.

- **Camping Ground**

Camping ground in Belian Camp is also available, particularly for large and adventure tourist group. The camping ground can accommodate twenty double tents at a time. Large kitchen and common toilet cum showers are also available as well as a pavilion.

Other facilities available for tourism in MBCA are:

1. Reception and information counter open daily except on Sundays.
2. Maliau Basin Nature Gallery opens daily and provides details information on Maliau's flora and fauna.
3. The Conference room with maximum capacity of forty people for a meeting and 100 persons for a seminar.
4. Environmental Education Classroom for EE programme and it can accommodate up to thirty-five people at one time.
5. The Environmental education laboratory which is also for the EE programme is equipped with basic amenities.
6. A Mini theatre equipped with an LCD projector accommodate up to 50 people.
7. Maliau Laboratory for researchers and scientists and is equipped with basic laboratory amenities.
8. The Audio Visual Lounge that is equipped with Astro, a DVD player, and a karaoke set.
9. The Rest house dining hall that serves *ala carte* and buffet menu.
10. The Maliau Basin souvenirs and gift shop, which opens daily during weekdays and half day during the weekends.

Other facilities available at the Study Centre: -

1. Sports Field.
2. Prayer room (Surau).
3. Telecommunication repeater.

In addition to the facilities at the Study Centre, satellite camps are also available along the trails. These are particularly for visitors doing jungle trekking: -

1. **Agathis Camp:** Set on the bank of a 15-metre wide stream in hill mixed dipterocarp forest. This facility is located at the southernmost edge of the MBCA, about 20 km to the north of the security gate, and this is the main starting point for trails to Nepenthes Camp and Ginseng Camp. The Camp is well-equipped and comfortable with hammock-style accommodation for up to thirty visitors.
2. **Nepenthes Camp:** Formerly known as Camel Trophy Camp and was constructed by participants of Camel Trophy rally in 1993. It was located strategically at the meeting point of the lower montane forest and the rare montane heath forest on the basin's southern plateau. The facility comprises a two-storey building complete with bunk beds, showers, and solar electricity which can accommodate up to fifteen visitors. A thirty-three-metre high observation platform near the top of a large *Agathis borneensis* tree provides an opportunity to observe birds at close range and allows breath-taking views of the surrounding forest canopy.
3. **Ginseng Camp:** Constructed in 2005 near the impressive twenty-seven-metre high Ginseng Falls, the camp can accommodate up to twenty visitors with hammock-styled beds, toilets, and showers.
4. **Seraya Camp:** The facility is located on the newest and most significant future trail in MBCA due to the shortest distance to Maliau Falls. It is 4 to 6 hours trekking from Belian Camp near the Study Centre. The trail around Seraya Camp is also passing *Rafflesia tengku-adlinii* site which is rare species in MBCA.

Appendix 15.0 (Cont.): Some photos of facilities in Maliau Basin Conservation Area (MBCA)



Appendix 15.0 (Cont.): Some photos of facilities in Maliau Basin Conservation Area (MBCA)



Appendix 16.0: Some photos of visitor in Maliau Basin Conservation Area (MBCA) and



Appendix 17.0: Some photos of the researcher during field work in Maliau Basin Conservation Area (MBCA)



Appendix 18.0: The researcher curriculum Vitae or biodata

PERSONAL INFORMATION

Full Name : Wilter Azwal Bin Malandi



[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
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EDUCATION

Year 2009 : Phd Candidate (Recreation Ecology), Sheffield Hallam University, UK (On-
Year 1999 : Master's Degree in Forestry, Universiti Putra Malaysia
Year 1995 : Bachelor's Degree (Hons.) in Forestry, Universiti Pertanian Malaysia
Year 1991 : Diploma in Forestry, Universiti Pertanian Malaysia
Year 1990 : SPM, Aliran Sains Tulen, SMK Mat Salleh Ranau (Grade 1)
Year 1988 : SRP, SMK Kundasang Ranau
Year 1984 : Primary Five Examination National Primary School (SRK), Kauluan Ranau

FIELD OF INTEREST

1. Recreation Ecology in Forestry
2. Landscape ecology conservation and Ecotourism Resource Management

EMPLOYMENT HISTORY / PROFESSIONAL EXPERIENCE

Year 2009 – Present : Senior Lecturer at FPT, Universiti Malaysia Sabah, Kota Kinabalu
Year 2000 – 2009 : Lecturer at SITF, Universiti Malaysia Sabah, Kota Kinabalu
Year 1998 – 1999 : Tutor at SITF, Universiti Malaysia Sabah, Kota Kinabalu.
Year 1998 – 1999 : Invited Lecturer at Mara Technology University, Kota Kinabalu, Sabah
Year 1996 – 1998 : Forest Officer (Forest Research officer) in Plant Improvement and Seed Production (PISP), ICSB Sabah Foundation.
Year 1995 - 1996 : Executive Engineer (Wood Industry Research executive) at Aokam Perdana Group Sdn Bhd, Keningau Sabah

Participation in Associations, Boards, Committees and other bodies

1. Member of World Wide Fund (WWF)-Malaysia
2. Member of Radio Amateur Class B under Malaysian Communication and Multimedia Commission (MCMC)
3. Member of Malaysia Nature Society
4. Member of Flora of Peninsular Malaysia
5. Member of British Wildlife and Nature Society
6. Member of Malaysia Kidney Association
7. Member of Kundasang Kinabalu Four Wheel Drive

RESEARCH ACTIVITIES

- Title: Recreation Impact on lower vegetation and soil along selected trails in Nuluhon Trusmadi Forest Reserve, Tambunan Sabah. Funds (2014 - 2015)
- Title: Recreation Impact on lower vegetation and soil along selected trails in Kawang Forest Reserve, Kinarut Sabah. Funds (2013 - 2014)
- Title: Preliminary assessment of recreation impact on lower vegetation along trails in Gaya Island Park. Funds (2013)
- Title: Ecological impact of recreation activities along trails in Maliau Basin Conservation Area, Sabah Malaysia. Funds (2009 - 2012)
- Title: Growth Rate of Dandelion (*Taraxacum Officinale*) on Fertile and Infertile soil in Monteki, Mesilau Kundasang. Funds (2005 - 2006)
- Title: Penilaian Kos dan harga penyelenggaraan bagi 5 kategori tanaman di Universiti Malaysia Sabah Source of fund / Grant: Universiti Malaysia Sabah . Funds: RM16,700.00. (2003 - 2005)
- Title: Early pioneer regeneration study on *Pinus caribaea* colony in Kundasang Sabah. Source of fund / Grant: Universiti Malaysia Sabah. Funds: RM20,000.00. (2003 - 2005)
- Title: Effect of different fertilizer and soil component on rattan growth at the nursery stageSource of fund / Grant: Innoprise Corporation (Yayasan Sabah) & Cirad-Foret . Funds: . (1997 - 1997)
- Title: Effect of shade treatment on rattan growth at nursery stageSource of fund / Grant: Innoprise Corporation (Yayasan Sabah) & Cirad-Foret. Funds: . (1997 - 1997)
- Title: Establishment and setting up a nursery at Luasong Forestry Centre, TawauSource of fund / Grant: Innoprise Corporation (Yayasan Sabah) & Cirad-Foret. Funds: . (1997 - 1997)
- Title: Feasibility study for commercial Teak production by vegetative propagation in the nursery, Luasong Forestry Centre, TawauSource of fund / Grant: Innoprise Corporation (Yayasan Sabah) & Cirad-Foret. Funds: . (1997 - 1998)
- Title: Production and development of bamboo industry in SabahSource of fund / Grant: Universiti Malaysia Sabah. Funds: . (2000 - 2002)
- Title: Rapid assessment of Imbak Canyon Waterfall Trail as Tourism and Recreation AttractionSource of fund . (2004)

- Title: Staff and workers perception and evaluation toward tree planting and landscape activities in UMS main campus Source Funds: RM1,000.00. (2000 - 2001)
- Title: Teak (*Tectona grandis*) progeny and provenance testing in Taliwas, Lahad Datu Source of fund / Grant: Innoprise Corporation (Yayasan Sabah) & Cirad-Foret

PUBLICATION

BOOK

1. Wilter Azwal Malandi, 2015. Ecological Impacts of Recreational Activities.
2. Wilter B. Malandi , Suhaimi Esa, Kelvin Kueh, Dr. Monica Suleiman. 2003. *seminar Pengurusan Asrama Kebangsaan (spark)*. Dlm. Universiti Malaysia Sabah: Universiti Malaysia Sabah. ISBN: 983-2188-945-4
3. Wilter Azwal Malandi dan Siti Rahayu Bt Mohd Hashim 2001. Rekabentuk Landskap Dan Pemilihan Species Tanaman Di Kawasan Kolej Kediaman ,: P213-222 , ISBN: 983-2188-945-4

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1. L Kammesheidt, A Berhaman, J Tay, G Abdullah & M Azwal (2009). Liana abundance, diversity and tree infestation in the Imbak Canyon Conservation Area, Sabah, Malaysia. *Journal of Tropical Forest Science* 21(3): 265–271 (2009).
2. Siti Rahayu Mohd Hashim, Noraini Abdullah & Azwal Aziz. 2007. Multiple Weighted Score Analysis On Rating Factors Of Students Satisfaction. *Borneo Science* 21. 21: 21-28. ISSN: 1394-4339

NEWSPAPER ARTICLE

1. Suzianah Jiffar. 2007. Taman Pertanian Sabah Kaya Pelbagai Tarikan. *berita Harian*. 11 April 2007.
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DESIGN/ INOVASION & CONSULTANT

September 2007	: Indoor Landscape for stage in Canselor Hall on UMS Convocesyen 9th, 2007
11 – 12 September 2004	: Indoor Landscape for stage in Canselor Hall on UMS cemomorative Convocesyen Tun Dr Mahathir Mohamad, 2007.
4 – 5 September 2004	: Indoor Landscape for stage in Canselor Hall on UMS Convocesyen 5th, 2004
10 – 11 October 2003	: Indoor Landscape for stage in Canselor Hall on UMS Convocesyen 4th, 2003
Year 2003	: Landscape design to improve the artificial waterfall and water fountain in Universiti Malaysia Sabah.(RM112,605.00)
Year 2002 - 2003	: Design and developing landscape at Science and Technology School corridor as outdoor lecture centre. (RM386,587.00).
Year 2002	: Design and developing landscape along main gate UMS (RM60,587.00).
Year 2004 - 2005	: Design and developing landscape at UMS's Logo (RM95,000.00).

Appendix 19.0: Some of the papers presented out of this research in MBCA

No	Title of paper	Publicity
1.	Human Impact on plant ecology changes in a protected area Case study: Maliau Basin Conservation Centre (MBCA) Sabah, Malaysia (Poster)	Wilder by Design Part 2: Wild Thing?? Past & future ecologies – histories, realities and myths, Sheffield 2014
2.	Recreation Impact on the Soil of Tropical Rain Forest in Maliau Basin Conservation Area, Sabah, Malaysia	In the Bog (The ecology, landscape, archaeology, and heritage of Peatlands) Conference, Sheffield UK, 3rd to 5th September 2014.
3.	Trampling impact on plant ecology changes along selected trails in Maliau Basin Conservation Area (MBCA) sabah, malaysia	In JSPS Core-to-Core Program, International Workshop on Long Term Monitoring and Data Analysis of Forest Resource Environment, Kota Kinabalu, March 2017
4.	Plant Diversity Along Permanent Trails in Maliau Basin Conservation Area (MBCA), Sabah Malaysia: Monitoring of Visitor Impact.	"2nd Symposium of JSPS Core-to-core Program, Bangkok,Thailand" Dec 2017
5.	Visitor Impact on soil and vegetation along selected trails in Maliau Basin Conservation Area, Sabah, Malaysia	Malaysian Outdoor Recreation Carnival 2021 (MOREC21), Kuala Lumpur 2021