The implications of spatial and temporal scale on the supply, distribution and value of ecosystem services in Guyana

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Declaration of Authorship

I, Lisa Ingwall King hereby declare that this thesis and the work presented in it is entirely my own. Where I have consulted the work of others, this is always clearly stated.

Signed: … ……………………………..

Date: …9 June 2014…………………………........

Abstract

Engagement with the complexities of scale when using the ecosystem services (ES) concept in natural resource management has been increasingly regarded by many scholars as a necessity for a successful outcome, and thus in need of greater attention. This thesis explores and reveals some of these scale complexities using a case study approach of the North Rupununi in Guyana. Working with the local indigenous Makushi group, the thesis focuses on how spatial and temporal scale affects the supply, distribution and value of ES to the local communities and stakeholders at the national and international scale.

A mixed method approach (including focus groups, in-depth/informal interviews, participatory mapping, hydro-ecological surveys and water quality sampling) was employed to allow for both qualitative and quantitative data to be collected and analysed. The approach revealed both the constraints of the ES concept when applied with indigenous communities and the additional understanding a more qualitative approach can contribute. The findings reveal the spatial and temporal patterns of the supply and demand of crucial ES (fish and freshwater) for the communities in the North Rupununi. Key connectivity sites in the landscape were also identified, with the link between the Amazon and Essequibo watersheds being the most important. This key site is mapped for the first time. Investigation into temporal scales revealed how the fishing pattern changes with the season both in terms of location, but also related to fish quantity and quality to some extent. Long-term trends for both the water and fish were exposed, and a decline in the fish populations could be confirmed, particularly for the popular fish species. These research findings have provided new insights into the spatial and temporal complexity of key ES for Guyana, which will be crucial to secure their healthy state and continued supply for the future.

Contents

List of figures

List of tables

List of plates

List of maps

Abbreviations and acronyms

CBM	Community Based Management
CBNRM	Community Based Natural Resource Management
CCA	Canonical Correspondence Analyses
CI	Conservation International
CBD	Convention of Biological Diversity
CV	Contingent Valuation
DCA	Detrended correspondent analyses
EPA	Environmental Protection Agency
ES	Ecosystem Services
EU	European Union
GIS	Geographical Information Systems
GPS	Global Positioning System
GT	Georgetown
ICCA	Indigenous territories and community conserved areas
ICDP	Integrated Conservation and Development Project
IPA	Indigenous protected areas
IUCN	International Union for the Conservation of Nature
LCDS	Low Carbon Development Strategy
MA	Millennium Ecosystem Assessment
MCDA	Multi-criteria decision analyses
MoAA	Ministry of Amerindian Affairs

MRU	Makushi Research Unit
NGO	Non-Governmental Organisation
NRDDB	North Rupununi District Development Board
PCA	Principal Component Analyses
PES	Payment for Ecosystem Services
REDD+	Reduced Emission from Deforestation and Forest Degradation
SES	Social Ecological Systems
TEK	Traditional ecological knowledge
UNDP	United Nations Development Program
UNDP EI	United Nations Development Program’s Equator Initiative
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WHO	World Health Organisation
WTA	Willingness to Accept
WTP	Willingness to Pay
WWF	World Wildlife Fund

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Chapter 1

Introduction

> "*North Rupununi is a nice place to live, it has a lot of many things, and we have land and many different environments. That is why I love Rupununi.*"
>
> (Older man, Kwatamang)

Humans' impact on the Earth and its natural ecosystems continues to rise and cause deleterious effects on both the natural world and human well-being. Since the mid-twentieth century, human influence on ecosystems has been faster and more extensive than in any other period of human history (Millennium Ecosystem Assessment (MA), 2005). The continued exploitation of natural ecosystems has led to the degradation and unsustainable use of an estimated 60 percent of the world's ecosystem services (ES) (MA, 2005). ES are commonly defined as the benefits people derive from ecosystems (MA, 2005). Even though these degradations have severe natural and socio-economic consequences, they are rarely acknowledged (Busch *et al*., 2012). If no action is taken to reverse this negative trend, the degradation of ecosystems is predicted to worsen, possibly resulting in catastrophic irreversible changes for large parts of the world (Busch *et al*., 2012; MA, 2005; Rockström *et al*., 2009).

Part of the solution to prevent, or at least reduce further loss of ES, is to have a better understanding of how they function, and provide value to different stakeholders. This thesis thus aims to contribute towards these important areas, and will focus on Guyana as a case study to bring insights into how the supply, distribution, and value of ES are influenced by spatial and temporal scale. A better understanding of how the condition and trends of ES are affected by spatial and temporal scales is crucial for their conservation and sustainable management (Vihervaara *et al*., 2010a). Additionally, data on the spatial patterns of the source and supply area of ES and how they are linked across scales are essential for better locating future development projects and thereby reducing their negative effects. Furthermore, a better understanding of how people at different spatial and organisational scales value and perceive ES is also important when it comes to reaching fair management and development agreements between stakeholders.

The thesis will use the ecosystem services concept as the conceptual framework. Despite being a relatively new concept, its increasing popularity is clear among scientists, NGOs and decision-makers (Burkhard, 2012; Seppelt *et al*., 2011; Vihervaara *et al*., 2010a). Its popularity can be linked to the fact that the concept of ES addresses the multi-functionality of ecosystems while including human beings as part of the system; this allows for a deepened and extended view of traditional natural resource management (Busch *et al*., 2012; Vihervaara *et al*., 2010b). In addition, and perhaps the greatest reason for the concept's popularity is that it allows for many of the ES to be quantified, enabling the allocation of monetary values to individual ES (Daily, 1997; Metzger *et al*., 2008; among others). Decision-makers have thus been in favour of this approach, as they find a financial value a familiar and useful measurement on which to base decisions. However, some ES are not easy, or even suitable, to quantify and a lively debate on which is the most appropriate valuation method(s) is on-going. Furthermore, a core aspect of the criticisms concerns the ethics of allocating a monetary value to nature, which is questioned by some (Child, 2009; Spash, 2008), and will be addressed further in the thesis.

The ES concept can be linked to the research orientation of socio-ecological systems, i.e. coupled human-environment systems (Folke, 2006b; Holling, 1973; Vihervaara *et al*., 2010a). Gallopín (1989, p.19) defines a socio-ecological system as a "system that includes societal (human) and ecological (biophysical) subsystems in mutual interaction". This approach is thus strongly interdisciplinary as it focuses on how social/human and ecological/environmental systems are linked (Daw, 2008). The ES approach is also utilitarian, which means that the ecosystem can only provide a service if a human can benefit from it, either by using it or deriving well-being from it (Busch *et al*., 2012). Thus, ES are strictly linked to the spatial dimension of the area where an ES is provided (Busch *et al*., 2012). Consequently, establishing the spatial extent and flow of ES is essential to securing a healthy supply of ES. Furthermore, the MA and other sub-global ecosystem assessments emphasise the importance of ES for human well-being and their necessity in meeting long-term development goals (Layke *et al*., 2012; MA, 2005; Shackleton *et al*., 2008).

The ES concept has immense potential to become an invaluable tool for conservation (Vihervaara *et al*., 2010b). However, substantial knowledge gaps still exist about the condition and trends of many ES; knowledge about the options for their assessment, mapping and management are also still incomplete, within many geographical areas and ecosystem types (MA, 2005; Vihervaara *et al*., 2010b). This thesis aims to contribute towards these knowledge gaps with a focus on the condition, trends, value, spatial pattern and provision of freshwater ES in the North Rupununi, Guyana.

1.1 The science of ecosystem services concept

To secure a continuous flow of ES, a better understanding is needed of their condition and the extent of their use (Maes *et al*., 2012). However, much data is still lacking on these issues, particularly for countries like Guyana, which have immense biological diversity but poor economic resources (Maes *et al*., 2012). Furthering the understanding of this type of research is important because continued provision of ES depends on the biophysical conditions of ecosystems; being able to assess the status of ES is thus a necessity and a first vital step towards documenting changes in their condition and availability (Burkhard, *et al*., 2012; Busch *et al*., 2012; Metzer *et al*., 2006). This research information is also needed to predict potential thresholds[1] for ecosystems, which may allow for a more sustainable use of the ES (Kremen, 2005). Furthermore, explicit spatial information on the state and trends of ES is also desperately needed to enable the further use and mainstreaming of ES into policy-and decision-making (Maes *et al*., 2012).

1.1.1 Ecosystem services' interconnectedness and the implications of spatial and temporal scale

The ES concept is strongly linked to issues of scale because of its interdisciplinary nature of combining social and ecological systems and its cross-scalar distribution (Scholes *et al*., 2013). Gibson *et al*. (2000, p. 218) define scale as "the spatial, temporal, quantitative or analytic dimensions used by scientists to measure and study objects and processes". ES are produced heterogeneously across landscapes and times, meaning they are supplied at various spatial and temporal scales (Fisher *et al*., 2009; Syrbe and Walz, 2012). However, to date, there has been relatively little elaboration of the scales of ES, and little understanding exists about the interactions between connected systems and how ES at one scale may feed into ES at another (Kremen, 2005; Porro *et al*., 2008; Wilbanks, 2006). Thus, research is needed to further the understanding of how spatial and temporal scale affects the condition and supply of ES (Fisher *et al*., 2009; Syrbe and Walz, 2012; Turner *et al*., 2003). A key area of the thesis focuses on unravelling some of the scale complexities related to the ES concept.

An improved understanding of the spatial and temporal scale of an ES is important because it reveals insights as to how they function; this may lead to better management, as the right area

[1] Ecological threshold is the point at which there is an abrupt change in an ecosystem quality, property or phenomenon, or where small changes in an environmental driver produce large responses in the ecosystem (Groffman *et al*., 2006)

may be targeted and at the correct time to avoid degradation. This can be critical for the health of ES and the continued sustainable supply of ES to stakeholders at all scales (EFTEC, 2005; Syrbe and Walz, 2012).

1.1.2 Spatial pattern and mapping of ecosystem services

Burkhard *et al*. (2012) identifies that mapping of spatial patterns of ES is an area that needs much attention. To address this research gap the thesis aims to explore, identify and visualise the spatial and temporal scales of some ES in the North Rupununi, Guyana. Mapping is used as a tool to identify and visualise these processes. By mapping and documenting the spatial and temporal patterns of ES it allows for the provider (both species and ecosystems), the beneficiaries and the connectors in the landscape to be identified (Syrbe and Walz, 2012). This is important both for the management of ES but also for the implementation of ES into institutions and decision-making, so that more sustainable decisions can be made (Burkhard *et al*., 2009; Daily and Matson, 2008; Syrbe and Walz, 2012). Furthermore, only through mapping the spatial distribution of ES and their changes over time can more complex information be collected related to their spatial and temporal heterogeneity (Burkhard *et al*., 2012). Additionally, only by examining the spatial relationships of ES, as well as the use patterns and values of stakeholders, can hotspot areas be identified (Syrbe and Walz, 2012). These areas are important for the provisioning of the ES, but because of their richness they are also valued use areas by stakeholders, which potentially could lead to conflicts. Visualisation methods such as mapping of ES could help stakeholders understand each other's perspectives, hopefully leading to alternative resource management futures where multiple ES are provided (Raymond *et al*., 2009; Syrbe and Walz, 2012). The visualisation of ES can thus be a powerful tool for decision makers to ensure sustainable landscape management (Swetnam *et al*., 2011). However, as Turner and Daily (2008) and Burkhard *et al*. (2012) point out, there is a clear lack of relevant information to local scale decision-making; this makes this research even more relevant as spatial and temporal patterns of ES at the local scale of the North Rupununi are explored and established (Daily and Matson, 2008; Porro *et al.*, 2008). Tallis *et al*. (2008) also emphasise the importance of mapping the flow of ES as a prerequisite for the true integration of conservation and development.

Several mapping approaches of ES have been developed in the last few years to allow for visualising the dynamic pattern of ES (e.g. Egoh *et al*., 2008; Naidoo *et al*., 2008; Nelson *et al.*, 2009; Tallis and Polasky, 2009; Troy and Wilson, 2006). The different approaches all seem to struggle with combining spatial accuracy with comparability of different case studies (Burkhard *et al*., 2009). Martínez-Harms and Balvanera's (2012) review of mapping approaches identifies a number of weaknesses: the frequent reliance on secondary data, the broad scale of application, and the lack of validation techniques in many studies. Similarly, O'Higgins *et al*. (2010)

highlights that most land-development decisions are made at the local scale in which information is needed at much finer scales, but not much attention has been given to local scale mapping of ES – which is why this thesis addresses this area and aims to contribute to this research gap. Another problem with a common mapping method, highlighted by Di Sabatino *et al*. (2013), is the resolution when using land cover datasets from satellite imagery as a substitution for ES mapping. Their study established that wetlands, rivers and other small sized ecosystems are underestimated when coarse resolution land cover datasets are used to estimate size and subsequently value (Di Sabatino *et al*., 2013). To address this, the mapping approach used in this thesis is based on empirical data, is both fine-scaled and local, and included validation checks throughout the process to address the identified shortcomings of previous research.

1.1.3 Valuation and perspectives of ecosystem services

The value different stakeholders attach to services can differ depending on the scale they occupy because of the heterogeneous nature of ES supply. For example, at the global scale, carbon retention plays a significant role in the fight against climate change. Yet, at the watershed scale, water purification and biodiversity may be more important. On a national scale a small freshwater body might not have much value, but on a local scale it might provide food products that are vital for local people.

The most favoured valuation approach has been financial, which estimates a monetary value of ES that can easily be applied in existing economic systems and hence is easy to integrate into decision-making processes (Busch *et al*., 2012). Several different techniques have been used, such as cost-benefit analyses, contingent valuations and willingness-to-pay assessments (Burkhard *et al*., 2012; Farber *et al*., 2002). These methods have shown some promising results, but the issue of valuing nature is still quite contentious; many uncertainties and research gaps still exist. Many see the outcomes of the monetary valuation methods as disappointing, due to their economic focus and lack of appropriate pricing methods for the ES that are not on the market (Burkhard *et al*., 2012; Ludwig, 2001; Spangenberg and Settele, 2010).

Even though the monetary approach has been the most popular method, non-monetary and qualitative approaches are also being tested, and more and more scholars support them (Chan *et al*., 2012a & b; Chee, 2004). Vihervaara *et al*. (2010a, p. 322) state that “non-monetary values of ecosystems should be considered as key components in decision-making”. This is particularly true for ecosystems where little is known and hardly any baseline data exist, which is the case for this study in Guyana (Fearnside, 1999; Godfray *et al*., 1999).

This thesis addresses these issues and employs a non-monetary valuation approach to better understand the perspectives and values of stakeholders at different scales. Folke (2006a) and Janssen and Anderies (2007) highlights the research need for valuations of ES using a non-monetary approach, as this type of knowledge and understanding can be used to resolve conflicts and implement effective policy and management programmes that can enhance the robustness of social-ecological systems. Moreover, Sheil *et al*. (2006) emphasise that ES studies need to take into consideration differences that might exist between stakeholders' perception at different scales, which is in line with what this thesis aims to address.

1.2 The research location

This study took place in the Rupununi River catchment situated in southwest Guyana (04º N 05', 59º W 02') (Map. 1.1). The area occupies the watershed divide between the Amazonian basin and the Essequibo River catchment, the largest drainage basin of the Guiana Shield (Wetlands Partnership, 2006a).

Map 1:1: Map of Guyana; research area is marked with a white square (Source: Map from Google Earth)

The research was located in the North Rupununi for several reasons, primarily because the region is of global significance: it provides crucial hydrological services; it is known to have one of the highest freshwater diversities in the world with a fish population estimated at more than 400 species (de Souza *et al*., 2012; Watkins *et al*., 2005); it supports endangered species such as the Black Caiman (*Melanosuchus niger*), Giant River Otter (*Pteronura brasiliensis*), and recovering populations of one of the largest freshwater fish in the world, the Arapaima (*Arapaima gigas*); and its mosaic landscape of tropical lowland forest, savanna and wetlands sequester and store enormous amounts of carbon (Wetlands Partnership, 2006a). The region is home to the Makushi and Wapishana people who depend on the natural systems for their livelihoods and possess a great amount of knowledge about the dynamics of the ES; many of their traditions, myths, and stories are intimately associated with their local environment.

Poverty levels remain high throughout Guyana, particularly in interior regions such as the Rupununi. Guyana is one of the poorest countries in South America. It has a population of 751,223 (Bureau of Statistics, 2002), of which 9.2 percent is of indigenous origin, or Amerindian, which they prefer to be called. Among the Amerindians 85 percent live below the poverty line, making them the most vulnerable group in Guyana (Colchester and La Rose, 2010). Together with high levels of external debt and weak institutional capacity, there is increasing pressure on the government and local populations to choose economic activities which may be beneficial in the short term, but unsustainable long-term. Oil prospecting is already under way, and with plans to upgrade and expand road infrastructure, further extractive activities such as logging and mining are imminent threats. Nevertheless, due to its relatively pristine state and vast tracts of tropical lowland forest, the Rupununi has been the focus of recent international efforts to preserve ES. These include Guyana's President offering to place almost the entirety of Guyana's rain forest under international supervision, and highlighting conservation of the Rupununi as part of a payment for ecosystem services (PES) scheme[2] being implemented under the Reduced Emissions from Deforestation and Forest Degradation[3] (REDD+) and Guiana Shield Initiative (a UNDP-funded pan-Amazonian programme). Considering this context, it is easy to conclude that the Rupununi region is an excellent study location to investigate ES and its various natural and social facets.

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[2] Wunder (2005) defines PES as:

- **a)** a voluntary transaction where
- **b)** a well-defined environment service (or a land use likely to secure that service)
- **c)** is being 'bought' by a (minimum one) service buyer
- **d)** from a (minimum one) service provider
- **e)** if and only the service provider secure service provision (conditionality)

[3] REDD+ is a mechanism that is under negotiation at the United Nations Framework Convention on Climate Change (UNFCCC). The objective of REDD is to support activities that enable reductions in CO2 emissions that are caused by deforestation and forest degradation (IUCN).

Furthermore, there is anecdotal evidence that the Rupununi is the only area within the Amazonian and Guiana Shield watershed divide which is characterised by a flat inland floodplain (the site of the legendary lake of El Dorado). During the wet season (May to September) flooding allows the Amazonian and Guiana Shield waters to mix, effectively creating a water bridge between the two basins and a migration route for freshwater species. Thus this hydrological service at the watershed scale feeds directly into biodiversity services at the ecosystem scale. However, the specific locations of these links have not been identified. This makes the Rupununi an excellent research location, as this hydrological link needs to be found and established as soon as possible to ensure its maintenance and protection.

1.3 Research aims and questions

The goal of this thesis is to address some of the research needs identified and discussed in the above sections. Three main research aims were chosen, related to the value of ES, and the issue of how spatial and temporal scale affect ES in North Rupununi, Guyana. These aims are as follows:

1. To better understand the perspectives different stakeholders at different scales have of ES in Guyana and potential areas of conflict.

Research questions:

- How and why do the perspectives of ES differ among stakeholders at different scales?
- What are the potential problems and areas of conflict when using the ES approach to value ES?
- What are the benefits of using a non-monetary valuation technique of ES?

2. To assess the status and trends of ES and explore how they vary over temporal and spatial scales.

Research questions:

- How do seasonal variations affect the status and supply of ES?
- Does the status of ES differ spatially?
- Has the status of ES changed during the last decade?
- What drivers are the most threatening to the delivery of ES in the North Rupununi?

3. To establish spatial patterns of the supply of ES and key connectivity sites between ES at different scales.

Research questions:

- What does the supply of ES look like in the North Rupununi?

- How does the provision of ES in the North Rupununi vary spatially with the season?
- Are there any differences in the utilisation pattern of ES between communities?
- Where are the connections (scaling) between different scales for key ES?
- What impact do the interactions between scales have on ES?

1.4 The importance of freshwater ecosystem services

The research focuses on freshwater and fish as the main ES due to their interconnected nature and their threatened status, as both are among the most threatened habitats and biota in the world (Welcomme and Petr, 2004). Over 50 percent of all freshwater fish species – a disproportionate share – are found in large rivers, of which the Rupununi River is part as it flows into the Essequibo River, the third largest in South America. The Rupununi is also an unregulated river, which is becoming rare in the world; most rivers in developed nations have had their flow regulated by dams, which cause tremendous changes in the quality of both the water and the biota. It is thus of even higher importance to protect a free flowing tropical floodpulse river such as the Rupununi (Welcomme and Petr, 2004). Furthermore, Guyana's water resource, which is believed to be 10-15 percent of the available freshwater on Earth, is a particularly valuable ES considering the predicted global water scarcity problem for 2025 (Inland Fish Policy, 2013; Rosales, 2008). This water resource and all the ES a riverine system provides can be considered of global importance and thus need to be conserved and managed appropriately, in which further research and knowledge is needed (Inland Fish Policy, 2013; Rosales, 2008). In addition to these reasons, focusing on freshwater and fish as ES also makes sense from the perspectives of poverty alleviation and human well-being, as fish contributes immensely to the diet, jobs and income of poor rural communities like the ones in the North Rupununi (Allan *et al*., 2005).

To sustain the relatively pristine conditions of the North Rupununi some type of management is most likely needed. Welcomme and Petr (2004) emphasise that conventional methods (e.g. stock assessment of individual species) of researching rivers and fisheries are generally inadequate, as they normally only focus on a few species and do not take an ecosystem approach, nor include the knowledge of the local fishers. Therefore, new approaches need to be used to understand the ecology and the fisheries of these systems. Welcomme and Petr (2004) particularly highlight the usefulness of including traditional ecological knowledge held by local communities to further the understanding of these systems. Although, it is not just more knowledge regarding the biophysical systems that are needed for successful conservation and management – research studies need to focus equally on the social context of the fisheries and to understand the human behaviour of how people use and value the ES (Berkes, 2003; Castello *et al*., 2013; Ostrom *et al*., 1999).

1.5 Local and regional relevance of the research

The research will be relevant to several stakeholders and at a number of scales. It will make a significant contribution to current debates on how ES function in a social-ecological context. Several national and international organisations, including the UK's Natural Environment Research Council and International Union for Conservation of Nature (IUCN), as well as many authors (e.g. Cumming *et al*., 2006; Rodriguez *et al*., 2006) have underlined the urgency for a better understanding of how ES function at different scales, their interactions and their perceived value in a social-ecological context. More specifically, the research will assess the links and feedbacks between the ES and human systems, how these may develop in the face of environmental change and what social or economic benefits there might be for people by correct decision-making and management approaches.

At the national scale, the research aims to inform development plans for the region (infrastructural, resource extraction) and contribute to Guyana's obligations to the Convention on Biological Diversity. At a local scale the research will arm the communities with new maps visualising the most important ES distribution and supply areas. These maps will also show the temporal difference between the dry and wet seasons, which is completely new for the area and could be very important for future land and development discussions. A better understanding of the ES condition and how they vary with spatial and temporal scale will also be important to ensuring a healthy and sustainable supply of the ES. Additionally, the thesis also strives to validate the Makushi's ecological and cultural knowledge, which may increase their influence on decision-making for the area.

Significant value will also be added by looking at how ES function within natural systems at a range of scales and how different stakeholders perceive ES, their importance and linkages. This holistic approach will provide a much better understanding of the pressures that ES are under and will hopefully lead to more appropriate and inclusive management approaches, which may even provide an assessment process that is replicable for low-income countries similar to Guyana.

1.6 Outline of thesis

The interdisciplinary approach of the thesis has required me to amalgamate different scientific areas, those of the social and natural sciences. The layout of this thesis has thus adopted a more human geography structure, where the results and discussion of the findings are discussed together in the same chapter, while the overall layout of chapters adheres to a more traditional natural sciences structure.

The language used has been adapted accordingly to the discipline of the four results chapters. However, a compromise for both areas was inevitable to make the language flow from one chapter to the next. In total the thesis comprises eight chapters as follows:

Chapter 2: The Literature review outlines and discusses the existing research which informs this thesis. It starts with a review of how community-based natural resource management projects were developed and their strengths and weaknesses. It follows by outlining the development of the ecosystem services concept, and the conceptual framework used in this thesis. Thereafter, the complexities of scale are thoroughly outlined and discussed, before the issue of valuation of ES is discussed. The chapter ends with a brief review of tropical freshwater systems and fisheries where current research needs are identified.

Chapter 3: The Methodology starts with a comprehensive discussion around ethics and my positionality in the research process. This is followed by a more in depth description of the research location both ecologically and socially. The research design is then outlined and justified, and the step by step process of collecting the data is described. Lastly, the approach and methods used to analyse the data are described, together with the limitations of the research.

Chapter 4: Stakeholders' perceptions of ecosystem services: implications of scale and the use of the ecosystem services concept, reveals and discusses the findings in relation to the first research aim regarding the perspectives and valuation of ES by stakeholders at different scales.

Chapter 5: Ecosystem services in the North Rupununi: their status, and the effect of temporal scale and spatial heterogeneity. This chapter describes and explains the findings related to the second research aim. The status of ES (water quality, fish and biodiversity) in the North Rupununi is described alongside discussions of long-term trends and how the seasons affect the condition of ES.

Chapter 6: The importance of spatial scale for ecosystem services in the North Rupununi. This chapter illustrates the spatial patterns of the ES and their mapping, which are linked to the third research aim. It also discusses the spatial patterns of ES use and supply, and the consequences these findings have on the well-being of the local communities and potential future changes.

Chapter 7: Implications of the research findings for the management of the North Rupununi. This chapter discusses different management options available for an area like, the North Rupununi, in light of the new research findings and concludes with some recommendations.

Chapter 8: Conclusions. This chapter summarises the contribution this thesis has made to further the understanding of the complex relationship between ES and spatial and temporal scale. The chapter outlines and discusses the research findings and their wider applications.

Chapter 2

Ecosystem services and natural resource management: issues with scale, valuation and assessments

The previous chapter outlined the urgent need for a better understanding of ES condition, distribution, value, and the importance of temporal and spatial scale. This chapter develops these arguments in more depth, providing the theoretical grounding on which the later empirical research will be based. The first section explores the development of different conservation approaches leading up to the concept of ES. This section focuses particularly on the conditions that are required for community-based management projects to be successful. The second section focuses on the ES concept: its background, classification system, and use. The third section seeks to outline and discuss the complexity of temporal and spatial scale in relation to ES, while the fourth section discusses the issue of value and perspectives of ES, with an overview of the numerous methods of valuation. The fifth section describes some relevant ecological concepts, such as 'source and sink' and 'hotspots'. The last section addresses the ecology and conservation of tropical wetlands and flood pulse river systems with a particular focus on fish, as this is the social-ecological system this thesis centres its exploration on.

2.1 Natural resource management in developing countries

Since the end of the nineteenth century, conservation scientists have established protected areas to conserve wildlife and biodiversity (Adams *et al*., 2004). This top down 'Control and Command' narrative is sometime referred to as 'fortress conservation', and was the preferred conservation discourse and practice for much of the twentieth century (Büscher and Whande, 2007). The protected area approach is founded on the principle of putting up borders to keep wildlife in and people out. It has been the cornerstone of most national and international conservation strategies, as they act as refuges for species and ecosystems which would not be able to survive in the changing landscape (Dudley, 2008). However, this top down fortress conservation approach has been widely criticised, as local people have been removed from their land and the right to use the area has in many cases been taken away from them. This approach often led, and still leads, to great conflicts between local people and protected areas (West *et al*., 2006). As a result, the conservation goals are usually not met, and in some cases it has even led to increased poverty for the communities involved, as they have not been able to access the resources they depend upon (Fisher and Christopher, 2007).

The conception that poor people cause environmental degradation is long-standing, and was one of the main arguments for the Command and Control narrative (Garnett *et al.*, 2007). In 1798, Thomas Malthus wrote that poor people "seem to always live from hand to mouth. Their present wants employ their whole attention and they seldom think of the future" (p. 30). This statement indirectly suggests that poor people are incapable of thinking of the future, and thus are more likely to engage in unsustainable behaviour (Gray and Moseley, 2005). The colonial powers in the Global South embraced this notion and commonly identified the activities of poor local peasants as key causes of environmental degradation (Gray and Moseley, 2005). In the 1980s, the concept of sustainable development renewed vigour for the poverty-environment degradation idea, and in 1996 the World Bank stated, "Poverty is also a factor in accelerating environmental degradation, since the poor with shorter time horizons… are unable to invest in natural resource management" (World Bank, 1996, in Gray and Moseley, 2005, p. 9).

However, environmental justice literature argues the opposite is true – that it is in fact the poor who are often more concerned about the environment, as they are the ones who depend upon the natural resources the most. Geist and Lambin (2002) support this argument, as they found in their meta-analyses on a global scale that poverty is not generally a driver of tropical deforestation. Furthermore, scale is an important issue in this context, because wealth might lead to better environmental conditions locally, but with wealth comes higher demand for resources, which usually leads to pollution in other locations. The different sides of this argument suggest that the link between conservation and poverty is more complex than earlier believed (Gray and Moseley, 2005).

The limited conservation success of protected areas in developing countries together with the realisation of the complex relationship between conservation and poverty led to the decline in its popularity as a conservation approach, and the acknowledgement that major changes were needed to address its weaknesses. From these realisations, a more integrated approach developed, which recognised the interconnectedness of social and ecological systems; this meant humans had to be part of the solution, as without their participation the conservation goal would be unsuccessful (Berkes and Folke, 1998; Mishra *et al*., 2009).

The first type of these projects was called 'integrated conservation and development project' (ICDP), and the first was set up in the mid-1960s for a development project in Zambia (Garnett *et al*., 2007). This project was different, as it set out to manage wildlife sustainably for the benefit of the local people. Yet it was not until 1982, at the World Parks Congress, that the principle of incorporating local people's needs into protected-area planning was agreed. During the following two decades, the 80s and 90s, a paradigm shift in conservation and natural resource management occurred, away from the costly state-centred Command and Control approach, towards one where the community plays a central role in the management and protection of natural systems (Shackleton *et al*., 2002). The main objective of this approach was to create a bottom up participatory model, where the resource users are involved in taking decisions relating to the resources they depend upon, and the aims of both conservation and development should be met. This approach is called 'community-based natural resource management' or just 'community-based management' (CBM), and several different types exist: integrated conservation and development projects; community-based forestry; community-based wildlife management and community-based ecotourism.

Focusing on the community level for management and conservation makes a lot of sense, considering that it is often local communities that detect ecosystem change first, as they are the primary resource users. Their roles include knowledge, experience, institutions and organisational capabilities, which should be acknowledged and embedded in any governance system that aims to strengthen the capacity of a community to manage ecosystems sustainably for human well-being (Fabricius *et al*., 2007). The community perspective is essential, as many local communities have contextual knowledge about their environment that has evolved through generations of experimentation, trial, and error (Berkes, 2003). This vital knowledge has many names such as indigenous knowledge, local knowledge, and traditional ecological knowledge[4] (TEK), but regardless of its name it should be incorporated into ecosystem management policies and strategies to improve their sustainability (Fabricius *et al*., 2007). In addition to this, the direct dependence on natural resources for most rural poor people means that a more effective natural resource management should aid in tackling poverty (Frost and Bond, 2008).

However, despite the many benefits identified by using a community-based approach, the success rates of these projects have historically been limited (Garnett *et al.*, 2007). There are several successful case studies such as the 'Poverty and Environment Amazonia project', which provided farmers with additional income through a multilayer agroforestry system that is biodiversity friendly (McNeeley and Scherr, 2003). Another example is Mamirauá Sustainable Development Reserve in Brazil, which managed to transform a reserve from the strictest protection category, where neither human habitation nor extraction was allowed, to a

4 TEK has been defined as 'a cumulative body of knowledge and beliefs, evolving through adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment (Berkes, 1999, p.87).

Sustainable Reserve where local people are allowed to harvest sustainably and are employed to undertake conservation and surveillance work. As a consequence, the local people are now supportive of the reserve, as goals of income generating activity and conservation are able to be combined (Koziell and Inoue, 2006). Despite these positive examples, the community approach has not managed to achieve the anticipated shift towards sustainable land management in the tropics. Many books and articles have been written on this subject; the main reasons identified for the limited success rate will be discussed in the following section.

2.2 What is needed to make community-based management more successful?

For centuries many indigenous communities have been able to manage their resources sustainably. However, in today's globalised world, society is more interconnected and complex than in the past, which means there are several factors and powers beyond the control of most communities (Carlsson and Berkes, 2005). This multi-scalar issue of natural resource management has been identified as a key reason it is difficult to create successful CBM projects (Berkes, 2006). Many other limiting factors for the CBM have been identified in the literature and these are listed in Table 2.1. Apart from these issues, another factor emphasised in the literature as particularly important when designing CBM schemes is the community's capacity and its knowledge level (Berkes, 2003). The issues of both scale and knowledge will be further discussed in relation to the ES approach in the following sections.

Table 2.1: List of the most common reasons for unsuccessful CBM projects

Issues	**Summary**	**References**
Oversimplified views of community	Communities are often heterogeneous and showing characteristics of complex systems. In a community, people's interests may vary depending on gender, age, class, socio-economic group or ethnic group. Due to these complexities within communities any management project needs to consider the different opinions and wishes that might exist within a community.	Brown (2002); Leach *et al*. (1999); Berkes (2003); Chakraborty (2001); Agrawal & Gibson (1999); Berkes (2006)
Lack of social and cultural consideration	An interdisciplinary approach to conservation and development is not only essential to optimise the efficiency of these programmes but equally important for ethical reasons.	Caillon and Degeorges (2007)
Failure to consider true social cost for the communities	Without the knowledge of the social cost of a protected area the right compensation for the impoverishment caused cannot be correctly established, and it may lead to increased poverty	Brockington and Schmidt-Soltau (2004)

	for these communities.	
Inadequate decentralisation, participation and incentives for the communities	Several studies have found that decentralisation of decision-making is the most important factor for a project to be successful.	Brooks *et al*. (2006); Garnett *et al*. (2007)
Lack of context considerations	An adequate biophysical assessment has to be made in the area to provide data on sustainable extraction rates, main ecological threat, and an absolute limit on the extent to which productivity can be enhanced to compensate for the loss of production from a protected area or reduced harvesting.	Garnett *et al*. (2007)
Inappropriate investment and type of development promoted	Another constraint for CBM projects is that they have proven difficult to find adequate benefits from the natural forest and the protected area for local people. It has been argued that the generated economic benefits of protected areas are often far less than needed. This has led to the conclusion that CBM is only viable in situations where there are few poor people.	Kepe *et al*. (2004); Wunder (2001)
Use of weak institutions	Taking an institutional approach focuses on the ability of communities to create and enforce rules, which makes CBM more likely to be fruitful.	Agrawal and Gibson (1999); Olsson and Folke (2001)
Inadequate understanding of management of the 'commons'	The key issue for a community is to have the ability to limit access of outsiders and to self-regulate its own use.	Ostrom (1990); Hardin (1968); Berkes (2006, 2007)

The issues identified in the literature (Table 2.1) as responsible for the patchy success achieved with the CBM approach will most likely be equally important in any future management attempts. So regardless of whether a CBM or an ES approach is used, these issues need to be considered and addressed, both in research and in practice, as more understanding of this area is necessary to improve the success of conservation and development programmes.

2.3 The ecosystem services approach

The ecosystem services concept is a relatively new approach to natural resource management, as discussed in the previous chapter. It was developed to better describe the connectedness of human society with the natural world, and illustrate how human well-being is dependent on ES. Vihervaara (2010b, p. 316) describes the ES concept as "it translates complex ecological interactions into common language, and increases our awareness of our dependence on biodiversity and healthy ecosystems". It has mainly been developed since the 1990s, though the idea of human and natural systems being coupled had been discussed earlier. Mooney and Ehrlich (1997) trace the beginning of the concept back to George Perkins Marsh's *Man and Nature* in 1864, whereas Vihervaara *et al*. (2010b) refer to Odum (1959) as the first paper to discuss the coupleness of human and natural systems. The next mention of environmental services was in Westman (1977), which came from a more economic angle. Apart from these studies there was also Nguyen (1979), Ehrlich and Mooney (1983), and de Groot (1987), which highlighted the utilitarian benefits of ecosystems for people. The concept continued to grow and became more mainstream in the literature throughout the 1990s with papers such as Costanza and Daly (1992), Perrings *et al*. (1992) and Costanza *et al*. (1997). In the beginning, the concept was mainly seen as an education and communication tool, as a way to make decision-makers understand that ecosystems provide humans with vital benefits for free. However, since the end of the 1990s a shift occurred towards focusing on the economic value of ES. Costanza *et al*. (1997) and Daily (1997) published the first two major papers on the importance of assigning an economic value to ES, and since then valuation has dominated much of the debate. This is an issue that will be discussed in more detail later on in the chapter (see section 2.4).

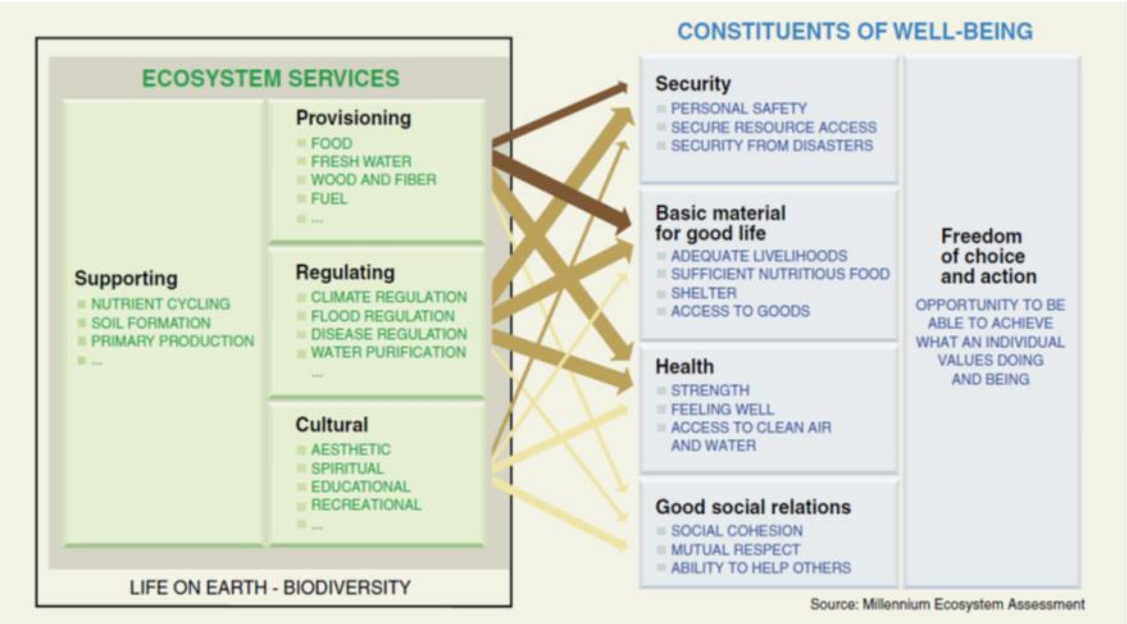


Figure 2.1: Classification of ES by the MA and how ES are interlinked with human well-being (Source: MA, 2005)

The most commonly used classification of ES is the one presented in the MA (2005) (Fig. 2.1), where they divide the different ES into four categories: provisioning, regulating, cultural and supporting services. Provisioning services include all the goods that are extracted from ecosystems, such as food, timber and water. Regulating services are the processes in the ecosystems that regulate the environment, such as climate regulation, water quality and waste treatment (MA, 2005). Cultural services are those that provide recreational, spiritual, educational, social and aesthetic benefits. Supporting services represent the underlying processes for all of the other services to function, such as soil formation and primary production (MA, 2005).

Despite the popularity of this classification of ES some criticisms have been raised by a number of authors (Boyd and Banzhaf, 2007; Fisher *et al*., 2009; Wallace, 2007). Wallace (2007, p. 236) states that "if ES are to provide an effective framework for natural resource decisions, they must be classified in a way that allows comparison and trade-offs amongst the relevant set of potential benefit", and that is not the case with the MA classification. Moreover, he argues that the MA classification mixes ecosystem processes (means) with the final ES, the goods, which could lead to double counting, and limits the ES concept's contribution to decision-making concerning biodiversity. In contrast, Boyd and Banzhaf (2007) propose a classification more rooted in economic principles, which would allow a universal ecosystem accounting unit to be established. Costanza (2008) argues that the world needs multiple classification systems as the framework is used for different purposes, that having several systems is an opportunity to enrich our thinking around ES, and that it should not be seen as a problem that several systems exist. In this study, the MA classification is used because it is the most popular method, which allows for more comparisons to other studies, and because there is no risk of double counting as no monetary valuation will be estimated.

Figure 2.1 also illustrates how the ES concept is linked to the constituents of human well-being. Carpenter *et al*. (2009, p. 1209) state that "the fundamental challenge is to understand the dynamics of ES and human well-being as they interact from local to global scales in the context of multiple changing drivers". It is within this field that the thesis's findings aim to contribute. For this research the Millennium Ecosystem Assessment conceptual framework (Fig. 2.2) will be used, which is a framework of interaction between ES, human well-being, biodiversity and drivers of change (MA, 2005). The MA's conceptual framework positions humans as integral parts of the ecosystems and shows that a dynamic interaction exists between humans and the ecosystems at all scales (local, regional, global). Changes to the human condition cause both direct and indirect changes in the ecosystem, which then cause changes in human well-being (MA, 2005). The framework also recognises that the changes humans cause to the ecosystems also influence other species and ecosystems (MA, 2005).

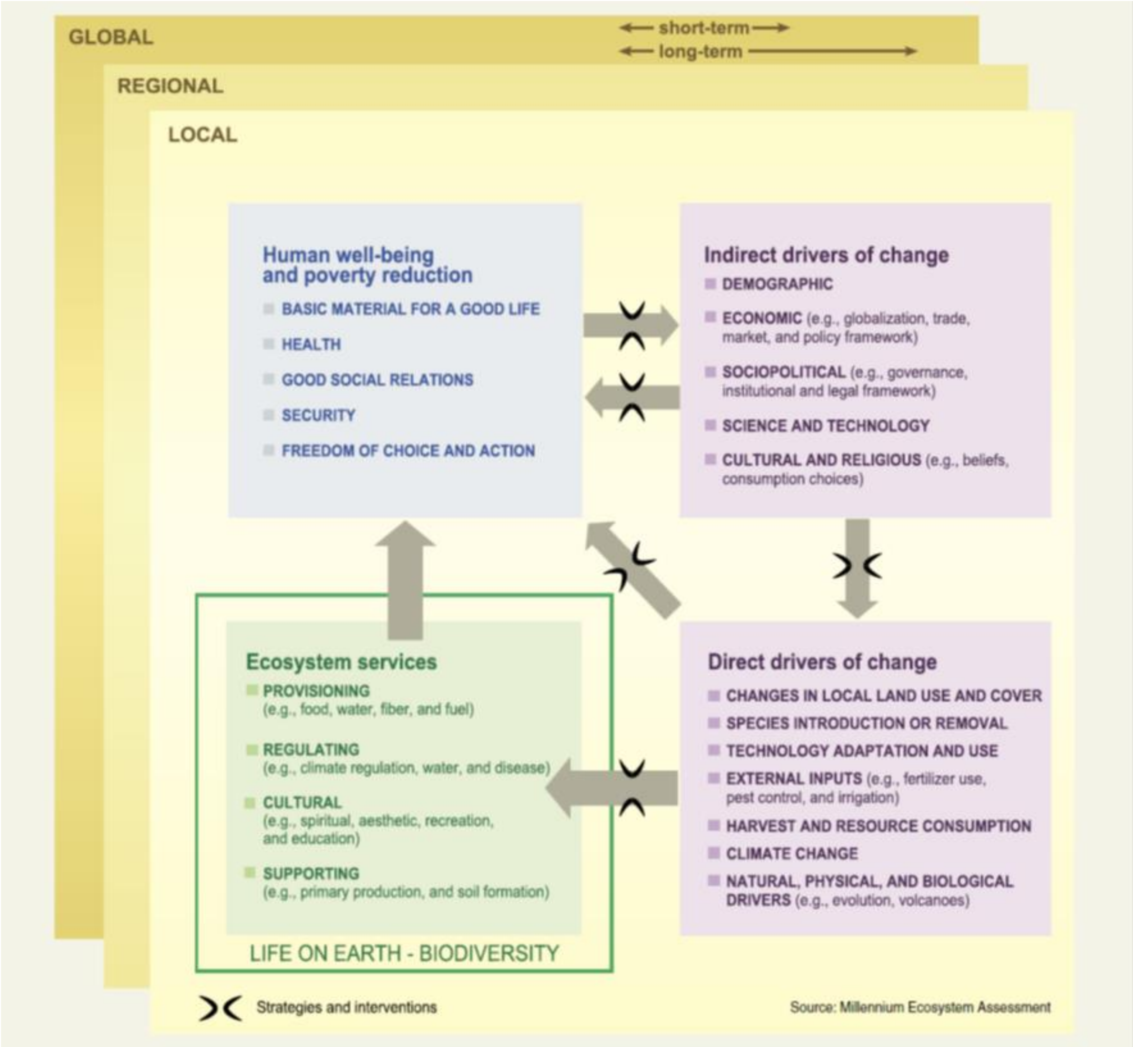


Figure 2.2: The Millennium Ecosystem Assessment conceptual framework (Source: MA, 2005).

As a concept and framework, ES have proven to be an effective communication tool, and the concept has been embraced by many decision–makers around the world. Many researchers have also embraced this new concept and used it to identify, measure, value, map and/or model the stocks and flows of different ES and the synergies and/or trade-offs that may occur (i.e. Kremen, 2005; Luck *et al.*, 2009; Tallis and Polasky, 2009). Several new management approaches, such as REDD+ and PES, have also been developed and tried since the end of the 1990s.

The ES concept has brought many benefits that will aid in the sustainable management of biodiversity and ecosystems. Ingram *et al*. (2012) identify at least three of these new opportunities which include: (i) the development of broader constituencies for conservation and expanded possibilities to influence decision-making; (ii) opportunities to add or create new value to protected areas; (iii) the opportunities to manage ecosystems sustainably outside of protected areas. Despite these benefits, the utility of the ES framework and its associated tools are being questioned and discussed among conservationists (Ingram *et al*., 2012). Particular areas of concern are: species without utilitarian or economic value; ecosystems whose value varies with time and spatial scale; ecological processes that do not directly benefit people; and critical ecological functions that may be undermined in attempts to optimise a target service (Ingram *et al*., 2012).

The main areas where more research is needed within the field of ES science were discussed in the previous chapter; these areas, which also correspond to the focus of this thesis, are described and discussed in more detail in the following sections. First, the issue of scale is discussed in relation to ES and their management. Then the issue of valuation of ES will be outlined in more detail. The last section focuses on the need to improve the understanding of fish as an ES in a tropical small-scale fisheries context.

2.4 Implication of spatial and temporal scale for ecosystem services

Scale is a foundational concept in geography together with space, place and territory (Born and Purcell, 2006). However, how the concept of 'scale' is used varies greatly, particularly between human and physical geography (Sayre, 2006). Physical geography understands and use scale in a cartographic and geographic sense, where geographic scale refers to the spatial extent of a study or phenomena and cartographic scale refer to a distance on the ground and how this is captured on a map (Marston, 2000). Thus, for physical geography, scale is mostly viewed as an empirical spatial extent and of being hierarchical in nature (Marston 2000). Whereas, in human geography the key principles about scale are: scale is socially produced, scale is both fluid and fixed, and scale is a fundamentally relational concept (Born and Purcell, 2006). Scale is of pertinent concern in this thesis, as the research aim is to bring some clarity to the relationship between ES and temporal and spatial scale. This section will therefore outline and discuss scale-related issues within both the human and physical geography, such as why it is an important factor to understand when studying social-ecological systems, and where the knowledge gaps are in the literature.

2.4.1 Human geography views on scale

The issue of scale has received increasing attention by human geographers since the early 1990s (Marston, 2000). The traditional view of scale and the one which is used in physical geography and ecology is that scale is self-evident or a pre-given platform for geographical processes. This has been questioned by some human geographers who have introduced a more dynamic conceptualization of scale where the emphasis is on process, evolution and socio-political contestation (Brenner, 2001). Marston is one of the scholars leading a critical discussion on views of scale and she highlights in her review of scale that “what is consistent among social theorist in geography is the commitment to a constructionist framework and the rejection of scale as an ontologically given category" (2000, p. 220). The more traditional views of scale have assumed scale to a preordained hierarchical framework for ordering the world – local, regional, national and global (Marston, 2000). In the review, Marston identified Howitt (1998), amongst others, whom insist that scale should not be seen as size (census tract, province, continent) and level (local, regional, national), but as a relational element in a complex mix that also includes space, place, and environment (Marston, 2000). Howitt (1998) also highlighted that only considering size and level, which has been the more traditional view of scale, oversimplifies scale and it is important to understand scale as relational as it enables the recognition of all three facets of scale (size, level and relational), thereby complicating the concept.

Marston *et al*. (2005) continue to challenge the more traditional view of scale by suggesting that three choices exist for the thinking of scale. First the hierarchical scale could be affirmed; or second, hybrid models can be developed which integrate vertical and horizontal understandings of socio-spatial processes; or third, the hierarchical scale can be abandoned. The third option was proposed to be adopted, which resulted in a lot of debate among the academic community (Jonas, 2006, Hoefle, 2006).

Hoefle (2006), defending the concept of scale, used one of his research sites in the Amazon to illustrate that even if social movements try to circumvent top-down political hierarchies, these need to be understood as the failure and success of alternative politics in the Amazon hinge on working through all scales of political alliances. He suggests a framework which illustrates the true complexity of scale and to some extent illustrate the power embedded in particular constructions of scale (Fig. 2.3).

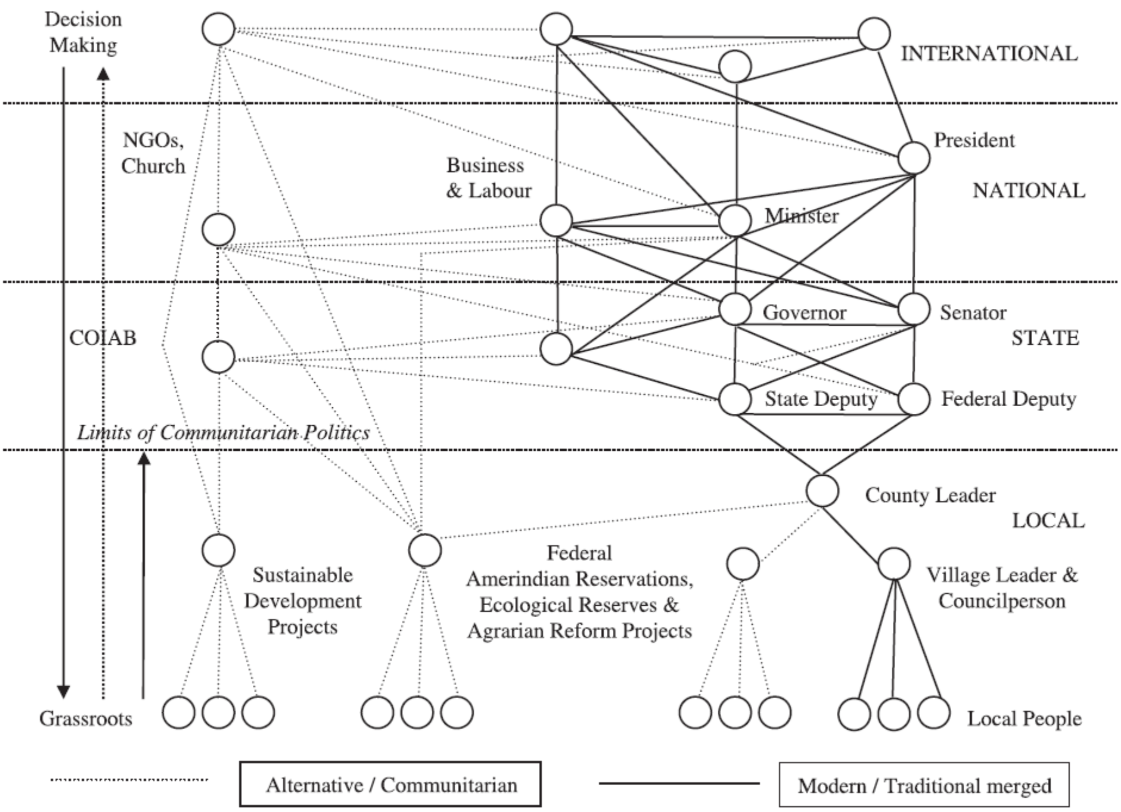


Figure 2.3: The juxtaposition of hierarchical and alternative politics in the Brazilian Amazon (Source: Hoefle, 2000)

In the Amazon, for example, a wide range of actors from community, municipality, regional, national and global-level all engage in a power struggle (Hoefle, 2006). Hoefle (2006) argues that scale is needed here to understand the political complexity and the power dynamics (Fig. 2.3) as the power at each scale of this complex web needs to be understood and included for any development and environmental programme to work. Whereas Marston *et al.* (2005) argues that the very idea of these different scales should be challenged. However, attempts by international NGOs to ignore this complex network due to frustration of the intermediary scales of power and work directly with local communities often fails because of by passing national or regional players who are committed to nationalist objectives and thus act as a barrier for foreign NGO efforts (Hoefle, 2006). Therefore, this example shows that development and environmental projects need to be based on multi-scalar politics which recognises the hierarchal structure of power to be successful (Hoefle, 2006). This thesis has thus adopted a more physical and ecological approach to scale in relation to studying the impacts of temporal and spatial scale on the patterns of ES. However, in regards to studying the perspectives of ES among stakeholders at different spatial scale a more integrated approach from the different disciplines are adopted.

2.4.2 An overview of ecosystem services and scale

Most ES can be broadly classified as operating on local, regional, global or multiple scales. For example, predators that provide pest control for crops generally operate at a local scale, while forests contribute to climate regulation at local, regional and global scales (Kremen, 2005). Understanding and considering the spatial scales at which ES operate is important, because it has been shown that stakeholders at different spatial scales often attach a different value to ES and that different stakeholders construct problems at particular scales i.e. the politics of scale, depending on the impact of the ES on their income and /or living conditions (Hein *et al*., 2006). This is particularly important when the valuation is used for developing landscape-level conservation and management plans. Stakeholders' different interests at different scales often result in different visions for management of the area, which will be further discussed in the next section on ES and valuation. This can, in turn, lead to conflicts over management if these different interests are not properly understood and acknowledged. The valuation of ES according to scale can also be used as a basis for establishing compensation payments to local stakeholders and to provide insight into the appropriate institutional scales for decision-making on ecosystem management (Hein *et al*., 2006).

In the scale of a socio-economic system a hierarchy of institutions, or a vertical scale, can be distinguished (Becker and Ostrom, 1995). These reflect the different scales at which decisions on the utilisation of capital, labour and natural resources are taken. The lowest institutional scale includes individuals and households. Higher institutional scales are the communal, municipal, state, provincial, national and international levels. The supply of ES affects stakeholders at all institutional levels, but whether they are regarded as valuable or not depends on the scale and the stakeholder (Berkes and Folke, 1998). Analysis of the value of an ES at different spatial scales requires assessing at which scale and to whom the benefits of the ES accrue. By considering scale, and stakeholders, it is possible to identify the appropriate institutional level for decision-making (Hein *et al*., 2006). This thesis will explore this topic further, as more research is needed within this field. It relates to the first research aim and the results are discussed in chapter 4.

Identifying the spatial areas that provide an ES is crucial to ensuring its sustainable use. Sometimes an area contributes disproportionately to ES provision, for example, having a higher than average number of fish; in these instances, the areas need to be prioritised and managed accordingly (van Jaarsveld *et al*., 2005). There are also areas where ES supply falls short of demand, e.g. if the demand for fish is higher than the amount of fish that can be extracted/supplied by the river or lake. In these areas, which often coincide with areas of high biodiversity value, tensions often arise because of human needs and aspirations (van Jaarsveld *et al*., 2005). These regions with high socio-ecological tension need to be subjected to careful planning in order to maximise ES without compromising their integrity. These areas are also where trade-off analysis may be of particular importance for decision makers (van Jaarsveld *et al*., 2005).

2.4.3 Trade-offs between ecosystem services

Trade-offs of ES occurs when one or several ES are used or prioritised more heavily than other ES (Busch, 2012; Rodriguez *et al*., 2006). In some cases trade-offs may be an explicit choice, but in others, trade-offs arise without premeditation or even awareness that they are taking place (Rodriguez *et al*., 2006). Knowledge and awareness of the interactions between ES are necessary for making sound decisions about how to manage natural systems appropriately (Balvanera *et al*., 2001; Raudsepp-Hearne *et al*., 2010). Some of the difficult decisions managers of ES have to make are the necessary trade-offs between: (i) the provision of different types of ES; (ii) current and future benefits to society; (iii) societal needs and ecosystem requirements; and (iv) placing emphasis on providing access to services in one region over another. The decisions are further complicated as they invariably revolve around trade-offs between different value systems, needs and desires among communities (Busch, 2012; van Jaarsveld *et al*., 2005).

Trade-offs in ES can be classified along three axes: spatial scale, temporal scale and reversibility (Rodriguez *et al*., 2006). Spatial scale refers to whether the effects of the management decision (i.e. trade-off) are felt locally or at a distant location. Temporal scale refers to whether the effect takes place relatively rapidly or slowly. Reversibility expresses the likelihood that the perturbed ecosystem service may return to its original state if the perturbation ceases. An example of a spatial scale trade-off is the USA, which relies heavily on additional fertilisers in their agriculture. The effects of the high level of artificial fertilisation have resulted in massive changes in downstream areas. Fertilisation by many individual farmers has had the cumulative effect of creating a hypoxic (‘dead’) zone in the Gulf of Mexico. The dead zone has resulted in declines in shrimp fisheries, as well as in other local fisheries in the region. This example demonstrates that attempts to maintain and increase the provision of one service, food, have caused substantial declines in many ES in other locations. The effect of this trade-off is felt over a large spatial scale, and is likely to last for a long time (Busch, 2012; Tilman *et al*., 2002).

Trade-offs across ES often occurs when management actions affect more than one service at a time; these may operate at different scales simultaneously. Knowledge of the different scales at which policies should be targeted is a key component of management. Often more than one ES is traded off to enhance another ES. A good example is the reduced number of the Gyps vultures in India (Juniper, 2013; Rodriguez *et al*., 2006). The Gyps vultures play an important role as natural rubbish collectors in many parts of the country, particularly of cattle carcasses, which are usually disposed of on the edges of towns and villages. As the vultures declined, the number of carcasses increased, and with them the number of carnivorous animals feeding on the carcasses, particularly feral dogs, went up. These areas became dangerous for the local population as many feral dogs had rabies. It was eventually found that the decline of vultures was due to the use of the anti-inflammatory drug diclofenac in cattle, which was used to improve their health (Juniper, 2013). This example shows that an action taken to improve the welfare of animals had a series of cascading unanticipated and unknown effects on many other ES, including a likely impact on human health in the area (Rodriguez *et al*., 2006).

The valuation of ES by the conventional methods only captures the services that are perceived by society as more important, which is usually the provisioning and regulating services. This means that these methods do not fully capture trade-offs of cultural and supporting services. To enable the inclusion of trade-off effects in policy making Rodriguez *et al*. (2006) suggest that natural resource managers should implement monitoring programmes that monitor both short-term provision of ES and the long-term evolution of slowly changing variables on site and if possible at several scales. This could then lead to those policies taking into account ES trade-offs at multiple and temporal scales.

2.4.4 Scale-related complexities in natural resource management

In the past, nature was viewed as linear and predictable, whereas now, nature is recognised as being complex, with several scales that are linked both with internal levels and cross-scale linkages (Berkes *et al*., 2003). Berkes (2006) identifies four scale-related issues that need to be explored for natural resource management to be successful: (i) complexity at the level of the community itself; (ii) the existence of external drivers of change; (iii) the problem of mismatch of resource and institutional boundaries, i.e. the issue of fit; and (iv) the necessity to identify and deal with cross-scale issues.

First, the concept of community has in many instances been idealised and simplified, whereby communities are seen as small, homogenous, and without internal conflict, and are assumed to be able to act as democratic and consensual units (Brown, 2002; Chakraborty, 2001). In reality, communities contain individuals that harbour different aspirations, leadership rivalries, varying degrees and kinds of resource exploitation, and overexploitation (Berkes, 2003; Leach *et al*. 1999).

Second, small-scale community systems are rarely free of the influence of external drivers. External drivers mean “any natural or human induced factor that directly or indirectly causes a change in an ecosystem” (MA, 2003, p. 210). Key factors causing change in a system are central government policies and global markets. A good example of this can be found in Chakraborty's

(2001) study, based on a case study of the Terai region of Nepal, where it was shown that the main reason for deforestation had been the erosion of traditional institutions in forestry, which occurred as a result of changes in the forest policy of the state and demographic and technical changes. This example illustrates the need to take the issue of external drivers into account where possible to make the management more sustainable (Berkes, 2006).

Third, the ecological scale typically needed far exceeds the space that any single community can possibly manage (Barrett *et al*., 2001; Folke *et al*., 2007). It is very rare that the resource boundaries match the institutional boundaries, which then leads to a scale mismatch problem. An extreme example, which highlights the general point, is that no single community could manage a migratory species, such as wildebeests or whales (Barrett *et al*., 2001). The problem of 'fit' between institutions and resource boundaries depends on a number of ecological reasons, including the complexity and dynamics of ecosystems, uncertainty, irreversibility and disturbance (Brown, 2003). Young and Underdal (1997, p. 2) describe the issue of fit in the following way: "The problem of fit asserts that the effectiveness and the robustness of social institutions are functions of the fit between the institutions themselves and the biophysical and social domains in which they operate". The problem of fit is about linkages between functional diversity, key structuring processes and resilience in ecosystems (Folke *et al*., 2007). Social-ecological systems have many levels with different spatial and temporal dimensions. The links between social and ecological systems also vary depending on what scale they occupy (Berkes, 2003). The question that needs to be asked when it comes to conservation at the community level is: How does the scale (temporal, spatial, functional) of an institution relate to the ecosystem being managed, and does it affect the effectiveness and robustness of the institution? (Folke *et al*., 2007) Natural resource management is more likely to work if there is a fit between the level and boundary of the ecosystem and the institution designed to manage it (Berkes, 2006; Folke *et al*., 2007; Robards and Lovecraft, 2010).

Fourth, in natural resource management it appears that most cases are cross-scale. In community-based management, the community represents the lowest scale, the next level up is regional government and agencies, then the national government and the top scale is international organisations and institutions. The cross-scale linkages between institutions are so pervasive that focusing on one scale alone, either the community or the governmental, is never likely to be sufficient to provide for effective management (Berkes, 2006). Cross-scale interplay of institutions involves both horizontal (across space) and vertical linkages (across level of organisation) (Ostrom *et al*., 2002). For management at the community scale, both horizontal and vertical linkages are needed; the horizontal linkages could be for example in community-based wildlife initiatives, where networks between communities involved in the project are built up so that they can talk about their experiences and learn from each other. Such linkages may include multi-stakeholder bodies and networks of non-governmental organisations (NGOs) (Berkes, 2003).

Vertical linkages across scales of organisation can take a number of different forms. Co-management is one of them, and in some cases so are multi-stakeholder bodies, development organisations, citizen science organisations, policy communities and social movement networks (Berkes, 2004). Berkes (2007) suggests that linkages are vital for CBM projects to be successful. He states that from the results of the United Nations Development Equator Initiative (UNDP EI) rich networks of support involving more than a dozen partners and links across four or five scales of organisation seem to be needed to achieve successful CBM projects. One of UNDP EI's examples is the institutional linkages facilitating the activities of an Arapaima giga conservation project in Guyana. Here the linkages cross four organisational scales: the community; the regional level involving the North Rupununi District Development Board (NRDDB), a regional NGO representing the communities, and its key partner, Iwokrama; national government agencies; and the international level involving donor organisations (see Fig. 2.4).

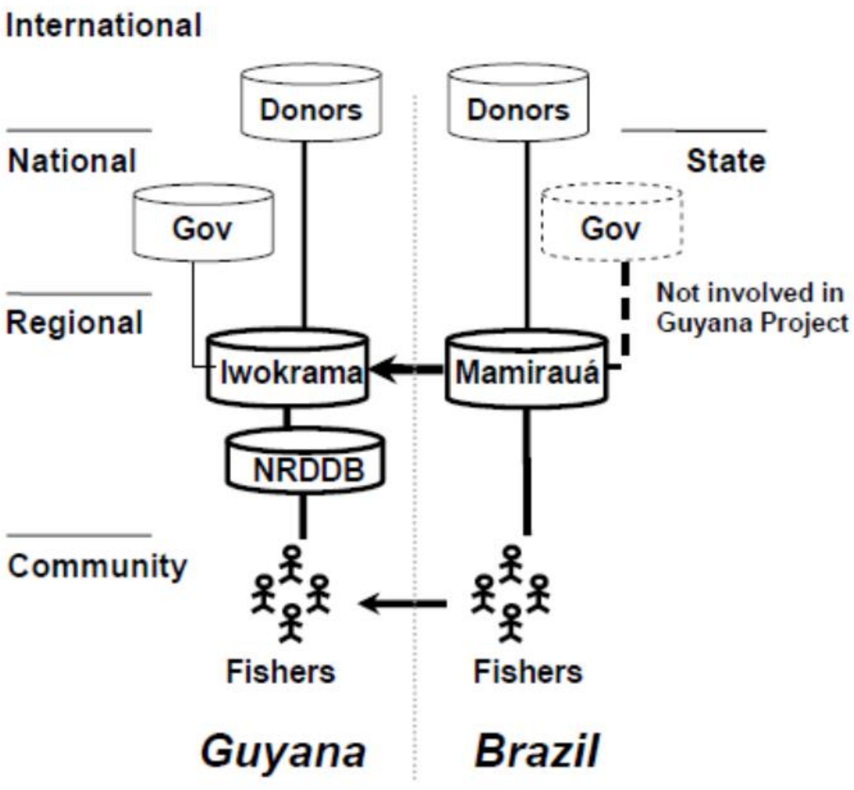


Figure 2.4: Diagram showing organisational linkages across scales in the Arapaima Management Project (Source: Fernandes, 2006)

In the literature the evidence is becoming clearer that systems that consciously address scale issues and the dynamic linkages across them are more successful at assessing problems and finding solutions that are more politically and ecologically sustainable (Berkes, 2007). This leads to the conclusion that in a world that is increasingly recognised as being multi-scalar, solutions must be as well. Top-down approaches are too insensitive to local constraints and opportunities, and bottom-up approaches might be too insensitive to larger problems and external drivers. Cash *et al.* (2006) suggests that what is needed is a middle ground that addresses the complexities of multiple scales, be it institutional interplay, co-management, boundary/ bridging organisations, or an integration of all three.

2.5 Ecology of ecosystem services: scale, meta-ecosystems and source-sink concept

According to Brown (2002, p. 7), "the study of scaling is a way to simplify ecological complexity in order to understand the physical and biological mechanisms that regulate biodiversity". The concept of scale in ecology spread rapidly in the 1980s and increased exponentially during the next decades, leading to a paradigm shift in how ecological research was conducted (Schneider, 2001). As the popularity of the concept grew so did the recognition of the problem of scale. It was acknowledged that natural systems are made up of multiple processes that operate simultaneously on numerous spatial scales (Sayre, 2005). Temporal scale is central to the understanding of 'paradigm shifts', which the resilience concept[5] describes as the transfer from one stable equilibrium to an unstable, or another, unfavourable stable equilibrium. This recognition raises questions of what is the right scale for observation, because if an ecosystem's equilibrium is only stable over a certain time period, the same ecosystem state could be considered either stable or transient, all depending on the scale of observation (Wu and Locks, 1995). Spatial scale shows similar patterns. Any result depends upon the scale of observation, which is linked to different processes being determined by that scale (Levin, 1992), i.e. if one moves along a scale far enough, the dominant process will change (Sayre, 2005).

To aid in this complexity of scale, Levin (1992) provides some general conclusions: first, there is no single correct scale for ecological research; the researcher has to choose the most appropriate scale for the process they are studying. Second, only by addressing ecological phenomena across scales can an integrated, unifying ecology be achieved. Third, research on scale has to be interdisciplinary. Fourth, ecological change needs to be acknowledged as a historical process, where human activities may play a decisive role; human disturbances may

[5] The Resilience concept is "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Holling *et al*., 2004).

depend on the context or sequence in which they occur (Sayre, 2005). Fifth, multiscaled empirical research has revealed the existence of thresholds of change in the behaviour of ecological phenomena. These are points where linear patterns or relationships are disrupted (Brown, 2002). The existence of thresholds indicates that what happens at a small scale cannot necessarily be extrapolated up and vice versa. Sayre (2005) describes the issue of thresholds as a fundamental challenge to reductionist science and its faith in quantitative methods.

Linked to issues of scale is the ‘source and sink’ concept, which is a dominant framework in ecology (Gravel *et al*., 2010; Pulliam, 1988). The ‘source and sink’ habitat concept is based on changes in population dynamics across heterogeneous landscapes and the persistence of populations in ‘sink’ habitats through reliance on inputs from ‘source’ habitats (Liu *et al*., 2011). This means that sink populations may be sustained if they are connected to a ‘source’ habitat (Gravel *et al*., 2010). The connection between habitats is not only restricted to neighbouring habitats; some animals migrate considerable distances, for example spawning fish and migratory birds. This spatial flow of material, nutrient and/or organisms between habitats influences both the ecosystem’s productivity and structure (Christie and Reimchen, 2008). Spatial flows of organisms have been extensively studied within the context of metapopulation, source sink, and metacommunity theories (Hanski and Gaggiotti, 2004).

The meta-ecosystem concept is defined as a set of ecosystems connected by spatial flows of energy, materials and organisms across ecosystem boundaries (Loreau *et al*., 2003). Loreau *et al*. (2003) describe the concept as “a powerful theoretical tool to understand the emergent properties that arise from spatial coupling of local ecosystems, such as global source and sink constraints, diversity-productivity, and stabilization of ecosystem processes and indirect interactions at landscape or regional scales” (2003, p. 673). By using the meta-ecosystem concept it has been shown that dispersal by organisms affects patterns of local and regional species diversity and species’ relative abundance (Loreau, 2000). Dispersal is also known to alter the dynamics of prey-predator systems (Holyoak and Lawler, 1996; Loreau *et al*., 2003). Thus, any increase of dispersal rates either stabilises or destabilises the local interactions, all depending on initial conditions (Loreau *et al*., 2003). The meta-ecosystem concept could potentially provide novel fundamental insights into the processes and functioning of ecosystems, which would lead to an increased ability to predict consequences of land-use changes on biodiversity and the provision of ES to human societies (Loreau *et al*., 2003).

Another concept relevant to this thesis is that of hotspots. Diamond (1975) describes the ‘Hot Spot Hypothesis’ as a network of sites that are connected by migrant species. This means that migratory species play an important role as a connecting agent between ecosystems (Granado-Lorencio *et al*., 2005). By identifying hotspots in the landscape it allows for multiple spatial indices to integrate, which permits for identification of priority areas for ES management (Granado-Lorencio *et al*., 2005; Crossman and Bryan, 2009). This corresponds well to what this thesis seeks to accomplish – to identify hotspots of both connectivity and biodiversity values.

2.6 Valuation and perspectives of ecosystem services

Many scientists (see for example Carpenter *et al*., 2009; Costanza *et al*., 1997; Daily, 1997) now believe that the principal reason for the degradation and decline of ES is that their 'true' values are not considered in economic decision-making. This is founded on the assumption that most decisions are based on market prices; however, for many ES no market exists, which means that the decision-makers have no clear indication of the true value of the services. A better understanding of the value of non-market ES is therefore needed to improve their management and protection.

However, to put a value on ES is not straightforward, particularly with the valuation of non-market services. It is difficult to encapsulate the 'true' value of a non-market service, and the monetary valuation in itself raises ethical questions. According to Farber *et al*. (2002), most ecologists and many natural scientists would prefer not to use the term 'valuation' at all. They argue that it is either impossible, or unwise, to place a monetary value on such 'intangibles' as human life, environmental aesthetics, or long term ecological benefits (Costanza *et al*., 1997). On the other hand, ecological economists (such as I.Bateman and B. Day) claim that ES are already valued every day when decisions are made regarding development and natural resource management.

Another argument from ecologists is that ecosystems should be protected for purely moral or aesthetic reasons. However, Costanza *et al*. (1997) claim that there are equally compelling moral arguments that may be in direct conflict with the moral argument to protect ecosystems – for example, the moral argument that no one should go hungry. Accordingly to Costanza *et al*. (1997), including moral arguments in the valuation of ES makes the valuation more difficult and less explicit. Yet, they argue that both the moral and economic discussions should take place parallel. Costanza *et al*. (2007) also argue that although valuation is difficult and fraught with uncertainties, there is no choice whether or not to value ES, because the decisions that the society already takes imply valuations of nature (although not necessarily expressed in monetary terms). Villa *et al*. (2002) support this view, and state that quantifying the value of ES is important for the social recognition and acceptance of ecosystem management across multiple geographical scales. For example, if considering wetlands, they produce many services and have multiple values; many different stakeholders are involved in wetland use, often leading to con-flicting interests and the over-exploitation of some services (e.g. fisheries or waste disposal) at the expense of others. To ensure a more balanced decision-making (i.e. where multiple uses and values are considered), it is crucial that the ‘true’ value of wetlands are recognised (Ramsar, 2006).

2.6.1 Different valuation methods for ecosystem services

There are several existing methodologies for estimating a value of ES. Apart from ecological criteria, social values and perceptions play an important role in determining the importance and economic value of natural ecosystems and their function (de Groot *et al.*, 2002). The valuation methods that will be discussed fall within five basic types: i) direct market valuation; ii) indirect market valuation; iii) contingent valuation; iv) group/discourse-based valuation; and v) non-monetary methods.

2.6.1.1 Direct market valuation

This is used for services with a market value. These are mainly applicable to provisioning services, the ‘goods’ produced by the ecosystems, and some cultural services such as recreation and regulation services. For example, New York City opted to use natural water regulation services of largely undeveloped watersheds, through purchase or easements, to deliver safe water instead of building a US $6 billion water filtration plant (de Groot *et al*., 2002). This implies that those watersheds are worth up to US $6 billion to New York City (de Groot *et al*., 2002). Considering this example, it is clear that wetlands can be worth a lot of money; property owners are now allowed to capitalise on the demand for wetlands by using trading programs set up for them. Thus when a decision comes up that will affect wetland-related ES, the market value for these services can be used to compare the suggested alternative, which should lead to more sound decision-making (Ramsar, 2006).

2.6.1.2 Indirect market valuation

This is the type of valuation used when services have no explicit market price, such as most regulation and cultural services and all supporting services. Ecological economists have developed a number of techniques for valuing ES that are not valued on the market. The underlying concept of these techniques is based on what a society would be willing to/be able to pay for a service (WTP) or what it would be willing to accept (WTA) to forego that service. The economic valuation methodology essentially constructs WTP for a service, or constructs the adequate compensation for a service loss (Farber *et al*., 2002). To establish the WTP or the WTA for ES, six major valuation techniques have been developed, as described below.

- Avoided Cost: the value which the services allow society to avoid that would have been incurred in the absence of those services. Examples are flood control, which avoids property damages, and waste treatment by wetlands, which avoids health costs.

- Replacement Cost: the value of the cost to replace the service with a man-made system. An example is natural waste treatment by marshes which can be (partly) replaced with costly artificial treatment systems
- Factor Income: the value in which services enhance incomes. An example is natural water quality improvements, which increase commercial fisheries and thereby the income of fishermen.
- Travel Cost: the value of the travel cost to reach an ES. The travel cost can be seen as a reflection of the implied value of the service. An example is recreational areas that attract distant visitors whose value placed on an area must be at least what they are willing to pay to travel to it.
- Hedonic Pricing: the extra value people are willing to pay for associated goods. An example is housing prices on beaches, which usually exceed prices of identical inland homes near less attractive scenery (Farber *et al*., 2002; de Groot *et al*., 2002).

2.6.1.3 Contingent valuation

Contingent valuation (CV) is the conventional application of ecosystem valuation. The method is based on hypothetical scenarios, where a person is asked how much they are WTP for a particular service, or their willingness to accept a loss of a service. This method creates a hypothetical marketplace where no actual transactions are made, which has been successfully used to give a monetary value to commodities that are not exchanged on regular markets. Many applications of the method deal with public goods, such as improvements in water or air quality, and amenities such as national parks. CV has proven particularly useful when implemented alone or jointly with other valuation techniques for non-market services, such as travel cost or hedonic approaches (FAO, 2000). Examples where CV has been used extensively are in the United States, where it has significantly aided policymaking. The World Bank and other donor organisations have also used CV for their policy work. In a project by the World Bank they used the CV method to determine the demand for water supply; it was shown that the method correctly predicted 91 percent of the households that connected to the piped water system (Cropper and Alberini, 1998).

When conducting CV in developing countries, it has been shown that most studies pose WTP questions that use a dichotomous choice approach, where the respondent is asked whether or not they would purchase the specified commodity at the stated prices. This approach is nowadays preferred over alternative approaches, because it reduces the cognitive burden placed on the respondent, and mimics the behaviour of people in regular marketplaces (FAO, 2000).

2.6.1.4 Group valuation/discourse-based valuation

The Group/Discourse-based valuation method is based on the principles of deliberative democracy, and the assumption that public decision-making should result not from the aggregation of separately measured individual preferences, but from a process of free and open public debate (de Groot *et al*., 2002). This method was developed after calls that the CV method only focused on individuals' values of ES. The basic idea of this method is that small groups of citizen-stakeholders can be brought together to deliberate on the economic value of a public service, and that the value derived in this forum can then be used to guide environmental policy. The group is not meant to negotiate, but rather to engage in a deliberative process for making consensus-based judgment that could be of both monetary and/or qualitative value. It is assumed that small groups of citizens can make informed judgments about ES in terms of widely held social values as much as for personal utility (Wilson and Howarth, 2002). Wilson and Howarth (2002) argue that carefully designed discursive methods will help ensure the achievement of social equity goals. Their key message is that CV and the other discourse-based valuation methods should be seen as complementary of each other. However, they do recommend that ES valuations should be cautious of relying upon information generated solely by conventional approaches before more research has been conducted. Additionally, they advise that research conducted in the field of ES valuation should have the principle of social equity as a goal and thus focus on discourse-based methods including stakeholders from all scales (Wilson and Howarth, 2002).

2.6.1.5 Non-monetary methods

Using a non-monetary valuation method similar to the one used in this thesis (chapter 3), Raymond *et al*. (2009) try to capture local people's perception of ES using a community value mapping method, which builds on the concept of identifying and locating ES. They then used this data in the landscape values methodology to link local perception of place to a broader measure of environmental values at the landscape level. To gather this data, Raymond *et al*. (2009) conducted in-depth interviews and performed a mapping task with 56 natural resource management decision-makers and community representatives in Australia, which quantified and mapped values and threats to the ES. This data was then used to map the spatial distribution of ES, and threats in the region, using Geographical Information Systems (GIS) based techniques (Raymond *et al*., 2009). Recent studies using the landscape values methodology have found a moderate degree of spatial coincidence between local biodiversity value and science-based priority areas for management (Brown *et al*., 2004). Brown *et al*. (2004) suggest that incorporation of local perspectives of ecosystem values can complement and strengthen scientific assessments; they propose that both methodologies should be taken into consideration in the conservation planning process.

Van Jaarsveld *et al*.'s (2005) study based on the 'Southern African Millennium Ecosystem Assessment (SAfMA)' incorporated a wide range of participatory research techniques to collect and integrate local knowledge into their value assessment of ES. The techniques they used were focus group workshops, semi-structured interviews, a range of Participatory Rural Appraisal techniques (Chambers, 1994), and forum theatre. This was supplemented with free-hand mapping by community-members, which was incorporated into GIS. Combining local knowledge with formal knowledge can lead to a great deal of uncertainty; it is therefore important to validate the data. Van Jaarsveld *et al*. (2005) used several types of validation: i) cross-validation, meaning local experts validate scientific knowledge, and scientists validate informal knowledge; (ii) 'triangulation', which means that different sources of knowledge are compared (maps, transect walks and semi-structured interviews); and (iii) report-back meetings, where participants present their findings to other local people in an open forum. By using several different techniques in a complementary fashion to validate local knowledge, the credibility of the data is considerably enhanced (van Jaarsveld *et al*., 2005). This is supported by Kaplowitz and Hoehn's (2001) study, which examined whether focus groups and individual interviews revealed the same information regarding natural resource valuation. They concluded that these two methods should be used, because each method yielded somewhat different perspectives on the range of services, values and issues. For example, the focus group revealed more services but withheld more sensitive information regarding some developments in the area. In the interviews, individuals revealed more controversial information, but came up with fewer services. This may be because people feel more comfortable revealing more information when fewer people are present (Kaplowitz and Hoehn, 2001).

2.6.2 Criticism of the conventional valuation methods

The UNESCO World Heritage Conference (2003) and MA (2005) urged the global scientific community to recognise a more comprehensive view of the value of nature, which stems from the intrinsic relationship between culture and nature, people and place. According to Kumar and Kumar (2008), market-based valuation techniques have been declared inadequate for a long time, and the market-constructed CV method, albeit robust, does not seem to capture the expanse, nuances, and intricacies of many of the ES. They argue from a psycho-cultural perspective that the common person's perspective of an ecosystem is quite different to what is conceptualised by conventional economists. Any valuation method must acknowledge and embrace the fact that an individual's identification with nature, their changing preference and learning formation and ecological identity, play a very important role in how they value ES (Kumar and Kumar, 2008). Concepts like ecological identity and sense of place are very important cultural ES. Many indigenous people still have strong heartfelt, spiritual bonds with sacred landscapes, groves, and species (Butler and Oluoch-Kosura, 2006), and people with no direct contact with nature still appreciate and benefit from these cultural services (Frumkin, 2001). Wilson (1984) describes the relationship between humans and nature as ‘Biophilia’, meaning humans have an innate attraction to nature, reflecting an evolutionary-driven understanding of human dependence upon ES (Butler and Oluoch-Kosura, 2006). This relationship between humans and nature has a strong bearing on the psychological well-being of the individual. This still remains uncaptured by most of the conventional valuation methods (Kumar and Kumar, 2008).

An alternative approach to valuing ES is needed, either to be included in the conventional methods or to be used independently more broadly in policy-making (Spash *et al*., 2009). There are key elements of the way in which humans value the environment that appear to be missing from economic explanations of behaviour (Spash *et al*., 2009). This is due to the philosophical basis of economic theory and the psychological model of behaviour they adopt (Kumar and Kumar, 2008). Economic theory assumes a utilitarian philosophy in which a decision’s consequences are determined based on what makes economic sense (Spash and Hanley, 1995). They also assume that individuals are able and willing to consider trade-offs in relation to ES (Spash and Hanley, 1995). However, a body of empirical work has found that a significant proportion of survey respondents treat the environment in a manner which is inconsistent with economic theory (Spash, 2006; Spash and Hanley, 1995). They believe that certain aspects of the environment, such as biodiversity, have an absolute right to be protected; in other words they refuse all “commodification of environmental resources” and they thus refuse to put a value on the environment (Spash *et al*., 2009).

Models of human behaviour have been developed by social psychologists to find out what motivates people to answer the way they do in surveys on valuation of ES. The models challenge the assumptions of mainstream economics but can be integrated into the CV method. Examples include the attitude-behaviour model or theory of reasoned action (Fishbein and Ajzen, 1975) and the related theory of planned behaviour (Ajzen, 1991). Spash *et al*. (2009) suggest that economics should use some of these theories to improve their understanding of human behaviour and produce values of ES that are more complete. They also state that assessing ES value for policy purposes requires understanding the importance of motives behind values, including ethical positions, environmental attitudes and social norms. Failure to consider these multiple values of ecosystems and failure to include stakeholders from multiple scales will lead to policies that do not represent the public opinion. Therefore, more research is needed into non-monetary valuation of ES, which is one of the areas this thesis aims to contribute.

2.7 Traditional ecological knowledge and ecosystem services

Both TEK and Western science are based on an accumulation of observations, but TEK differs in that it is largely dependent on local social mechanisms, which internalise the knowledge they gain over the generations into social institutions and worldviews (Berkes *et al*., 2000). Communities therefore have a unique position in that they have accumulated knowledge and experience from their immediate environment for centuries (Berkes *et al*., 2000), putting them in a very good position to manage their natural resources. Berkes (2003) identifies the end of management by the expert-based approach, and argues that working through partnerships between managers and resource users can help to build a more complete information base that can deal with the implications of complex systems. Working on a participatory approach is also important for civil society because it helps empower indigenous people and community groups (Berkes, 2003).

TEK shapes the base of livelihood strategies and can increase the diversity of ecosystems, which in turn helps to buffer against shocks such as climate and economic fluctuations. It is also very valuable to use when managing ecosystems as it has the capacity to generate services by establishing adaptive institutions that share knowledge (Fabricius *et al*., 2007). Therefore, land use and spiritual practices that nurture diversity can support the adaptive capacity of social-ecological systems. TEK is also important for issues such as 'sense of place' and 'identity and pride', which are major motivations for communities to engage proactively in ecosystem management (Fabricius *et al*., 2007).

TEK is mainly maintained and transmitted through applying it in practice. This means that TEK is highly sensitive to changes in the relationship between people and their ecological resource base (Fabricius *et al*., 2007). According to Gadgil *et al*. (2000), the erosion of TEK and ecological resources depends on two factors: first, new resources are becoming available, such as modern medicine, which make communities less dependent on traditional medicinal plants and animals; and second, communities are increasingly losing control over their local resource base, due to new policies from state and corporate interests. Additionally, Agrawal and Gibson (1999) point to the increased mobility and larger settlements that come with urbanisation and industrialisation as major reasons for the weakening of communal bonds in many communities. The erosion of community capacity and identity leads to unsustainable use of natural resources, and it may leave communities ill-equipped to manage their environment. An example of this can be found in Xu *et al*.'s (2005) study, which examined a number of case histories in China and found that recent developments have devalued and in some cases eliminated TEK and practices in the quest to strengthen the centralised state. Xu *et al*. (2005) highlight that the most powerful contemporary forces shaping both local cultures and biodiversity are the various government policies that aim to modernise, standardise, and scale up production to meet the demand of expanding markets on all levels. As previously discussed, TEK and indigenous cultures are necessary to ensure successful natural resource management. The research approach of this thesis has therefore involved working in collaboration with local indigenous communities and conducting participatory research founded and guided on TEK.

2.8 Ecosystem services assessments of tropical rivers, fish and wetlands

Aquatic and wetlands ecosystems are among the most productive and endangered in the world, as discussed in the previous chapter. They provide a multitude of ES: fish, habitat, clean water, and fibre, and are in many cases important recreational sites with high aesthetic value (Daily, 1997). The longitudinal dimension of a river can be described as a 'river corridor' which consists of a dynamic mosaic of spatial patterns and ecological processes arranged hierarchically across a range of scales (Ward *et al*., 2002). In South America, most large rivers are still unregulated, which is rare in comparison to the rest of the world (Hamilton, 2002). Consequently, these rivers retain their natural hydrological characteristics and thus have extensive floodplains. Floodplains are defined as "areas that are periodically inundated by the lateral overflow of rivers or lakes, and/or by direct precipitation of groundwater; the resulting physiochemical environment causes the biota to respond by morphological, anatomical, physiological, phonological and/or methodological adaptations and produce characteristic community structures" (Junk, 1989, p. 112). Normally flooding occurs annually, due to a combination of geomorphological and hydrological conditions of the landscape that produce the annual flood pulses (Junk, 1989). The hydroperiod (days area is flooded) is linked to the size of the floodplain, logically meaning that the larger the floodplain, the longer the flooding occurs.

Rivers' floodplains are ecotones in which the terrestrial and aquatic environments meet and allow for the exchange of carbon and nutrients between the river channel and the floodplain (Thomaz *et al.*, 2007). This hydrological connectivity between the river and the terrestrial environment therefore influences the productivity of the entire river system and has been linked to the high aquatic biodiversity found in these floodplains (Lasne *et al.*, 2007; Tockner *et al*., 1999). Many of the rivers in South America are nutrient poor, therefore much of the biota rely on the floodplain for their diet, either directly or indirectly (Junk *et al*., 1989; Granado-Lorencio, 2005; Saint-Paul, 2000). Amoros and Bornette (2002, p. 761) describe the 'hydrological connectivity' that the floodpulse creates as ''the permanent and episodic links between the main course of a river and the various waterbodies lying in the alluvial floodplain''. Ward *et al*. (2002, p. 517) states that "hydrological connectivity plays a major though poorly understood role in sustaining riverine landscape diversity and rigorous investigations of connectivity in diverse river systems should provide considerable insight into landscape-level functional processes”. Thus, it is within this field of hydrological connectivity and spatial and temporal heterogeneity that this study will be located.

The hydrological connectivity is inherently linked to the flood pulse of the river (Junk *et al*., 1989; Tockner *et al*., 2000). It affects dispersal rates, reproduction, and age and shape of the biota communities (Labbe and Faush, 2000) and it controls several habitat features, such as vegetation cover, substratum and flow intensity (Amoros, 2001; Lasne *et al*., 2007). This result in natural floodplains creating a landscape made up of various aquatic habitats ranging from lotic to semi-lotic, and lentic habitats (Lasne *et al*., 2007). This in turn has meant that species evolving in these environments have adapted to the natural flow regime and require the spatial heterogeneity to fulfil their whole life cycle (Lytle and Poff, 2004). As a result, many fish species need different habitats for reproduction, growth and refuge (Lasne *et al*., 2007).

In South America the principal criterion used to classify rivers is the amount of suspended sediment in the water (Meade, 1994), which in most cases reflects the water’s optical properties (Goulding, 1980). Three different types can be distinguished: whitewater rivers are muddy in colour due to their high sediment content, blackwater rivers have dark transparent water because of the large amounts of dissolved humic substances, while clearwater rivers drain areas where there is little erosion (Furch and Junk, 1997; Saint-Paul *et al*., 2000). Apart from the low transparency of whitewater rivers, they also differ from black and clearwater rivers in their extensive development of floating and attached herbivorous plant communities, which are most commonly absent in the other water types due to their low nutrient levels (Goulding, 1980).

The ancient Guiana Shield has eroded during geological eras, therefore its surface now consists mainly of resistant formations that release little material into the streams and rivers that drain them. This is partly the reason why many rivers in the Guiana Shield are blackwater with high transparency, low nutrients and low pH. The nutrient levels can be higher if rivers flow across carboniferous strips that supply calcium and other ions (Sioli, 1968).

Much more research is needed into tropical rivers and floodplains; in particular, studies on inundation patterns of major floodplains in South America, which the Rupununi is part of (Ward *et al*., 2002). Floodplains in South America have remained poorly understood because of remoteness and the difficulty of using optical remote sensing technologies due to the high cloud cover over the humid tropics (Hamilton *et al.*, 2002). Hamilton identifies particular areas that need to be addressed in relation to flood plain research as “seasonal timing, predictability, and inter-annual variability in the floodpulse because those features affect the ability of the biota to cope with and benefit from the inundation, and thereby influence which plants and animals can inhabit particular floodplain areas” (2002, p. 1).

2.8.1 Small-scale fisheries: an important ecosystem service in developing countries

Fisheries, particularly small-scale fisheries, are a very important ES, especially for the well-being of many people in poorer communities around the world. As briefly discussed in the previous chapter, small-scale fisheries make important contributions to the local economy in many poor countries (Andrew *et al*., 2007; Chuenpagdee, 2011). They provide both vital protein and income to many rural communities (Allan *et al.*, 2005). The term small-scale fisheries, which normally includes traditional, artisanal and subsistence fisheries (Berkes, 2003), is characterised by a high biodiversity of the catch, frequent use of traditional fishing gear, such as traps and lines, but may include some small engines and tends to be used mostly in developing countries (Berkes, 2003).

Despite the importance of fisheries to human well-being, this ES is being used unsustainably in most waters (Welcomme and Petr, 2004). The overfishing that takes place in freshwaters is often overlooked due to weak reporting and because the decline is often due to a complex mix of pressures (Allan *et al*., 2005). Furthermore, the consequences of overfishing are poorly understood – how it may affect the species, size and trophic composition of fish assemblages (Allan *et al.*, 2005). Therefore, the assessment and management of these fisheries is usually inadequate or absent. Subsequently, in many cases small-scale fisheries fall short of their potential to be a significant driver for development (Andrew *et al*., 2007). For small-scale fisheries to reach their potential they need to be more highly valued by societies so they are used and managed to become more resilient (Allison and Ellis, 2001), because as Armitage and Marschke (2013) and Garcia and Cochrane (2005) argue, a multitude of factors from both inside and outside the community influence small-scale fishery systems, such as economic development and climate change (Mansfield, 2011). Many forces outside the domain of small-scale fisheries operate with an irresistible power, and it is unreasonable to expect fisheries management to overcome them by themselves. To solve or at least improve the use and management of small-scale fisheries is a crucial challenge, and to do it, further understanding of the drivers pushing small-scale fishers is needed. Equally important is a better understanding of fishers’ fishing strategies and patterns, which is what this study aims to contribute towards (Armitage and Marschke, 2013; Chuenpagdee, 2011).

2.9 Conclusions

In this chapter the main paradigms of natural resource management have been discussed and several of the key associated factors that add complexity to the issues of scale and value were reviewed. The use of an ES concept approach to natural resource management, which was shown to be the most popular during the last decade, stressed the benefits this approach provides such as being more holistic, and better at recognising and addressing the complexity of nested socio-ecological systems.

In the review of the scale concept, the different views of what scale constitute for different disciplines were illustrated and the importance of addressing both temporal and spatial scale in natural resource management was made clear. Using the ES approach in natural resource management makes the scale issues even more crucial due to its inherent scale qualities. This is due to the three distinct components of ES, which are; the stock, flow and beneficiaries. The stock of ES is found at site-scale and from the stock flows the ES to wider spatial scales to reach the beneficiaries which might be found at different scales, from local to global. Therefore, more research was identified to be needed that particularly increases the understanding of the relationship and implication of spatial and temporal scale on ES.

The issue of value was also reviewed and the different types of values that are used in natural resource management were discussed. The most popular type of value in connection to the ES approach was shown to be the economic value. The importance in some instances to estimate an economic value to aid decision-making was identified. However, the chapter also critiques many aspects of the economic valuation as being predominately based on unrealistic assumptions of human behaviour. In addition, the methods with which these monetary values are calculated are very sensitive to the wording of the question and information given prior to the survey. From this discussion and the identification of alternative ways of estimating value, the gap in understanding value in a non-monetary way was highlighted and is another area which this thesis aims to contribute.

The importance of key ES, such as water and fish, for human well-being was also highlighted in the chapter. The reliance of ES for people living a subsistence lifestyle, like the Amerindians in this study, was made particularly clear, as most rely on the water and fish provided by the ecosystems for their survival. These two ES were demonstrated to need much further research as there is not much data available on tropical freshwater systems and fish as an ES. They are also particularly suitable for studying issues of scale and values, as watersheds and rivers flow over large spatial areas where different stakeholders use and value water and fish differently. Thus, these services have many cross-scalar issues in terms of both geographic and social scale as the water and fish ES are interlinked with issues of values and perspectives of stakeholders at different geographic and social scales that need to be better understood.

To conclude, this chapter has introduced the literature of natural resource management, and in particularly focused on the ES approach. It has clearly illustrated the further need of research within several of these research topics to which this thesis aims to contribute. The next chapter, Methodology, will describe how and where the research was conducted and the rational for choosing the interdisciplinary methodology approach this thesis has embraced. The following chapter will start with reviewing the author’s positionality during the fieldwork phase of the research and the ethical aspects of conducting this type of research on indigenous land as a foreigner.

Chapter 3

Methodology

The research methodology was underpinned by a philosophy of collaboration and participation with both the local and national stakeholders. The interdisciplinary nature of the thesis meant that methods from both human and physical geography were applied, resulting in a mixed method approach including both qualitative and quantitative methods. This approach was applied to allow an in-depth understanding of the relationship between the local people of the North Rupununi and the ES they depend upon (Seixas, 2004). The ethnographic principles of observing, listening and participating allowed for further insight into how the ES are used, valued and their dynamic spatial and temporal dimensions (Chambers, 1991; McAllister and Vernooy, 1999).

In this chapter, the first section will discuss the ethical considerations and my positionality within this research. The second section will provide a description of the study site, its people, communities and the landscape's physical attributes. The third section will outline the research design and the multitude of methods used to collect the data. The fourth section will describe the data analyses undertaken, and lastly the limitations of this study will be discussed.

3.1 Ethics and positionality of this study

The research ethics I employed in the field were essentially my own moral principles, based on the fundamentals that we are all equals and I am an outsider on the communities' land and in their home. An awareness of the described power relationships between researcher and the researched (Rosaldo, 1989) meant that active approaches to break down this hierarchical mindset among the participants were used.

Throughout the research, conscious actions have been taken to ensure a sound ethical approach. Before the research began, when the research proposal was being written, advice and consent were sought from the following Guyanese national and local development and conservation organisations: North Rupununi District Development Board (NRDDB), Iwokrama International, United Nations Development Program (UNDP), and International Union for Conservation of Nature (IUCN). The information received from these organisations was used to shape the research proposal to make it as relevant and useful as possible for national and local stakeholders.

The first field work visit was conducted in April 2010, to discuss the research proposal in more detail both with national and local organisations, and to arrange logistics for the main field work period. During this three week stay, separate meetings to discuss the relevance of the research were conducted with representatives from Iwokrama International, Conservation International (CI), World Wildlife Fund (WWF), University of Guyana (UG), UNDP, NRDDB and Bina Hill Institute. In general, there was a positive response to the suggested research and only minor changes to the proposal were suggested; these were later addressed along with amendments to the research design.

Before I returned for the main field work period (October 2010 to August 2011), I sought and received research permission for me and my husband, who worked as my research assistant. Permission to do research in Guyana and on Amerindian land was obtained from the Guyanese Environmental Protection Agency (EPA); the Ministry of Amerindian Affairs (MoAA); and the NRDDB.

Once on site in the North Rupununi (November 2010), I wrote to the Toshaos (village chiefs) and village councils of the five communities I wanted to work with, asking for their permission to do research in their respective communities. In the first two communities (Kwatamang and Annai), I attended village meetings to introduce myself, where I explained the purpose of the research, what it would involve, and finally asked for their permission to undertake the research in their village and on their land. Some discussion followed where villagers asked about the benefit for them and why it might be important work. This was explained and after some deliberation among the village councillors they granted me permission.

The village meeting in Kwatamang instantly gave me an insight to the difficulties of doing research in this area. During the meeting quite harsh discussions were taking place and most of it in Makushi, which unfortunately I did not understand. After the meeting councillors and other villagers explained to me that their main concerns were: that a lot of research had already been done in this village, and residents were getting bored of giving their time for no apparent results;"we have not seen any benefits from the research – researchers come and take our time and then we do not see them again"; lastly, "what type of compensation can we get for participating?"

I believe their concerns were valid and important points for all researchers working with indigenous people to remember and contemplate. Firstly, researchers who consider their research to serve the general good of the people, the area and/or country, have to consider the scale issue both in time and space. As a lot of potential research benefits are more policy-related it takes a long time before any benefits can be seen by local people. There is also the spatial aspect – much of the research outcome is used on a national or even global level, making it hard to connect to the researcher that was in the community several years before. This, however, further highlights the importance of being honest and not raising local people's expectations (Simon *et al*., 2003; Young and Barret, 2001). I definitely tried my hardest not to raise their expectations about the research outcome, but at the same time had to highlight the potential local benefits I could perceive to validate the research, and to get the approval of the villages. Was I successful in not raising expectations? I am not sure – comprehension difficulties with languages proved later to be quite severe, and the ingrained view of what a white researcher stands for is hard to avoid or break down (Hovland, 2009). Still, I believe that after months of working with the communities good relationships had formed, a better understanding of the type of research I was conducting became evident, and no disappointment was expressed at any time, which might indicate that expectations were not raised.

Difficulties with the language were mutual in the beginning; unfortunately I had neither the time nor the resources to learn Makushi before starting my field work. Makushi is a mainly spoken language, only a few books exist, and there were no courses I was aware of, making it a difficult language to learn. I did however learn some Makushi while in Rupununi, and started all the focus groups with some introductory phrases in Makushi. The main issue was that even though most locals spoke some English it was still their second language, and many of the respondents did not handle it as well as their native Makushi. They thus struggled to understand me or to express themselves; some would let my interpreter translate, while others preferred to talk in English. It was actually a rather high proportion of people that wanted to speak English, even though their capacity was in many instances quite weak. I was told in one community that my English (Swedish accent) was easier to understand than my husband's (British English), whereas in another community I was told the opposite. My accent and use of the English language was very different from the participants and even from the local research assistants. I did spend a lot of time going through the research questions with the interpreter, explaining what we wanted to do and what we wanted to learn more about. However, in one or two villages it was difficult to keep them to their role as an interpreter, as in some instances, it was felt that the answers were quite influenced by the assistant's knowledge and opinion. With time though, I learned to some extent to accomodate my English with the use of more local phrases and expressions that made it easier to communicate, and the language became less of a problem.

The ingrained view of what a white researcher represents was hard to break in some communities (Clifford and Marcus, 1986; Rosaldo, 1989). I was well aware of the perceived power hierarchies and tried to break these down as much as possible. In each of the communities, in the initial meeting and in the introduction to all the focus groups and interviews I always highlighted that I am here to learn from you, you are the experts. How different people saw me, and approached me, was also very different. The issue that seemed to affect this the most was how much prior contact they had had with white people, or outsiders, which was not completely unexpected. This meant that the situations in each of the communities were different. In some, people relaxed quite quickly as they have had many outside researchers stay and work with them. Whereas, in other instances, it took a long time before the local guide became more relaxed in our presence. To finally see this transformation in our relationship was encouraging and rewarding, because as our relationship improved, so did their confidence as local research assistants, and with that growth so too the quality and quantity of the information gained in the field improved (Field diary, 15/04/2011).

As noted, residents of Kwatamang raised the issue of compensation. Compensation for research participation raises ethical questions and no clear consensus exists on this issue. Personally, I believe compensating participants for their time is completely natural and justifiable. Yet, it may be interpreted as an 'incentive' to participate in the research – this is controversial, as it might lead to more vulnerable people more in need to benefit participating and thus potentially skewing the data (Alderson and Morrow, 2006). Others see the research outcomes as sufficient benefit and believe participants should participate for the greater good; however, when working with people living a subsistence lifestyle, time can be very valuable, and I wanted to ensure I chose the correct ethical line. I thus consulted NRDDB and other researchers who had conducted studies previously in the same area to get their viewpoint on this matter. They informed me that food hampers are the most common gifts as a thank you for someone's time in the North Rupununi. I followed their advice and gave a food hamper (1kg sugar, 1kg flour and 1 soap) to each participant. Local guides and local research assistants were paid a salary that was in line with the average salary for the region, and similar working practices to home (UK) were applied as far as possible (lunch and beverage provided, minimum of 30min lunch break per day, and if the working day was longer than 8hours, or work took place at night, an additional payment was added to the salary).

Regarding the issue Kwatamang raised that a significant amount of research had already been done in their community, it later became clear that there is, or was, an issue in the community that created quite a divide among the villagers. Apparently, the senior councillor did not get on well with the church in the village, and some of the other councillors had thus turned their backs on him. Because the senior councillor showed me support, some of the other councillors were automatically against me. Still, if communities think too much research has been done it is a very valid point and something to bear in mind for future research projects. This is particularly true in regards to NRDDB and Iwokrama, which are normally the main organisations researchers contact to get permission. If they are aware of this feeling in one community they could steer other researchers away from contacting this community, or at least bear it in mind when planning future research design.

The issue of consent was explained to each of the communities when permission was sought, and emphasis was put on explaining that participating is a completely voluntary exercise, which means you do not have to participate unless you want to (Wiles, 2008). I also explained before every interview and focus group that it was completely voluntary, and that they did not have to do this if they did not want to. The research process and the outcome were also explained so the participant would have a better understanding of the reasons this research was conducted, and to make sure that they did not have any exaggerated expectations from the research.

3.1.1 Assigning the local research assistants and guides

In my research design I had decided to work with a research assistant that was experienced in conducting focus groups, and could handle both languages (Makushi and English) and terminology well. However, it became clear very quickly that this approach would not be possible, as in the first and second communities they demanded that I employ an interpreter/local research guide from their community.

I was aware of the Makushi Research Unit (MRU), which is a group of mainly women who have been trained in conducting research to document Makushi culture (Forte, 1996). I was told they had worked with other researchers in the past and thus had experience of conducting focus groups and interviews. It turned out that four out of the five communities had a MRU person that was happy and available to work with me. Time was spent with each assistant before work started to make sure they knew what I wanted to do and understood the research process. I was told by some of the research assistants that other villagers were jealous of them because they got to work and received payment. It was apparent this made some of the assistants uneasy, but they also made it clear that they wanted and needed to work to get the extra money. One assistant was quoted saying:

> "*That work [meaning research assistant] really saved me; don't know what I would have done without it*". (Field notes 20/03/2011)

The interviews and focus groups were also used to identify good local field guides. I wanted to work with several different guides from the same community to cross-check the data I had been given in the interviews and focus groups, but also to get the opportunity to observe and have more informal interviews in the field with different people. In some villages it was harder to find people that had time to work with me, but in most cases it was not an issue. The people who were asked to be my guides were people that seemed extra knowledgeable, and were at ease talking to both me and my husband (research assistant). Some also showed an interest and I tried to accommodate for this as far as possible. However, in some communities it was not my choice who worked with us; this was particularly so when I needed to hire the village's boat and engine. The Toshao then decided who was going to be the captain and who should be the guide. He explained that only a few people were skilled enough to take us safely on the river with the big engine (15 horsepower) and the guide should be someone that works for the village who is willing to be supportive in the 'self-help days'.[6] It was felt that through working with different guides more people would benefit. However, in three of the communities, after the initial mapping of ES and confirmation of the community mapping I ended up working mainly with one local guide in the other three communities. This was not a conscious decision – it was more a result of what worked relationship-wise, and who the Toshao wanted me to work with. I believe that better relationships with these guides were developed as we got to know each other more, and it made my field work easier to work with someone that is reliable, knowledgeable and that you get on with. Our understanding of each other also improved with time, and it felt that it benefitted the research as issues could be talked about more in-depth.

3.1.2 My positionality

As a white woman from Europe, I was aware of the power dynamic as discussed earlier, but I believe it was my gender more than ethnicity that had the most impact on the research and how they saw me. My husband worked as my research assistant; he was a note taker in the focus groups and in the interviews, and helped me collect the physical data such as measuring the water depth and assisting in the water testing, mapping, fishing and paddling. Many found it hard to get used to the fact that I was the researcher and he the assistant. It was never expressed in words to us, but laughter and talking behind our backs implied that this was considered strange. From spending time in the communities it was observed that women and men tended to socialise on their own, and that mixed groups were not common (Field notes 28/01/2011). I also found that most of the fishing was done by the men; women also fished, but they mainly seemed to fish near the village, where they did not need to travel far. With this in mind, it was understandable that when out in the field, the local guides, who were all men, would ask my husband what to do next, or call him the 'boss', instead of me. However, this became better with time. At times, it felt it would have been easier to do the job if I was a man, as my husband bonded easier with the local guides, and more with the men we were working with. I on the other hand tended to have a better relationship with the women who worked with me as local

[6] 'Self-help days' are times when the community comes together to work on something that needs to be done in the village or a person needs help. For example, if someone needs a new roof, then the household might provide food and drink as a payment or thank you to the other community members who come to help build the roof.

research assistants in the focus groups and interviews, and that relationship might have been harder if I was a man.

Aware of the views some villagers might have had due to us being white, foreigners and researchers, I felt it was important to take the time to share information about ourselves and our lives at home. We always travelled with a photo album of our families, homes and nature, and if people were interested we talked about our lives at home, the differences and similarities. At the end of every focus group I always asked if the participants had any questions to us, both related to the research and to other aspects of us as individuals and foreigners. This approach and the quite informal focus groups were on several occasions mentioned as being fun and interesting by the participants. After one focus group, a woman said:

> "*Normally when researchers come they talk at you for long time but you were interested in what we had to say and it was fun, it normally isn't"*. (Field notes 7/12/2010)

I took this comment as an indication that the design of the focus groups and the approach made participants feel valued and that the time was also useful for them.

I believe that being a researcher interested in natural resources and particularly fish numbers might have influenced the answers for some people that felt protective over their resource. When this behaviour was suspected it co-occurred in discussions around management of the fish. I therefore noted this down in the responses, which allowed me to take it into consideration when I interpreted the result (Field notes 13/12/2010).

A conscious decision was also made to dress as inconspicuously as possible, to try and reduce the view of me as rich foreigner, but at the same time to always dress respectfully, and as appropriately as possible. My husband and me also tried to use canoes and bicycles as often as was practically possible, which were the main local forms of transport. People asked why we did not drive or use motor boats more often, and we could honestly say that we could not afford to, as the cost of fuel was so high in the region. It did mean that some people thought we were a bit crazy; others did not comment at all, as it is the way people moved around. I believe that in some communities more respect was given to us after the extensive paddling and cycling we did. I was told that one guide had said:

> "*Those white people love paddling, no stop in them"*.

I felt that it was obviously important to paddle too, and not for one person to paddle for the three of us. In the beginning it took some convincing and some time in certain communities before we were allowed to have a paddle. I felt that this helped to break down the stereotypical picture of the white person, which I think for many people was based on the tourists that they have seen, met or taken care of. For them to distinguish between researchers and tourists was harder in communities with eco-lodges, but towards the end it felt like we had broken through some of the barriers, even with the professional tour guides.

3.2 Description of research site

Plate 3.1: Landscape photo over North Rupununi and Lake Amuku, Yupukari, with Pakaraima Mountains in the background (Source: author's photograph)

3.2.1 The North Rupununi

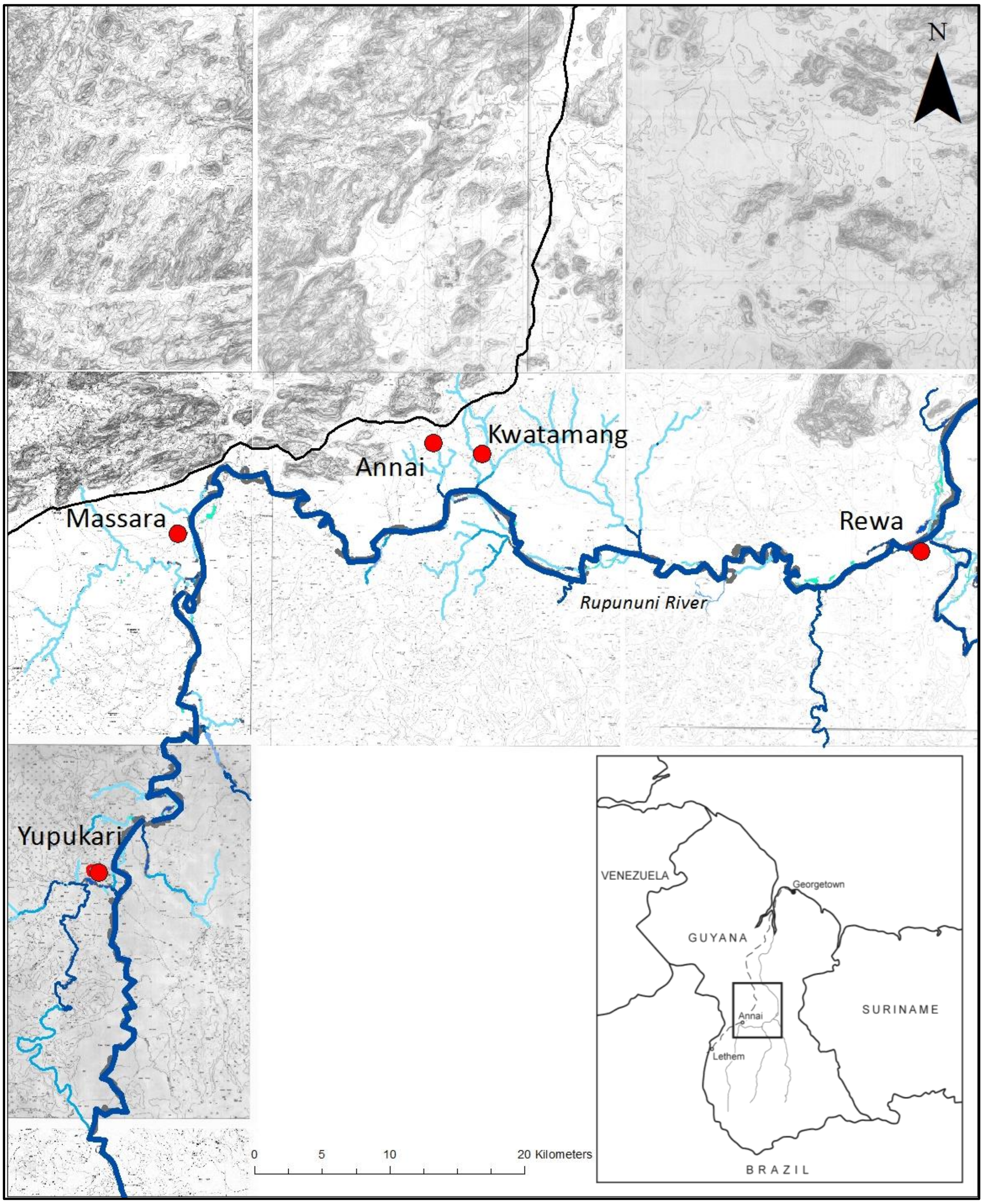
The whole Rupununi system is on the eastern margin of the larger Roraima savanna system that extends into Brazil, separated only by the Ireng and Takatu Rivers, which eventually form the Rio Branco (Wetlands Partnership, 2006a). The Guyana Rupununi system is divided by the Kanuku Mountains, which split the area into a North and a South part. The North part is also divided from east to west, where the western part of the savannas is drained by tributaries of the Takatu River and the eastern part of the savannas drains into the Rupununi River, which is part of the larger Essequibo watershed (McConnell, 1964). It is in this part of the North Rupununi District that the research took place (Map 3.1).

Plate 3.2: Grass Pond near Rewa village, one of the many ponds in the North Rupununi (Source: author's photograph)

The paleogeographical history of the Rupununi area is dynamic as with many other Guiana Shield river systems (Lundberg, 1998). The Northern part of the Rupununi savanna contains a rift valley, referred to as 'Takatu Graben' located between the Pakariam and Kanuku Mountains (de Souza *et al*., 2012). The rift extends 280km long and 40m wide along the border of Guyana and Brazil, centred over the town of Lethem, Guyana (Hammond, 2005). During the early Cretaceous, the Takatu Graben was filled with a large endorheic[7] lake, Lake Maracanata, which during the Paleogene started to transform into a fluvial system (Crawford *et al.*, 1985). This fluvial system became the main stem of the proto-Berbice, a large north east flowing river which drained most of central Guiana Shield during the majority of the Cenozoic (McConnell, 1959). During the Pleistocene, the draining patterns shifted and the lower proto-Berbice shifted away from present Berbice and joined the Essequibo River which is still its point of confluence (de Souza *et al*., 2012).

The geology of the Rupununi region is complex due to its age and long history of activity partially described in the previous paragraph. Volcanic rock formation, regional metamorphism, rifting, uplifting, and oscillating periods of sedimentary deposition and erosion have shaped the area into a patchwork landscape of varying geological characteristics (Mistry *et al*., 2008). The different geological attributes contribute significantly towards the area's soil profile and structure which in turn have a critical role in determining the type of vegetation that is dominant and its distribution (Mistry *et al*., 2008).

[7] Endorheic Lake is a waterbody that do not flow into the sea.



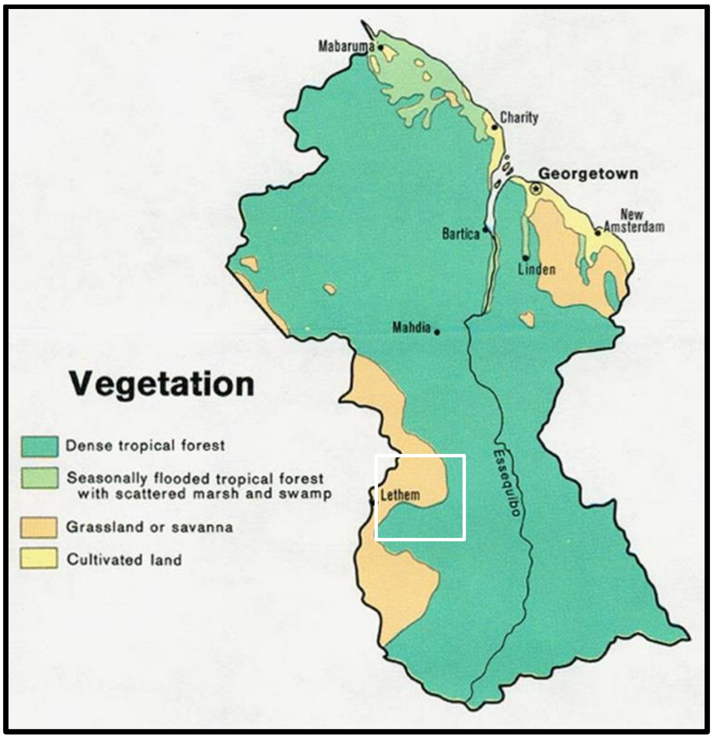
Map 3:1: Map of research area in North Rupununi (Source: author's own amended base maps from Guyana Lands and Surveys Commision, and Wetlands Partnership, 2006a)

The North Rupununi is made up of a mix of savanna, tropical lowland forest and wetland ecosystems, including over 750 lakes, ponds, creeks and inlets (see Plates 3.1 and 3.2; Eden, 1964; Fernandes, 2006). These diverse ecosystems provide a unique range of habitats hosting a rich biodiversity. The forested regions of the North Rupununi area are generally mixed forest, varying from tropical moist forest, tropical dry forest and on mountains, tropical mountain forests (Mistry *et al*., 2008). Common timber species found in these forests are: Wallaba (*Eperua spp*.), Mora (*Mora excelsa*), Silverballi (*Ocotea spp*.), Bullet Wood (*Manilkara bidentata*) and Greenheart (*Chlorocardium rodiei*). An important non-timber product species is Crabwood (*Carapa guianensis*), whose seeds produce a well-known oil that is used for medicinal and industrial purposes globally, but is also used locally as an important traditional medicine (Forte, 1996). Other non-timber product species are Kokrite (*Attalea regia*) and Ite Palm or Tibisiri (*Mauritia flexuosa*) which are used heavily by the Amerindian communities to make thatch roof. To date, levels of deforestation have been very low in the North Rupununi, as the Amerindian communities only clear small areas of forests for subsistence farming through traditional shifting cultivation methods (Forte, 1996; Mistry *et al.*, 2008).

The savanna in the North Rupununi is located in the western part of the area which can be seen in the coarse vegetation map of Guyana (Map 3.2). It is here that the majority of the communities in the North Rupununi are located, and historically ranching has been the dominant human activity but mainly led by the non-Amerindian population, although Amerindians also contributed significantly with labour. Ranching has subsided in recent year and today most ranching is done by the Amerindian (Field notes).

The Rupununi River, the main focus for this research has its source in the south of the Rupununi savannas during the wet season, whereas the Kanuku Mountains are the source during the dry season (see Map 3.3 for catchment area).The river meanders north through the whole district until it flows into the larger Essequibo River. The Rupununi is a whitewater river that is 300m at its widest during the dry season (Wetlands Partnership, 2006a).

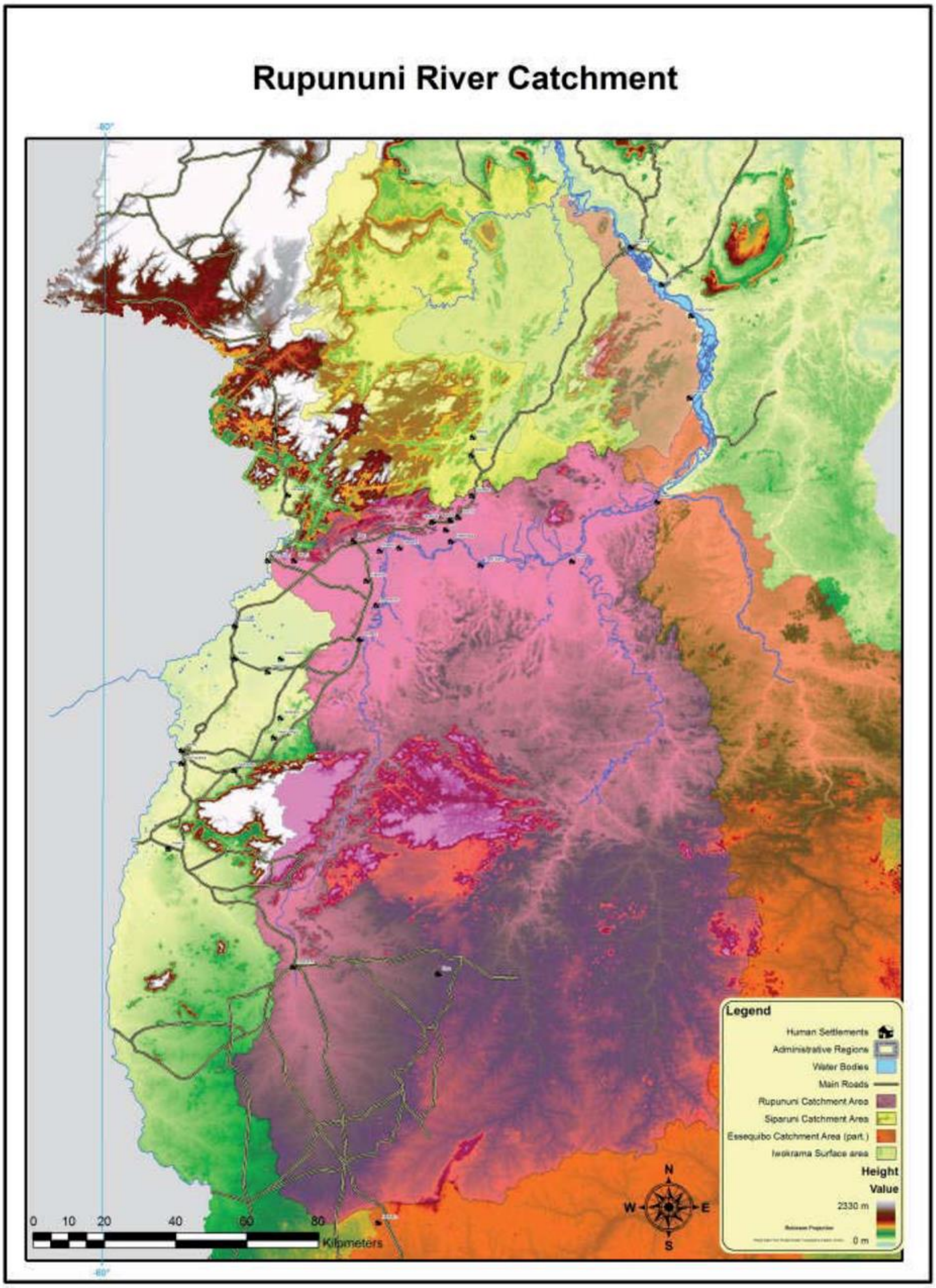
The principal rainy season is from May to September, but there is also a short rainy season during December to early January. This totals an average annual rainfall of about 1780 mm, which varies from year to year (Hawkes and Wall, 1993). During the rainy season, the Rupununi River floods into the surrounding savannas and forests; this flooding creates a unique wetland, with an approximate size of 3,480 km^2 and a hydroperiod of 49 days (de Souza *et al*., 2012). This area becomes an important feeding and spawning area for the fish from the Rupununi and the Essequibo River systems (Wetlands Partnership, 2006a). The mountain streams of the Pakaraima foothills, the northern border to the savannas, are also major fish breeding and feeding areas during the high water period (Wetlands Partnership, 2006a).



Map 3:2: Vegetation map of Guyana; study area marked by white square (Source: http://www.mappery.com/map-of/Guyana-Vegetation-1973-Map)

The wetlands have a high habitat diversity including white, black, and clearwater creeks, foothill and mountain streams, dissected river systems and ox-bow lake formations. The high habitat diversity and remnant populations of Amazonian endangered species result, in part, from ephemeral linkages to the Rio Branco River through flooded savannas, termed the Rupununi Portal (de Souza *et al*., 2012). An area of the western part of the North Rupununi savannas occupies the former Maracanata basin, thus creating a low lying area where the flood waters from the Rupununi River can connect up to Lake Amuku which drains south west wards instead into Takatu River, Branco River and ultimately to the Amazon River (de Souza *et al.*, 2012).

The North Rupununi has been estimated to host over 65 percent of the wildlife found in Guyana and among these are many endangered species, including the ‘Giants of El Dorado’ (Mistry *et al*., 2008). These include the Harpy Eagle (*Harpia harpyja*), Capybara (*Hydrochaeris hydrochaeris*), Jaguar (*Panthera oncca*) and Giant Anteater (*Myrmecophaga tridactyla*). Similar high diversity of the waterways was discussed in chapter 1, where records indicate that over 400 species of fish inhabit the Rupununi waters and there are healthy populations of internationally endangered species such as Black Caiman (*Melanosuchus niger*), and Giant Otters (*Pteronura brasiliensis*). It is a known fact that Amerindian communities have coexisted with this rich and diverse wildlife for thousands of years (Forte, 1996).



Map 3:3: Map of Rupununi River catchment (Source: Mistry *et al*. 2008)

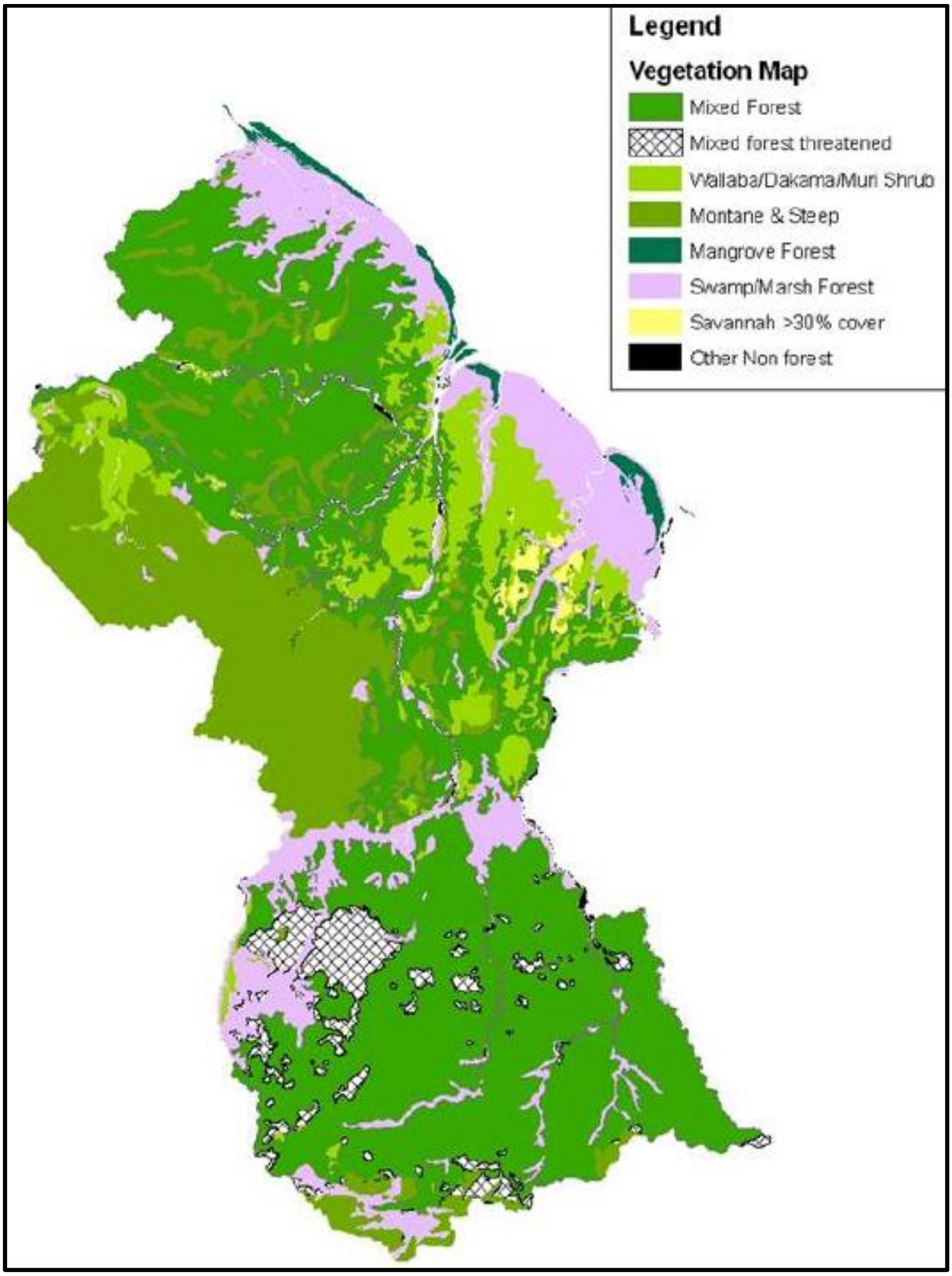
3.2.1.1 Pressures in the North Rupununi

With one of the highest poverty levels in South America, Guyana's government and local populations are under increasing pressure to choose economic activities with short-term benefits which are unsustainable in the long-term (Colchester and La Rose, 2010). As mentioned in chapter 1, the healthy ecosystems are being threatened by several activities, such as oil prospecting and mining, which are already underway in the area. Plans are also in progress to upgrade and expand road infrastructure, and a licence to log pristine forest in an area south of Rewa village was granted in 2013. In addition to these, the North Rupununi was identified as a good area to expand intensive agriculture and aquaculture in the Low Carbon Development Strategy for Guyana (LCDS, 2009). A national forest and land use classification map produced by the National Agricultural Research Institute indicate where areas of threatened forest are located, which shows that there are quite large areas in the Rupununi which are under threat (Map 3.4).

The North Rupununi has been identified by a petroleum company to have oil reserves; one site is already established called 'Hunting oil', located on state land. Another site was established to do a test drill during spring of 2011 near Macanata and very near Amerindian land and the head waters of Pirara River which link the Lake Amuku with the Takatu River. This exploration took place without any consultation with the local populations until after it had been established.

Test drills results were negative and the site was abandoned, but the massive gravel and dirt piles that had been brought to the site were left with the risks of contamination of this important waterway. Another area where the petroleum company want to do test drilling is on the north side of the Rupununi River by Rewa village. This is an area with no existing roads and intact tropical seasonal forest which is flooded annually. Road expansion and felling of the forest will have detrimental effects on the ecosystems in the area. However, residents in Rewa see a potential road as both a threat and a potential benefit as it would make market and school access easier. But they also worry of the pollution risks which come with these activities particularly on flooded grounds.

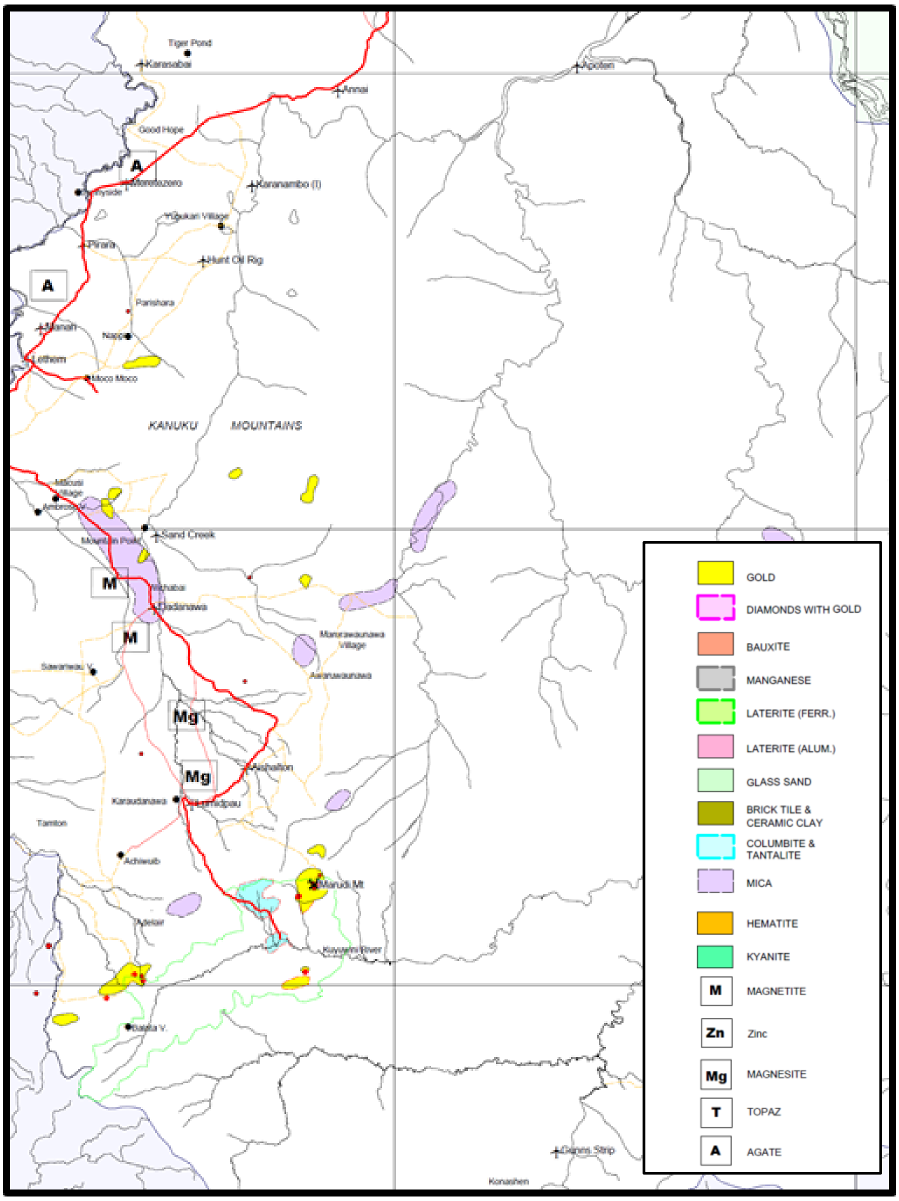
Mining for minerals is another threat to the waterways of North Rupununi. Guyana's Geology and Mine Commission has produced a nationwide map showing all the mining activities and Map 3.5 is focusing on the Rupununi region of Guyana. Map 3.5 indicates that there are quite a few mining activities going on in the south and central Rupununi, with the majority of the mining activities being the extraction of gold. Additionally some exploration of Magnatite, Magnesite and Agate has taken place in the area. Traditionally Amerindian communities have also done some gold mining along the river banks, but this has only been very small-scale and is something that has declined considerably in recent times. Yet, mining provides job opportunities which many young Amerindians explore by travelling away from their home community for months to work in this dangerous profession to help them secure enough money to establish their adult lives (Field diary).



Map 3:4: National vegetation map 1:1 000 000 Scale (Source: Guyana Forestry Commission)

The plans to expand agriculture focuses mainly on rice paddies, which neighbouring Brazil has established over large areas with severe consequence on the health of humans and ecosystems, as both water, fish and human have suffered from the pollution of pesticides and fertilizers

(Lauriola and Mistry, 2012). In recent years the number of rice farms on the Guyana side of the border has risen and a Barbados owned company which currently uses 120 acres was granted the permission to expand its operation to cover 1000 acres (Stabroek, 2013). Rice production on the savanna requires large quantities of fertilizers and pesticides and as the paddies require water, the diversion of river water is a common practice. This means that the pesticides used on the crop are easily spread to connecting waterways where the pollutants spread widely through the annual flooding.



Map 3:5: Map of mining exploration in the Rupununi (Source: Guyana Geology and Mines Commision)

Under the Initiative for the Integration of Regional Infrastructure in South America the current dirt road that runs through North Rupununi between Georgetown and the Brazilian border will be expanded to a paved highroad. This is another potential threat both for the state of the ecosystems of the area but also to the Makushi's way of life (Field diary). Access to Amerindian territory will become easier and more traffic will go through the area with both potential benefits and threats. Another crucial issue with the road construction is its location, as if not sited properly can affect flooding extent and even worse, jeopardise the connection of the Rupununi portal between the two watersheds. Thus, this research strives to provide useful data which can inform both the development planning and resource management of the area.

3.2.2 The people

The people traditionally inhabiting the North Rupununi are the Makushi. Although the Makushi are still the primary ethnic group (81 percent) in the area, many communities contain a mixture of other indigenous groups (Wapishana and Patamonas) and immigrants from the more populated coast (Bynoe, 2005; Wetlands Partnership, 2006a).

There is petroglyph evidence of Amerindians living in the Rupununi 7,000 years ago (Watkins *et al*., 2011). Other historical records date the Makushi presence in the region to the early parts of the eighteenth century (CIDR 1989; Elias *et al*., 2000). Originally, the Makushi lived a more nomadic lifestyle, where villages were small and made up of dynamic family groups (Watkins *et al*., 2011).The early Europeans brought with them diseases such as measles and chickenpox that diminished the population, killing up to 40,000 people in the 1740s (Watkins *et al*., 2011). The effect of these epidemics was felt until the 1950s, but the arrival of the Europeans is still being felt, as it completely changed the lifestyle of the Makushi. The Europeans established churches, schools and cash economies that made the Makushi less mobile; these structures are still present today and form the centre of most communities (Watkins *et al*., 2011).

The main livelihood activities for the Makushi are subsistence farming and fishing, with some hunting and gathering, trapping, brick making, and cattle ranching. The main local crop is cassava (*Manihot esculenta*), of which several varieties are grown to produce farine (roasted cassava grains), cassava bread, tapioca, and various beverages. There is also some local commercial exploitation of wildlife for the meat and pet trades (Wetlands Partnership, 2006a). Fishing and hunting the local wildlife represent the main local food source in the North Rupununi and fish particularly provide the majority of protein in the Makushi's diet (Watkins *et al*., 1999).

The traditional farming grounds are small, ranging from 0.5 acres up to 4-5 acres per household. Using the shifting cultivation method, the land is cleared by hand and axe with the aid of fire, and an area is used for up to 5 years before the nutrients have been extracted and a new area needs to be cleared. However, the Amerindians use the same land in a rotational fashion so they let a used area grow up and rest for 10-20 years before they use it again. In this way, they manage to use the land sustainably, as no new area needs to be converted unless the population grows or they want to expand some of their crop.

The Amerindian farming grounds are not only providing vital crops, they are also an important cultural space for the transmission of ancestral knowledge and skills (Griffiths and Anselm, 2010). Growing cassava for the Makushi is regarded as part of their way of life and thus anything that threatens this activity also threatens the viability of the Amerindian communities.

Selling a range of cassava products and some fish is the main source of income for most households in North Rupununi. Factors that influence the ability to earn money from these activities are related to some degree to access of good farm and fishing grounds. It was noted that for the majority of the communities where the research took place, the best farming grounds located closest to the the village on the most fertile soils, were used by the community's founding families. However, this might have consequences for the families that arrived later and thus have to settle with less fertile ground or farming areas further away from the communities. This was just an observation by the author and none of the participants or other people mentioned this as an issue. Furthermore, fishing as income generating activity did not have as evident link to the political power position in the communities. Still, access to a boat or not, seemed to be an indicator factor of the wealth of a household and a surprising number did not have a canoe. Only a few communities seemed to have retained the skills to make a canoe themselves and thus had to purchase one from communities that had kept their boat building skills alive and still had a good supply of the right type of wood for making the traditional dugout canoes.

In terms of income generating activities the establishment of the three community owned ecolodges provide a relatively new source of income for the area. Staff at the lodges work on a rota to allow more people in the community to benefit and to allow the employed people to take care of their farms and to do some fishing (Field diary). However, the communities have reported that the income generated from the ecolodges and the selling of cassava produce and fish, are not keeping up with the increasing cost of education and household necessities (Griffiths and Anselm, 2010). The lack of income and local job opportunities obliges both men and women to leave the Rupununi (Griffiths and Anselm, 2010). The men tend to migrate to mining or logging camps within Guyana, Brazil or Venezuela to find paid work, while the women tend to migrate to towns and cities to work in the domestic sector (Griffiths and Anselm, 2010). Most men and women knew about the high risks and dangers of both the mining and logging work but felt that there were no other alternative even though we heard many stories of how people had been disabled and a few had even lost their lives (Field diary).

The residents of the North Rupununi are distributed among 16 main communities, consisting of approximately 6,000 people (NRDDB, 2009). All of these communities have legal title to some of their traditional lands, and all of the communities currently practise customary user rights to their surrounding land and resources. Most of the communities are also in the process of applying for extensions of their titled land to better represent their customary resource area and to protect their way of life (in conversation with several Toshaos of the North Rupununi, Field diary). However, it is clear that some major injustices exist in the Rupununi (Mistry *et al*., 2008). Most of the land area in the Rupununi is still considered "state land" even though it should be regarded as customary resource area. On state land the Amerindian communities have no rights to determine how the resources are exploited even if an intended development is located in close proximity to their community. Many of the titled land demarcations still resemble rectangles drawn with a ruler around the community, done remotely by colonialists, and do not accurately represent the land traditionally used nor can it sustain many communities. Thus, the unethical distribution of land also contributes to the migration of Amerindians to earn money outside as their title land is not sufficient (Mistry *et al*., 2008).

Instead the state has the right to sell the rights to exploit land to outsiders, such as wealthy Guyanese businessmen from the coast and foreign companies with little or no benefits to the Amerindian communities, the original owners of the land (Mistry *et al*., 2008). These developments worry many communities and their leaders are concerned that their traditional lands are increasingly being occupied by mining, logging and other top-down infrastructure projects that threaten to undermine livelihoods and the Makushi way of life as discussed in the section above (Griffiths and Anselm, 2010). Amerindians have also voiced their concern about the national development and livelihood programmes which they feel fail to understand indigenous land and resource use. This is important as inappropriate and imposed models of development can themselves undermine indigenous livelihood systems (Griffiths and Anselm, 2010).

3.2.3 Research communities: multiple locations

Research was conducted in five communities (Annai, Kwatamang, Massara, Rewa and Yupukari) situated in the North Rupununi (see Map 3.1). The villages in North Rupununi are represented by elected Toshaos. These leaders came together in 1996 to establish the NRDDB, a regional, community-based NGO, which currently acts as the coordinating body for conservation and development initiatives in the area (Wetlands Partnership, 2006a).

These communities were chosen for numerous reasons, initially because they were part of the NRDDB, which was the organisation I decided to work with as it has a history of collaborating in research projects and represents the majority of the communities in the area. Other criteria that separated these communities from the others were that research regarding water quality and fish abundance had been conducted in some of these communities previously, so data was available to compare temporal changes of the ES. The aim was also to cover as large an area as possible with a particular focus on the Rupununi River. I therefore wanted to work with communities that were located near the river and that together spatially covered the majority of the river. When I arrived in Guyana in October 2010, I discussed with representatives of NRDDB and local experienced researchers which communities they would recommend working in, considering my prerequisites. After taking their guidance into consideration and acquiring a better understanding of the cost and difficulties of travelling in the area, the five communities were chosen.

3.2.3.1 Annai Central and Kwatamang

Annai is made up of five communities, where Annai Central is the oldest and Kwatamang is one of the four satellite communities that grew from Annai Central. Both of the communities are located near the main road (Annai 1 km, Kwatamang 4km) that connects the area to Georgetown, the capital, and to the coast (Map 3.1). The road is laterite, and although improved about 15 years ago, it still degrades during the rainy season, leading to access problems for the region. The road crosses the whole of the North Rupununi, and leads to the small town of Lethem, which is located on the border with Brazil.

Annai Central has a population of 523 individuals, with 80 households, and Kwatamang has a population of 415 individuals, with 81 households (NRDDB, 2009). Each of the communities has one nursery and one primary school. There is also a secondary school, one of only two in the whole of the North Rupununi, about 3-4.5km from each of the communities. Near to both of these communities is the Bina Hill Institute, which serves as the main office for the NRDDB and the site of the local college.[8] Other job opportunities in this area are located at the Rockview Eco-Lodge and the Oasis (a truck and bus stop serving food and drinks). In Kwatamang, the predominant income generating activity after fishing and cassava growing is brick-making, which takes place by the river. Both communities generate some income from the tourism industry by either working at the lodge and restaurant or as independent contractors working as boat captains and guides.

[8] Local collage is a technical institute concentrating on teaching youths from the area skills best suited for natural resource management and community development.

All the households in Annai Central are situated on one major hill that rises over the flat, low lying savanna, which is only 100m above sea level (McConnell, 1964). The distance to the river is approximately 4-5km, and in the height of the wet season water comes all the way up to the base of the hill. Without the constructed raised road leading to the main road, Annai Central would become an island during the wet season.

Kwatamang is more spread out, inhabiting three major hills, which are safe from the annual flooding in most years. However, the flooding cuts off the different hills from each other and they become more like islands separated by swamps, or pure flood water, during the height of the wet season. The centre of the village is about 3km from the main landing on the Rupununi River.

3.2.3.2 Massara

Massara is located about 30 km further south on the main road from Annai Central (see Map 3.1) and is a smaller community with a population of 240 people (Field notes, 20/03/2011). It has one nursery and one primary school. There are no tourist activities in the village, even though an interest and a wish to have tourists were expressed. However, some people work in the nearby eco-tourism lodge in Karanambo, approximately 15km away, whereas others benefit from making embroidery and other craft work to sell to both Karanambo and to Rockview lodge.

The centre of Massara, and where most households are, is located on a low hill surrounded by flat savanna. The village is about 1km from the river and about 3km from the main road. Some households live on hills near the main road while others live on two hills just south of the village centre. Massara's hills are probably more appropriately described as raised grounds, which all become islands during the wet season and are more vulnerable to flooding then Annai and Kwatamang.

3.2.3.3 Rewa

Rewa is located on the banks of both the Rupununi and Rewa River (see Plate 3.3 and Map 3.1). It was the community located furthest downstream in the research (53km from Kwatamang landing). While Apoteri is the community located furthest downstream by the mouth of the Rupununi River, it was decided that Rewa was a more appropriate community to work in, due to previous research data availability and lower fuel consumption, as Apoteri is a further 1.5 hour boat journey from Rewa.

Rewa is also a smaller community with a population of 270 individuals with 53 households (NRDDB, 2009). It is surrounded by tropical lowland forest that floods during the rainy season. Rewa is quite vulnerable to flooding; several houses are located near the riverbank and some years these houses are flooded and destroyed, which unfortunately occurred during the field research year of 2011.

Rewa has one nursery and one primary school. Since 2005 the community also runs a community owned eco-lodge. It has taken several years but the lodge is now bringing in tourists regularly during the dry season. The eco-lodge creates jobs and generates income for the community.

Plate 3.3: Welcome sign to Rewa village (Source: photograph taken by Mari Jönsson)

3.2.3.4 Yupukari

Yupukari is the community located furthest south in the study, which means it is closest to the source of the Rupununi River. The Rupununi River, as mentioned earlier, has its head in the South Rupununi's savannas during the wet season. However, during the dry season the majority of the water drains from the Kanuku Mountains and it becomes the main source for keeping the river flowing, as a large part of the river dries out further south.

The population of Yupukari is 400 individuals, and like Annai Central it is made up of several satellite communities (NRDDB, 2009). The centre of Yupukari is located on a rather high hill which the majority of households occupy. The river is just by the foothills, approximately 1km from the centre of the village. During the wet season, the water floods from the river and almost surrounds the village, but as the community is on a high hill there is no threat to the houses. Further inland, the savanna floods completely and a large inland sea forms called Amuku Lake. The flooding is to such an extent that it covers the whole area from the Pakaraima Mountains in the north to the Kanuku Mountains in the south, and to the west it links up with the flooded Piarara and Takatu River, which flows into the Amazon watershed (Map Appendix 6-9)

The community has a nursery and a primary school, as well as a community owned eco-lodge situated in the middle of the village, which brings tourists to the community, generating local income and work opportunities. The eco-lodge is owned by the community and its profits support the community NGO Rupununi Learners, which promotes literacy, IT skills and other educational activities to children of the village.

3.3 Research design

The field research began with a pilot visit to Georgetown and the North Rupununi in April, 2010, as briefly discussed earlier. During this month, meetings were held with several conservation and development organisations (Iwokrama International, UNDP, CI, WWF, and NRDDB), and with local people in the North Rupununi. These meetings allowed me to discuss the research in more detail, to ensure its usefulness and relevance for both the local communities and the national participating organisations. Furthermore, the pilot visit allowed me to understand and plan logistically for my main field research period.

I returned to Guyana in October 2010; this marked the start of the main field research period of the study, which continued until the end of July 2011. This extended period of field work was needed to first allow me to collect all the data I required. Working in five villages spread out over a considerable area where it is logistically difficult to travel required more time and effort. An extended field work period also allowed me to observe the seasonal changes in more detail, which was an important part of this research. Additionally, when working with indigenous communities, gaining their trust can take a long time (Christopher *et al*., 2008). I therefore thought it was important to allow extra time in each of the communities to enable this process to take place. Consequently, the more time I spent in a community the more accepted I felt and the easier the work became. So it was due to this multitude of benefits that I decided to spend an extended time in the field.

The interdisciplinary aspect of this study meant that the fieldwork had both social and physical elements. The social and human focused part of the research involved a range of qualitative and quantitative methods, with participation as the main focus. Participatory research is considered more ethical than conventional research approaches because the participant(s) is engaged in some or all stages of the research process (Chambers, 1994). To further improve the ethical aspects of this study an agreement of shared ownership of the collected data was made with the NRDDB.

The more physical part of the research included water quality testing and several different hydro-ecological surveys and mapping of ES. This part was based on the information gathered in the focus groups and interviews. In each of the communities I worked with, I spent two weeks in my initial stay to allow enough time to get to know the people and the area, and to manage to collect both the social and physical data. I started with conducting the in-depth interviews and then held the focus groups towards the end of the first week. The second week, I collected the physical data. Structuring my initial visits to the communities in this way allowed me to build relationships and to gather data in a more participatory fashion, as different field guides would show me the areas that needed mapping and monitoring.

3.3.1 Social and biophysical methods

A wide variety of research methods were used to collect data for this study. Apart from interviews held in Georgetown with national organisations and Ministries, they were mainly conducted in the North Rupununi (see Table 3.1). This section will outline and discuss the variety of methods and techniques used during the entirety of the study.

Table 3.1: Summary of social research methods

Methods	Target group	Times	Location
Focus groups	75 Villagers in North Rupununi	November 2010 –March 2011	Various (under the mango trees, women activity centre, benab, sewing centre, resource centre)
In-depth interviews	45 Villagers in North Rupununi	November 2010 –March 2011	Households or outdoors in shade from trees
Questionnaires	37 Tourists	January – June 2011	Eco-lodges in Rewa and Yupukari
In-depth interviews	8 NGOs, Governmental bodies and companies in Georgetown	May – July 2011	Respective organisation or companies' offices
Questionnaires	40 Fishermen in villages in North Rupununi	June – July 2011	Households

3.3.1.1 Focus groups

Focus groups were the main method used to collect data in the five communities (Plate 3.4). The questionnaire for the focus groups was divided into four main themes excluding the introduction (see Appendix 1). The introductory questions aimed to establish what ES they use and benefit from. Moreover, I wanted them to list the most important ES according to them, to allow the use of this list in the following questions. The first theme strived to explore the Makushi's perspectives and values of ES/natural resources; particularly how and why they value the resources they use and benefit from. I wanted to investigate what personal values and factors influenced the perceptions held towards the ES. The second theme wanted to establish spatial patterns of the distribution of the ES they value and how this changes with the season and through the years. I particularly wanted to establish the supply patterns of the ES in the landscape and where key features, habitats and connectivity between scales occurred, which sustained their health. The third theme focused on eluding both current and past threats to these ES; I wanted to establish the condition and long-term trends of the ES and what they thought was the reason for the change in condition of an ES. The last theme focused on management issues and the local people's attitudes towards it; I particularly wanted to capture their thoughts on management, if it was needed, and if so what type of management they would like to see.

I chose focus groups as a technique because it allowed for more in-depth discussions on a chosen topic in a group of people (Krueger, 1994; Stewart *et al*., 2006); this permits participants to consider their own views in the context of others, which might lead to new insights and knowledge (Patton, 2002). Furthermore, focus groups are in most instances a more time efficient method than interviews, because it brings together several perspectives on the same topic in one session (Kitzinger, 1995).

Plate 3.4: Focus group session in Massara (Source: photograph taken by Oliver Ingwall King)

Overall a total of 16 focus groups (including 75 people) were conducted in the North Rupununi, from November 2010, to March 2011 (see Appendix 5 for further details). The aim was to conduct four focus groups in each community; however, it proved to be difficult to find people that had the time and/or were willing to participate. This meant that in four of the five communities (Kwatamang, Annai, Yupukari and Massara) only three focus groups were conducted, whereas in Rewa the aim of four was met (Appendix 5). Krueger (1994) concludes that typically a focus group study consists of a minimum of three focus groups, but it could involve as many as several dozen. Thus, the decision was made that three, instead of four, focus groups would be sufficient to obtain reliable data.

I wanted the focus groups' composition to be of people that were knowledgeable about the natural resources and in particular fishing. To focus on fish, and fishing, as one of the main ES was decided through discussion with national conservation organisations, considering available data and the importance of the different ES for the local communities. Fish are the most important source of protein for the Makushi, as discussed in chapter 1. Prior to starting the field research, I had identified gender, age and occupation to be the dividing factors of the focus groups because I thought, and it is commonly believed, that these groups might provide different types of data and have different opinions (Morgan, 1998). However, due to the difficulty of finding willing participants, it was more feasible to separate according to only age and gender. I therefore decided that there should be one focus group with men over 40 years of age, a second with men under 40 years of age, and a women's group. The age of 40 was chosen to get as even a number as possible among the volunteers. Choosing these group divisions also had a more practical reason, which was to facilitate the ease of discussion within the groups, as it can be difficult to encourage women to speak when men are part of the group (Morgan, 1998). The men were separated for similar reasons, as sometimes younger people remain quiet if older men are present, or if they hold a different opinion to the older men they might feel uncomfortable disagreeing (Morgan, 1998). The decision to have two groups of men was taken to maximise the information gathered regarding fish and fishing, as men do the majority of the fishing, and thus should in principle be more knowledgeable of this practice.

During the focus groups I started with the first introductory theme to get everyone talking and thinking about the subject matter; what benefits they perceived from the different habitat types and what ES they used were questions that were asked. Photos of the different habitats were used to stimulate discussion and aid focus. This was followed by the Pebble distribution technique (Lynam *et al*., 2007), an exercise that aimed to explore participant perception and values of different ES by dividing scores represented by pebbles. I had initially thought to let each group decide on ten ES and value the ones they had identified in the introductory exercise. However, as not that many ES were always identified, and for the sake of consistency, I chose the most frequently identified ES based on the initial pilot interviews. From these ES I was able to choose ten that gave representation of the different ES categories (provisioning, regulating, supporting and cultural) according to the MA (2005) (discussed in chapter 2). The chosen ES corresponded well to the ones that were consistently identified throughout the fieldwork

I used enlarged photographs to represent the different ES and asked the participants to distribute the 100 pebbles I provided them with according to how important they thought the different ES were to them. I explained that the more important an ES is to them the more pebbles they should put on the photo representing the ES. I encouraged them to discuss the importance of these ES, which in most cases went well. Only one or two groups needed further explanation and encouragement before they got the hang of the exercise. When all the pebbles had been distributed and consensus been met, I went through and counted the pebbles, and asked them to explain why they had given the number of pebbles they had, and in what way the ES was important or not important to them. I really wanted to try and understand their motivation for the valuation of the ES and what factors seemed to influence their valuation.

The second exercise involved the use of a map over each community's titled land, which I had obtained from NRDDB, and transparent paper. I asked the participants to draw and mark the areas on the map where the ES they identified were located and how they changed with the seasons. This exercise went reasonably well. The difficulties encountered were: in some groups participants did not want to hold the pen, and draw on the map, because they said "don't want to mess it up", but this was overcome with some encouragement. Another difficulty identified was that of eyesight: many of the older participants could not see the map well, as many lacked, or had inappropriate, reading glasses. This was overcome by them describing where they wanted to mark on the map and letting other participants mark for them. I also offered paper and pen for them to draw by hand instead, but this was only taken up once.

The third exercise was a timeline, which I used to establish how the ES had changed over time, and identify reasons for potential changes. I had marked the timeline with 5 year intervals and asked them to discuss the status and trends of the ES identified (fish, wildlife for hunting, water, Black Caiman number etc.). I wanted them to indicate on the timeline when changes had started to happen or other events. Many participants found this exercise difficult as they could not remember how many years ago something had happened. I tried to establish a past event that could trigger memory, either individually or for the village. For example, when the school was built in the village, or when a person moved to the village. I used these memorable dates and asked about the fish and the other ES status to establish a timeline over how these might have changed with time. This proved to aid people memories and further data was able to be collected; however, some periods are still quite unprecise as for example, some gave 10-20 years as an indication for when things started changing, or when they occurred.

The fourth exercise was a fish abundance table. This table was first used ten years ago (Mistry *et al*., 2004) and now repeated to enable comparison of fish abundance. The table comprised the 25 most commonly caught fish species, and the participants were asked to tick first of all when the fish was present either in the dry or wet season. They were then asked to put a tick on the table according to the fish species abundance, choosing from four categories: Rare; Occasional; Common and Abundant. This exercise needed some extra encouragement and explanation before the participants embraced it. In one focus group, tension was felt that reporting low abundances might lead to trouble, and thus their result was quite different from the other focus group in that almost all fish species were abundant. This result was therefore judged as being compromised and omitted in the analyses.

The last theme of the questionnaire, management, only involved questions where the participants were asked to discuss their different views freely. This part went well and consistent data was collected.

For sampling I chose to use the purposeful sampling technique to identify participants (Patton, 2002). In this way it was hoped that the most knowledgeable people would participate to optimise the quality and quantity of information gained. This sampling method allows for the most knowledgeable people to be studied more in-depth (Merriam, 2009, p. 77).

To recruit participants, local gatekeepers from each of the communities were used, to assist in identifying people that would fit the criteria and were willing to take part. Introduction presentations in the villages and posters to inform what the research was about and to ask for people to volunteer were also used. The difficulty of finding people willing to take part meant that some of the focus groups had fewer participants then planned. As a result the size of groups varied from 3-11, with an average of 5 (mean 4.7) participants per group (further details on date, size and location of focus groups can be seen in Appendix 5).

The focus groups were undertaken in various places in the communities depending on where the participants wanted to meet. Places used were The Women’s activity centre in Massara; the Benab in Annai; and the benches under the trees in the centre of Kwatamang (see Table 3.1 for more). The focus groups were documented by my research assistant that acted as a note taker, and were about two hours in length.

3.3.1.2 In-depth interviews

In total 45 in-depth interviews were conducted with villagers in the North Rupununi. As a method, in-depth interviews were used to complement and validate the data gathered from the focus groups. I chose to use in-depth interviews as a method because they are known to generate detailed information about people’s knowledge, thoughts and behaviour in-depth (Boyce and

Neale, 2006). Furthermore, it is believed that more sensitive information will be shared in interviews compared to focus groups, and I also thought that perspectives on ES might be different depending on whether the participant was interviewed alone or in a group. Practically, the organisation of interviews also tends to be easier than to arrange focus groups, as it can be hard to find a time that is suitable for everyone.

The interview guide for the interviews was almost identical to the focus groups questionnaire (Appendix 1). The only difference was that some of the exercises were changed or omitted. Firstly, the Pebble distribution method was exchanged for a ranking table. Here the participant was asked to mark, on the table, what importance rank they would give the same list of ten ES (as in the focus groups) by writing a number from one to ten, where one is the most important and ten the least important. Both the mapping and timeline exercise were employed whereas the fish abundance table was omitted, because it took too long to go through the entire table.

Like the focus groups, the sampling strategy was again purposeful, with a target to identify information-rich people who could share a lot of material (Patton, 2002). The help of gatekeepers was needed to identify and locate people that were interested in taking part. The criteria used to guide the gatekeepers were; people in the village council, the Toshao, elders, people with a paid profession, key informants and/or people that have lived elsewhere.

These types of people were chosen because they were considered to have a particular type of knowledge that maybe not everyone possessed in the village. It was also believed that combined they should provide good information on ES, particularly in relation to changes that might have occurred over time. These groups may also know more about local politics and institutional operations that will be of importance for the project.

Informational redundancy, or data saturation, was the approach used to decide how many interviews I needed to do in each community (Marshall, 1996; Sandelowski, 1995). For each community it became apparent when new themes and explanations stopped emerging; an additional two interviews were then undertaken to ensure trustworthy results (Marshall 1996; Sandelowski, 1995). The number of interviews for each community can be seen in Table 3.2.

Table 3.2: Number of focus groups and interviews conducted in each community

Community	Number of focus groups	Number of interviews
Kwatamang	3	9
Annai	3	8
Rewa	4	11
Yupukari	3	8
Massara	3	9

The majority of the interviews took place in the interviewee's home, often outside in the shade but sometimes indoors if they preferred. The interviews were mostly documented by the note taker and me, apart from when the participants agreed to be recorded. The interviews took in most cases one hour; however in a few cases they lasted almost two hours. This was due to the participant talking more than the average person, or because they were more inquisitive and asked me more questions.

In Georgetown, I thought that having in-depth interviews with representatives from organisations and ministries would be the best method because I wanted the participant to reveal as much information and opinion as possible from their own and the organisations' points of view. Given the group dynamic and what they would have discussed as a group I thought it would be harder to extract differences between individual organisations. The interviews in Georgetown were deliberately done further into the field work phase to allow me to have a better understanding of the local situation in the North Rupununi (Table 3.1), particularly issues concerning the perspectives local people have on ES and the status of these services. My aim was to have in-depth interviews with development and environmental organisations, governmental ministries, tourism bodies and logging and mining companies. It proved to be very difficult to organise these interviews and as a result I did not conduct as many as planned (only 8 as seen in Appendix 6). The purpose of conducting interviews with these organisations and companies in Georgetown was to be able to compare their knowledge, perspectives and values of ES with those in the North Rupununi.

The questionnaire followed themes similar to those used in the Rupununi questionnaire (see Appendix 2). The introductory section aimed to make the participant comfortable and to find out how much they knew about Rupununi and their relationship to it. The second part focused on finding out about their perspectives on ES produced in North Rupununi. A ranking table similar to the one for the local communities was used to discover how they valued ES in

Rupununi. The only difference between the tables was the terminology used to describe the same ES, e.g. instead of flooding, water regulation was used. The third section focused on threats and changes in the status of the ES by asking the questions in the questionnaire. The last section wanted to elude their preferred method of management for the North Rupununi and for this again only questions were used. The interviews went well overall and they were all recorded and transcribed. They took place in the organisations' offices and lasted about an hour to an hour and a half, depending on how much extra information the participant volunteered.

3.3.1.3 Fish abundance questionnaires

A total of 40 fish abundance surveys were completed in four of the communities (Annai, Kwatamang, Rewa and Massara). The surveys were conducted by the local research assistants. In the fifth community (Yupukari) this was not possible as the working relationship with the assistant had not developed as much as in the other communities. I went through the surveys with the assistants and with some minor difficulties the recording went well. They were informed to approach only people that had not taken part in the interviews and focus groups previously.

The aim of the survey was to cross-check the data recorded during the focus groups. It was conducted during June to July 2011. The survey comprised the same fish abundancy table that was used in the focus groups (see Appendix 3) to ensure consistency and enable comparison.

The local research assistants did a professional job and completed the ten surveys for each community within two to three days. The compensation used for participation this time was fishing hooks, as suggested by the research assistants; they proved to be very successful, and simplified the work of finding volunteers to take part in the survey, according to the local research assistants.

3.3.1.4 Tourism questionnaire

In total 37 surveys were filled out by tourists over a period of six months, from January to June 2011. The questionnaires (Appendix 4) were conducted in the two communities that had an eco-lodge (Rewa and Yupukari). I handed out the questionnaires to the visiting tourists at the end of their stay, and explained the research when I was present in the communities. When I was absent the two Eco-lodge managers agreed to assist and distribute the surveys to the tourists on their last night.

The questionnaire was conducted to get an international perspective of the region and to understand how tourists value the ES. Additionally, information on what attracted them to the North Rupununi was collected and their satisfaction of their stay. I felt that a tourist would not appreciate spending an hour of their holiday being asked questions in a more in-depth interview and thus a survey would be more appropriate and sufficient to generate the data that was required.

3.3.1.5 Participant observation of fishing and monitoring

I used participant observation of fishing trips to document and get a better understanding of how and where fishing took place. I participated in 16 local fishing trips in total. These trips were divided quite evenly between the communities, with three trips in four of the communities (Kwatamang, Annai, Massara and Yupukari) and four trips in Rewa. When accompanying the fishermen on these trips I described: the fishing site according to a modified Wetland protocol questionnaire (Appendix 12) (Wetlands Partnership, 2006b); the event leading up to the fishing, including the bait search; the journey to the fishing site; and the type of method used to catch the fish. Notification of the water level and the size of the moon were also taken. For each fish caught, the species name, length, weight, and estimated size class were noted down.

In addition to this, I also documented, when appropriate, the fish catch of fishermen coming back to the villages or whom we met on the river. I noted how many fish they caught, the species, methods used, where they had been fishing and for how long. If time allowed I also measured the length of the fish.

By participating in the fishing activity, I could verify some of the information gained from the interviews and focus groups. I also used this time to have more informal interviews to clarify and validate data from the interviews and focus groups. This method gave me a deeper understanding of the landscape and how the local people lived, related to and used their land.

3.3.1.6 Local fish monitoring

I wanted to collect quantitative data to verify the qualitative data I obtained from the focus groups, and to add to the data I had already collected by monitoring the fishing activity of fishermen. The monitoring did not start straight away because I felt the need to get to know people better to be able to assess who might be interested to do the work. As I could not offer much in contribution, the monitors had to be interested and motivated themselves. One man from each of the four communities (tried in Yupukari but initiative fell through) worked on monitoring their fishing behaviour. This meant that after every time they had been fishing they filled in a spreadsheet (Appendix 9), with data on where they had been fishing, what species and how many of each fish they caught, what the fish weighed, bait they used, how long they had been fishing for and what method had been used. These spreadsheets were collected every time I visited the community and new blank forms were given out.

Employing local people as monitors in natural resource management is a strategy which has been used in many other projects (Danielsen *et al*., 2007). I chose to use this method because I did not have the capacity to collect this type of data myself, and I wanted to engage more with the communities and show how they themselves can monitor and gather data that can be used to manage their resources. The community monitors did an excellent job and collected valuable and trustworthy data over a six month period, which proved very useful in the analyses and enabled further cross-checking of the qualitative data to validate the findings.

3.3.1.7 Mapping with villagers

One of the goals of conducting the interviews and focus groups was to do community mapping and be able to use this information to physically map the areas where the ES are provided and how they change with the seasons. An additional aim was to map special features in the landscape that have been identified to be particularly important to sustain a healthy supply of ES. This was done by using maps from Guyana Land and Survey commission (from 1960). A transparent sheet was used on top of the maps and in this way each respondent and focus group could make their own marks on the maps. These drawings and marks were later transferred to two separate copies of the same map – one used for the field mapping and one to store in the field data file. In the field the map and a local guide were used to locate each site and then mark it using a Global Positioning System (GPS). To facilitate this process I worked with different local guides that I had met either from the interviews or the focus groups. By letting them take me out and show me the sites we had been talking about in the focus groups I could start creating a digital community map and spatial pattern over the ES. Additionally, I could detect where the old map was not correct and mark these out. By going out in the field it also allowed me to conduct more in-depth informal interviews with the guides to add data and to clarify things that had come up earlier, but also to validate the data collected during the community mapping sessions.

In each community I chose five sites in which to monitor water depth and describe further using the Wetlands Partnership survey (see Appendix 12, Wetlands Partnership, 2006b). These sites were chosen because they had been identified as the most important fishing and spawning sites by the villagers.

Table 3.3: Sites which were monitored for each of the five research communities (see Map Appendix 1-5 for location of sites)

Annai	**Kwatamang**	**Massara**	**Rewa**	**Yupukari**
Annai Creek	Kwatamang Creek	Bononi Pond	Rewa landing	Awarekru Pond
Devil's Pond	Kwatamang Pond	Massara Pool	Awarmie Inlet	Kwatata Creek
Wagon	Mouri Creek	Riverburst Pond	Grass Pond	Moby Pond
Pine Pond	Kwatamang Pool	Simonie Pond	Seawall	Dare Pond
Mannicole Creek	Takatu Pond	Bononi Creek	Rewa month	Code Pool

The initial mapping was done the week after the focus groups and interviews had been conducted in each of the communities, using a wide range of modes of transportation; walking, cycling, paddling canoe, and motor boat (long-foot or outboard). The factors monitored after the initial assessment were the variance in water depth and the connectivity degree, which was done by measuring the connecting creeks' depth and width from the dry season to the wet season.

The water depth was measured using a measuring stick or a rope with a weight on it. This method was used due to insufficient funds to purchase an eco-sonar; furthermore, a low-tech method was considered more appropriate to align with techniques replicable for the locals (see me and research assistants taking pond measurements, Plate 3.5). Widths of creeks were measured using a 20m tape measure; if the creek was wider than 20m the GPS was used together with a description and estimation.

Plate 3.5: Author with research assistant and local guides measuring water depth and documenting bio-physical characteristics of Awarekru Pond, Yupukari (Source: Photograph taken by Mari Jönsson)

For each depth site, three depth measurements were taken to establish an accurate average, and for each site the GPS position was taken. On recurrent visits to monitor the water depth, three depth sites were measured to get a more accurate depth variance. The GPS co-ordinates were used to locate the same depth site. However, in research sites where it was possible, a tree was also used to make it easier to measure small variances in water depth. The depth was measured one metre from the trunk of the tree towards the centre of the water body. It was found that by using this approach time was saved and when the water depth differences were small it gave a more accurate result.

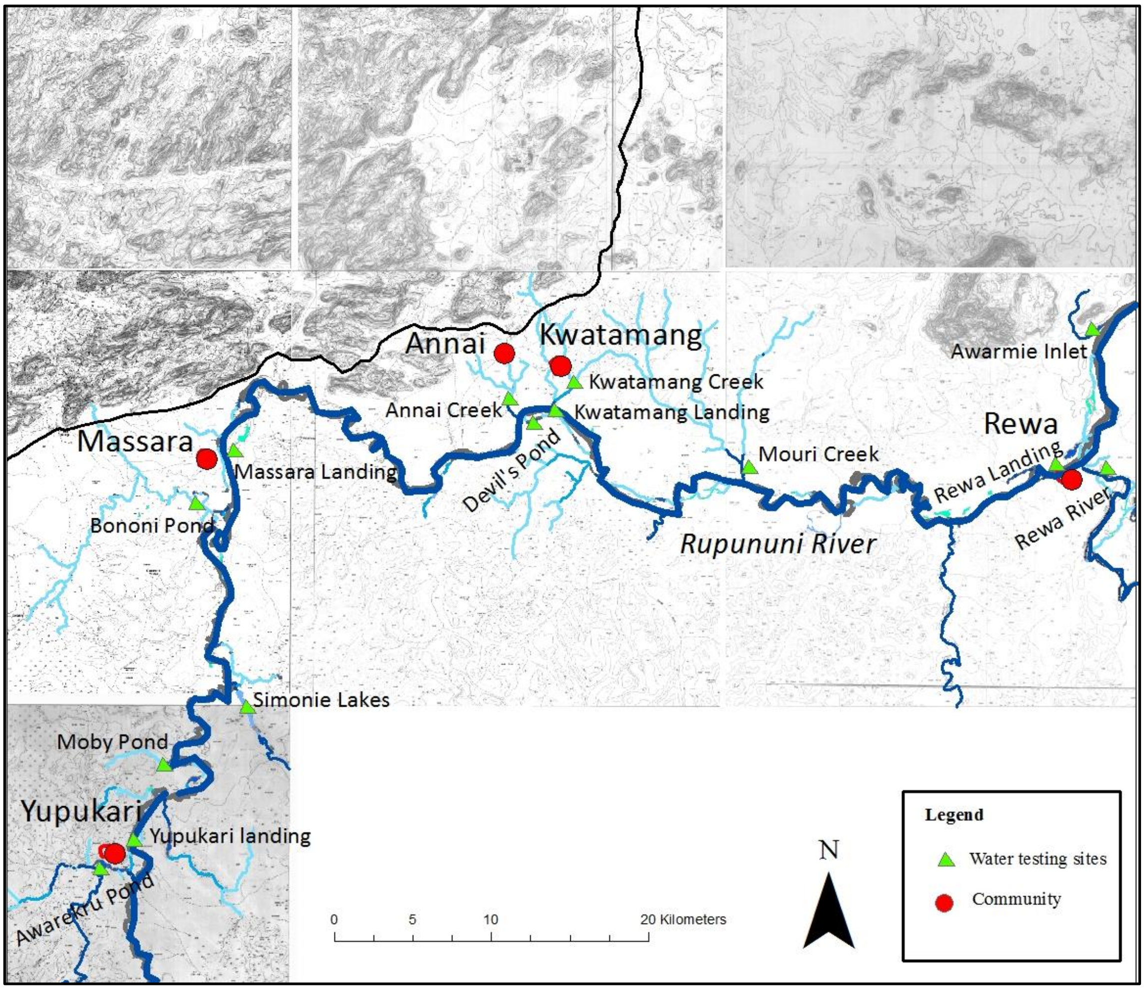
During the mapping exercise vegetation cover was also marked out. This was done by combining the GPS co-ordinates with drawing on the map and free drawings explained to us by the local guide. This was done because the maps available from the Guyanese Lands and Surveys Commission are from 1960, and though done to a great accuracy then, things have changed in the landscape. Another shortcoming of the maps is that they are not digitised and the topographic data is not very detailed, for example the contour lines mark only major hills. This means that anything less than 30m is shown as flat on these maps, which makes them less useful when it comes to mapping out flood extent and the multiple facets of landscape diversity.

Measuring and recording the water depth of the chosen sites was done on every visit to all of the communities. However, due to the difficulties of moving between communities, both in terms of cost and practicality of organising transport, visits to each community were not as regular as hoped for. This meant that water depth for each site was at a minimum measured once in the dry season, once in May when the water started to come up and once in the wet season when the savanna and forest were flooded. Yet, most sites were measured two to three times per season.

3.3.1.8 Water quality sampling

Sampling of the water quality took place in four different sites in each of the communities (see Map 3.6 and Plate 3.6) apart from Annai where only three sites were tested (explanation to follow below). The sites where chosen to represent different types of water bodies but also because the local people highlighted them as important fishing or spawning sites. To be able to monitor the Rupununi River over the longest stretch and to maximise the time period, the main river landing of each community was tested. However, because Annai's river landing is so close to Kwatamang's, and Kwatamang's landing is used by more people, it was decided to only test the water at this river landing. In this way sample chemicals and time were saved. In each village, a drinking water well was also sampled. In Yupukari and Massara, they have a main village well that most people get their water from, and thus this was the most appropriate water source to test. In Kwatamang, Annai and Rewa I asked the Toshao which well most people used and which well he wanted me to test. I followed their suggestion in those communities, but also added another well site to be able to compare the data. The other two sites were ponds, rivers or creeks that were highlighted as important fishing and/or spawning sites.

Plate 3.6: Author and research assistant analysing our newly collected water samples at Simonie Lakes (Source: photograph taken by Mari Jönsson)



Map 3:6: Water sampling sites (Source: Author's own amended base maps from Guyana Lands and Surveys Commision, and Wetlands partnership, 2006)

The water sampling was done using a Palintest Photometer 5000. All the samples were analysed for the following parameters: temperature; suspended solids (turbidity); conductivity (EC); pH; ammonia; chloride; nitrate; phosphate and iron. These water quality parameters were chosen because they may be able to indicate activity in the catchment, such as mining and logging, and they may be used to partially explain the relative abundance of certain species (Mistry *et al*., 2004). However, they were also chosen because these were the parameters that were tested in Mistry *et al*. (2004), which is the data I wanted to compare the results with. Unfortunately, not all parameters that were tested in 2000-2001 could be tested due to equipment unavailability and resource and time constraints.

The water sampling started in March 2011 in Massara, when I had eventually received the sampling equipment. The testing of turbidity, pH and conductivity was repeated 10 times as a minimum to reach a mean at each of the sites. For the other elements, tests using chemical pills were used to bring out a colour indicative of the concentration of the element being tested for. Each one of these tests was replicated twice to assure more accurate results, and five readings per test were done to improve reliability of estimated concentrations. Each of the sites was sampled at least two to three times in the dry season, and two to three times in the wet season. It would have been preferable if all sites had been replicated three times for each season; however, due to the late arrival of the equipment, difficulties and the cost of travelling, this was not possible.

3.3.1.9 Biodiversity survey methods

The Wetlands Partnership was a Darwin Funded Community monitoring project, used to assess the distribution and abundance of selected indicative species for biodiversity in the North Rupununi (Wetlands Partnership, 2006, 2008). The Black Caiman (*Melanosuchus niger*) was one of the identified indicative species which is the reason for this study to monitor their numbers (Wetlands Partnership, 2006b). The Caiman surveys were conducted using the spotlight method. Powerful torches were used after 19:00hrs to identify and count the number of Black Caiman eyes spotted along a 1000m stretch of a water body. The eye shine of the Black Caiman appears coal red while the Spectacled Caiman can be identified by a whitish eye shine. The data recorded was the number of Black Caimans spotted, the time of sighting and whether it was an adult or juvenile Caiman. To differentiate between the sizes, the eye colour, distance between eyes and closer inspection were used as a method.

Four monitoring sites were chosen, one site per community. Again Annai and Kwatamang were grouped together, as we were told by both communities that the Devil's Pond was the place with the highest number of Black Caimans in the area. Each site was sampled four times – twice in the dry season and twice in the wet season. In Rewa, Yupukari and Massara a motor boat was used to do the sampling, where the speed of the boat was much restricted to allow time to survey the water edge and to not make too much noise. A canoe was used in the Annai/Kwatamang site. The assistance of local guides with experience of spotting Caimans was used when possible.

3.4 Research analyses

A mixed research approach for an interdisciplinary research study requires a wide range of data analyses. This section will describe the data analysis methods used to obtain the results that will be outlined and discussed in the following chapters (4, 5, 6, and 7). First, the analyses used for the social data are described, followed by the analysis methods used to interpret the biophysical and spatial data.

3.4.1 Analyses of the social data

The social data was both qualitative and quantitative, and collected from the focus groups, interviews, questionnaires, informal interviews, field notes and observations. I started by first dividing these two types of data. Excel spread sheets and formulas were used to calculate descriptive statistics, such as mean, percentage and standard deviation, for the quantitative data. For the qualitative data I started the analyses with initial coding (Strauss and Corbin, 1998; Saldaña, 2011) or open coding (Merriam, 2009), where I examined all the textual data and started to identify segments (or single words) in the data set which gave meaningful information in relation to the research questions. Once a segment had been identified I noted in the margin either the exact word used, or a word(s) describing what the respondent was talking about or what it might mean. After reading through and coding the extensive material three times, I started again to go through the codes and comments. This time I wrote down the codes on small separate pieces of paper to allow me to visually see them and physically move them into the appropriate groups. The end product was 11 themes or categories (see Appendix 7) which were used to interpret the main pattern from the research findings and link to theory. The main challenge with constructing categories, or themes, is to recognise a recurring pattern that is representative for all the data (Merriam, 2009). Constructing these themes is “largely an intuitive process, but it is also systematic and informed by the study purpose, the investigator’s orientation and knowledge, and the meanings made explicit by the participants themselves” (Merriam, 2009, p. 183).

3.4.2 Analyses of the physical data

Physical data was collected from numerous sources, such as: the water quality and depth of about 25 different habitat sites; the length, weight, number and species of fish; Black Caiman numbers, mapping co-ordinates and spatial patterns. I analysed this data using descriptive statistics, multivariate statistics and Geographical Information System (GIS). For some of the data a t-test was performed to confirm the qualitative data result of significant difference between variables or sites. On these occasions I used the statistical software programme Paleontological statistics (PAST) (Hammer *et al*., 2001) along with data from, for example, the community monitors, to calculate if the abundance of the most common fish species were significantly different between the seasons.

Principal component analyses[9] (PCA) were used to analyse the physico-chemical water result, to investigate which parameter differed the most between the water habitats (river, pond, black-water pond, creek) and to visualise how similar or different the habitats are in relation to each other. After calculation variance was found to be quite high, which is often the case with this type of data, it was improved by removing the outliers.

To analyse the fish data from the community monitors I performed detrended correspondent analyses (DCA) (Hill and Gauch, 1980) and canonical correspondence analyses[10] (CCA) (ter Braak and Verdonschot, 1995), to investigate which of the variables affected the fish population the most. I used CANOCO 5.0 (ter Braak and Šmilauer, 2002) for both of these analyses and for the PCA. Again the total variance was quite high when I included all the fish species, but this was overcome by focusing on the 17 most abundant fish species, which expressed more similar numbers (reduced the number of zeros); through this the total variance was reduced.

To analyse the spatial data, the GPS co-ordinates that were collected during the mapping and field work were analysed using ArcView in GIS 10.0 (ESRI, 2011). The spatial co-ordinates were first organised in Excel spreadsheets according to the following categories: Rupununi River, ponds, creeks, spawning, depth, farm, hunting, community, fishing sites, Black Caiman spotted, Caiman nest, wet season, flood line and water line. As I had identified these categories to be appropriate layers for the spatial analyses and map production. I then imported this data to the ArcMap (ESRI, 2011) programme together with the base maps of the North Rupununi, which I obtained from the NRDDB and Guyana Land and Survey Commission. I then created the different map layers to visualise the spatial patterns and to map out the distribution of the ES. By producing these maps I was able to visualise many of the spatial patterns that were

[9] PCA is a multivariate statistical method which is used to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set (Jolliffe, 2002, p. 1).

[10] CCA is a multivariate method to elucidate the relationships between biological assemblages of species and their environment. The method is designed to extract synthetic environmental gradients from ecological data-sets. The gradients are the basis for succinctly describing and visualising the differential habitat preferences (niches) of taxa via an ordination diagram between biological assemblages of species and their environment (ter Braak and Verdonschot, 1995, p.255)

discovered during this study, such as the location and frequency of the fishing activity of the community monitors.

3.5 Limitations

As with similar research studies in remote locations where little research has been done previously, logistical difficulties are rife. For example, in the North Rupununi transport options were very limited; the road that existed was in bad condition and during the wet season large areas were cut off and no car traffic was possible. Therefore, most of the travel to collect the data and between research locations was done either by walking, cycling or paddling over large distances. Consequently, collecting data in a location such as North Rupununi is extremely time and energy consuming due to its remoteness.

In regards to the interviews and focus groups, the use of a gatekeeper might have affected the people I got to work with. As seen before (Broadhead and Rist, 1976) the gatekeepers tended to take me to people who were their friends and/or family. This pattern could potentially skew the research, as one might not get the full range of opinions on a topic. I did ask for particular people when I learned that they were skilled or influential, and at least half of the time I would say I then managed to speak to that person. However, it is difficult when one first arrives in a community, as it is hard to know about intricate relationship and power struggles. It took several months to discover and better understand these relationships. I thus found that for most of the time I could just ask for the particular groups of people that I wanted to include, for example I need to speak to someone who is working professionally, or I need to speak to more women to balance the stakeholders. I felt that the gatekeepers for the most part tried their hardest to get people to participate, and the slight tendency to have more friends and family of the gatekeepers might just be because they were easier to persuade as they were friends. As one of the gatekeepers said:

> *"He's my brother, I tell him what to do and he does it"*.

Another issue was that I was not allowed to use one local translator of my choice; instead I had to use the person that was assigned to me. Using one interpreter would have meant that they really understood what data I was after, which in some communities took some time to explain, and they did not always materialise so strongly in the interviews and focus groups. However, I feel that using a person from each of the communities most likely made the process of finding people to participate easier, as they also better knew who was knowledgeable and who was not. I therefore think that using several interpreters was not a negative thing; it allowed me to get to know more people and made it easier to integrate better into the communities.

Difficulties with getting people to participate were an issue in both the focus groups and in the interviews, and I had hoped more people would want to participate. Potential solutions to this could have been to provide lunch, which I was advised to do, but as this was not financially possible, I could not use this technique. The consequence of this lack of interest was mainly that it took longer to collect the data, as I had to wait to find someone who was willing. Saturation of data was definitely felt, so there was no implication on the data collected apart from having less than desired number of participants in the focus groups; however I do not think that any more data would have been revealed as the opinions were generally similar.

Difficulties in getting people to participate were also encountered in Georgetown, where I had hoped for at least 15 interviews with people from organisations, companies and governmental bodies linked with the North Rupununi. Unfortunately, this was not possible owing to the limited time and resources I had in Georgetown.

I chose to work in five communities because it allowed for a large area to be covered, which was important for the scale aspect of the research. I particularly wanted to get the longitudinal difference along the Rupununi River to be able to compare how communities and ES varied along the river. However, working in five communities also meant that less time was spent in each community and more time spent traveling. If I had worked in three communities instead, I could have spent more time in each community, which might have improved my understanding of the area and built better relationships. Still, I do not think I lack information or knowledge about a particular area, but I think building good relationships with people and the communities would have gone faster had I been able to spend more time in each community.

Language was another potential limiting issue. As mentioned earlier I employed and used a translator in all the focus groups and interviews. However the problem was that since many people spoke some English it made it harder, because people insisted on answering themselves even though their knowledge of English was very limited. That they wanted to express themselves is obviously a positive thing, however it did mean that is was hard to get an in-depth answer on some occasions without a lot of encouragement. Although sometimes it also worked the other way around, for the few people that preferred to speak Makushi, I found that in a few cases the translator was not giving the full answer and I needed to prompt them to give a fuller and not so abbreviated version of the answer. I believe that this issue did not interfere with me collecting enough data to answer the research questions, but being able to add more nuances and extra information might have added some extra depth to those interviews.

Makushi as a language was explained to me to be very descriptive, in the sense that the sentence construction was made up by describing pictures and that was the same way many spoke English. This realisation helped me to further my understanding of the local English dialect.

After a few months my understanding of their English dialect had improved and I was also able to speak English using more of their terminology, both of which made the communication a lot easier.

I also found myself struggling to properly interpret the local people's body language and facial expressions in the beginning of the field research. I found the Makushi facial expressions very minimal and not as easy to interpret as I am mainly used to European expressions.

On reflection I also wonder if a change in the order of the field work would have changed any of the outcomes from the interviews and focus groups. With time, my understanding of the language and of the Makushi way of life improved, and people became more open and trusting. If I had done the social part of the research later on in my stay, maybe I would have gotten more out of the participants. However, as the physical part of the research had to build on the social part this was not possible, and having the social part in the beginning also meant that I got to know more people, which would not have happened if I had only worked with a field guide.

On the physical side of the field research I had planned to do at least three replications for each season for both the water testing and the Caiman spotting. However, the practical challenges prevented the achievement of this goal. The time and the cost to organise travel made this impossible. Potentially I could have chosen to test fewer sites to give me more time to replicate, but I wanted to test the different habitat types for each community, which meant I needed to do four sites (river, pond, creek and well). The only exception to this was Kwatamang, where I judged it was more important to test the two most prominent spawning creeks of this area. After analysing the data I do not think that the shortness of repetitions reduced the quality of the data as the standard deviation of the samples are satisfactory.

Another potential limitation was the absence of testing dissolved oxygen, magnesium, aluminium and salinity, which had been tested in the comparative study of Mistry *et al*. (2004). The decision to reduce the number of parameters to be tested was done in discussion with researchers from Mistry *et al*. (2004), and was based on their previous result and this study's limitation of resources, time and logistics.

My main concern is the high concentrations of phosphate which was measured consistently. The sampling procedure was thoroughly tested using both Rupununi River and purchased mineral water, at the onset of the water sampling, which allowed comparison of results with listed concentrations of the mineral water. These tests indicated good accuracy of the equipment; however the higher than expected phosphate values raises concerns. Due to limitations in number of testing chemicals and time, further testing could not be repeated.

The only issue in regards to the Black Caimans data was the early onset of higher water in 2011. Higher water levels have been linked to fewer sightings of Black Caiman (Da Silveira *et al*., 2008). This could therefore have led to lower than expected numbers of Black Caimans in some of the habitats in the dry season.

3.6 Dissemination of research findings

During the field work part of this research a copy of the thesis was promised to each of the communities that was involved in the research. All the collaborative partners of NRDDB, Iwokrama International, UNDP and CI, will also receive a copy to ensure the research findings can be used on the ground and in policy and management work.

The produced maps in the Map Appendix will only be provided to the communities and to NRDDB to safeguard this potentially sensitive information. The decision was taken to not include the communities' ES maps in the thesis because of ethical reasons that these maps show sensitive information, which could potentially be used to endanger these natural resources. In addition an agreement was made with NRDDB that any information gained is co-owned with them and thus they have the right to decide who to distribute the maps to. The maps can only be accessed by request either to me, the author, or directly to NRDDB. If contacting me, I will forward the request to the NRDDB which will make the decision to allow or decline any further spread of these maps.

3. 7 Conclusions

In this chapter the research was contextualised, both in terms of biophysical and social aspects. The uniqueness and richness in biodiversity of this study site was described highlighting both the importance of properly managing this area for its sustainable supply of ES and as an excellent study site for this research project.

The interdisciplinary and participatory approach which this research project adopted was discussed in this chapter and the need and advantages of using this approach were illustrated. It is particularly clear that researching ES requires a consideration not only to the biophysical parameters and processes but importantly how the ES flow to the beneficiaries. To understand better the supply and demand of ES and foresee the sustainable management of ES, the social aspect of ES needs to be considered.

However, using this approach and conducting research in locations such as the North Rupununi certainly comes with extra difficulties and great physical exhaustion. Research involving indigenous people always requires thorough ethical considerations which this chapter discussed quite extensively. It was shown that conducting research as an outsider and being a white European woman is not easy. The positionality these characteristics brings has to be properly considered and evaluated in relation to the research and what my presence may mean to the villages and the data collected.

The physical challenges this type of research project brings leads often to several limitations due to logistical problems limiting access to research sites. Despite these difficulties a diverse range of methods were used to collect both quantitative and qualitative data. Each of these methods has been described in this chapter and the participatory nature of the chosen approach highlighted.

This chapter has given a detailed account of how and where this research was conducted and analysed. The next chapter will discuss the result of the first research aim, which explores the differences in stakeholders' perception of ES and the implication of spatial and temporal scale. The chapter particularly illustrates the result from the data gathered using the qualitative research methods outlined in this chapter and discusses what factors affect a stakeholder's perceived value of ES.

Chapter 4

Stakeholders' perceptions of ecosystem services: implications of scale and the use of the ecosystem services concept

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Understanding how people value the environment, and how valuation and perspectives differ among stakeholders at different scales, is essential for the success of natural resource management (Dutcher *et al*., 2007; López-Marrero and Hermansen-Báez, 2011). As discussed in chapters 1 and 2, many scholars have taken this one step further, arguing that the degradation of the Earth's ES is due to society's inability to appreciate their 'true' value in economic decision-making (Costanza *et al*., 1997; Daily, 1997). This assumption, as discussed in chapter 2, is founded on the fact that most resource and development decisions are based on market price, but that no market exists for most ES and therefore decision-makers have no indication of an ES's 'true' value. Consequently, there is a substantial research need within the field of ES valuation. As a relatively new concept there are unresolved issues still being discussed: what are the best valuation methods, who should assign the value, and what type of value should be assigned, monetary or not? My first research aim seeks to contribute to this knowledge gap. This chapter will explore stakeholders' perspectives of ES at different scales and how they value them in relation to each other; specifically, it will address the questions of how and why different stakeholders value ES the way they do.

Assigning monetary values to ES will hopefully lead to more pro-environmental decisions being taken at a national and international scale. However, monetary value is not the only factor that influences decision-making; although it may be an important one, other factors are present. For example, it has been recognised that decisions are influenced by social values, i.e. a set of ideals and beliefs to which people individually and collectively aspire to, and desire to uphold (Audi, 1999). These types of values also structure traditions, institutions, and laws that underpin societies (Jepson and Canney, 2003). It is therefore important to understand people's underlying value ground, to focus on 'why people value' the way they do and not just 'what is the value' (Kaplowitz, 1999).

Another key area is the importance of recognising that decision-makers are not only governmental or political leaders, but that local people are also decision-makers who take daily decisions on how to utilise their natural surroundings. They are also the ones that will be most affected by any decline in the health of a natural resource and any regulations imposed by national state bodies. Therefore, it is important to include local people in conservation initiatives if they are to be successful, which were discussed in chapter 2 (Berkes, 2003; Garnette *et al*., 2007; Menzel and Teng, 2009). The importance of including local people in natural resource management initiatives is not something new; on the contrary, it has been documented extensively (Berkes, 2003; Garnette *et al*., 2007; Sheil and Liswanti, 2006). Yet, their views and values are still rarely considered and included. This chapter thus strives to convey the importance of understanding stakeholders' values through a scale perspective where the views of stakeholders at the local, national and international scale are compared and ideas about politics of scale is discussed. The first section discusses the identification of ES, followed by the main section, which focuses on stakeholders' perceptions and values of different ES at different scales, discussing how and why these ES are important for the different stakeholders and their understanding of scale. The last section reflects on using the ES concept for research with indigenous communities; issues around monetary and non-monetary valuation of ES are also highlighted and discussed.

4.1 Identification of ecosystem services

In total, 19 ES were identified by the local participants in the North Rupununi during the focus groups and interviews (Table 4.1). On average participants named four different ES, and a few participants were able to name up to nine. Some services were mentioned much more frequently than others, such as fish, farm and wood. These top three ES, and almost two thirds of all the identified ES, were classed as provisioning ES (58 percent) using the MA (2005) classification of ES. About a fifth (21 percent) of the identified ES were found to be regulating services, whereas cultural and supporting ES only made up a tenth each.

Table 4.1: List of ecosystem services identified by the Makushi that they use and/or benefit from and the type of ES they belong to according to MA (2005)

Ecosystem Service	**Percentage of people that identified the ES**	**Type of Ecosystem Service**
Fish	77	Provisioning
Wood and other construction material e.g. Kokerit leaves	64	Provisioning
Farm land and its products	62	Provisioning
Water	39	Provisioning
Hunting	34	Provisioning
Wildlife	31	Provisioning
Travel on savanna and waterways	13	Provisioning
Grazing on the savanna by cattle	11	Provisioning
Medicinal plants	7	Provisioning
Craftwork material	7	Provisioning
Soil	4	Supporting
Tourism	5	Cultural
Clean air	3	Regulating
Beauty of Landscape	3	Cultural
Clay (for brick making)	2	Provisioning
Flood regulation	2	Regulating
Biodiversity	1	Supporting
Dispersal of seeds	1	Regulating
Weather	1	Regulating

The dominance of provisioning services is a similar result to other studies focusing on local communities (Hartter, 2010; Iftekhar and Takama, 2008; MacDonald *et al*., 2013; Martin-Lopez *et al*., 2012). In Iftekhar and Takama's (2008) study in Bangladesh, where locals were asked to identify the most important ES of a mangrove ecosystem, they found that the supply of products from the mangrove ecosystem was mentioned most frequently (57 percent), which is very much in line with the results from this study. Comparing the result with MacDonald *et al*.'s (2013) study in Australia, where they explored the values of non-indigenous community leaders, a similar dominance of the provisioning services was also found; however, their community leaders valued cultural services as second, whereas the Makushi valued the regulating services as second. This difference may be explained by the different lifestyles of the subsistence-living Makushi compared to a non-indigenous Australian. However, these results do indicate the dominance the provisioning services seem to have for both indigenous and non-indigenous people.

This result could be interpreted as demonstrating that the Makushi's values are of an anthropocentric nature, as MacDonald *et al*. (2013) concluded in their study in South Australia. However, this study argues that the more likely explanation for this result is the practical nature of human beings to think first of the products we use/need or benefit from, before some of the underlying processes these products depend upon. Another factor identified to explain this result is the link between the values or recognition a person assigns an ES and how much they know about the ES concept and ecology in general. An important example is that only one supporting ES was identified by the Makushi. This highlight that even people like them – who completely depend on ES for their livelihood – may not express a value to certain ES, like the supporting ES, as it requires a better insight to the ES concept and maybe even a more Western world view. Similar conclusions were also reached by MacDonald *et al*. (2013) that the relative silences in relation to supporting and regulating ES may reveal more a lack of knowledge about the concept and ecology than a lack of values among the community leaders. On the other hand, it could potentially be argued that the ES concept is a Westernised one that compartmentalises nature into different categories of services for humans, which does not correspond well to the worldview of indigenous people like the Makushi. This could mean that using the ES concept in research with indigenous people may give inaccurate results, as the non-identified ES may only be a result of the difference between indigenous and Western views on the relationship between humans and nature, and not a result of indigenous people not valuing the ES.

When considering this constraint of applying the ES concept, the outcome could either be that local communities, like the Makushi, should receive more awareness-raising to make sure they improve their understanding of the ES concept, so they will be able to argue and value them 'correctly', i.e. corresponding to their values. Or, the differences in worldview, lifestyles and values should be acknowledged and respected, and any consultation where the ES concept is involved should acknowledge this constraint. However, there are benefits for local communities to having a better understanding of the ES concept when it comes to situations where they need to negotiate with governments or other outside bodies. For Guyana, this might be an imminent discussion, as the national REDD+ scheme (as discussed earlier, chapters 1 and 3) is being implemented and communities will soon have to decide if they want to opt-in or out of this scheme, which will most likely have significant impacts on their lives.

4.2 Stakeholders’ perceptions of ecosystem services at different spatial scales

There is general agreement that local community views and perceptions should be better understood in good natural resource management practices (Baral, 2012; Boissiere *et al*., 2009; Sheil and Liswanti, 2006). Furthermore, it is important to acknowledge that ES are supplied at various spatial and temporal scales, which has a strong impact on the value different stakeholders attach to the services (Hein, 2006).

4.2.1 Local scale perception and value of ecosystem services

“We have land and land will sustain our livelihood, some say the land is our mother”.

(Older man, Kwatamang)

“Land is the most important, then comes fish because it is the food after the farm”.

(Woman, Rewa)

Plate 4.1: A typical farm land in the North Rupununi growing cassava (Source: photograph taken by author)

Livelihood activities were valued the highest among the local stakeholders in the North Rupununi (Table 4.2 and 4.3). The farm and its produce were the most important ES (see Plate 4.1 for typical North Rupununi Farm), followed by fish, wood and water. The local stakeholders’ views were rather homogenous and showed no significant difference by gender, age, and community and data collection method (Table 4.2). The dominance of provisioning services, as discussed earlier, is consistent with other similar valuation studies (Cunliffe *et al*., 2007; Pfund *et al*., 2011; Wilk, 2000). Schuyt (2005) showed that fish, water and agricultural crops were the most important products for local communities in the Yula wetland, Kenya, whereas Cunliffe *et al*. (2007) found that crop production, collection of eaglewood, harvesting of fish and wildlife, and the making of craft were the most important livelihood activities for the Punan Pelancau community in East Kalimantan, Borneo. Further discussion of why these ES are valued so highly will take place in the following section, 4.4. However, the homogenous result across the different local stakeholders groups (age, gender, income, method, community) is not in line with other studies, such as Rocheleau and Edmunds (1997) and Goebel *et al*. (2000), who found that women and men value and use natural ecosystems differently (Hartter, 2010). Rocheleau (1991) studied rural African communities where women tend to spend more time collecting resources for the family's food production than men, which may explain why values between genders differ in their study. In the North Rupununi, gender roles are also quite distinctive in the sense of what type of work a man and a woman should do. However, the men were the prime fishermen and work on the farm was done by both, albeit different tasks. The slightly more equal job division between genders might be the reason for the similar valuations found in this study.

Table 4.2: Average ranking of importance of ES by different groups in North Rupununi, based on gender, age, income, data collection method and location. Ranking assigned from one to ten, where one is the most important and ten the least important number

ES	Overall Ranking	Women	Men	People in a paid job	>40 year olds	≤40 years olds	Inter-views	Focus group	Kw	An	Re	Yup	Ma
Farm	1	1	1	3	1	1	1	1	1	2	1	1	1
Fish	2	2	2	1	2	2	1	3	2	1	1	2	2
Wood	3	3	3	4	3	4	4	1	3	3	3	5	4
Water	4	4	4	2	4	3	3	4	4	5	4	4	3
Soil	5	5	5	5	5	5	5	5	6	4	6	3	5
Weather	6	6	6	6	6	6	6	6	8	6	5	6	6
Biodiversity/ Wildlife	7	8	7	7	7	7	7	6	5	7	7	7	7
Eco-tourism	8	7	8	8	8	8	8	8	7	8	7	8	9
Flooding	9	10	9	10	9	10	9	9	9	9	10	9	8
Beauty of Landscape	10	9	10	9	10	9	10	10	10	10	9	10	10

Table 4.3: Median of importance of the ES from the Pebble Distribution Method (expressed in percent) for all the local communities

Ecosystem services	Median (%)
Farm products	16
Fish	14
Wood	14
Water	14
Soil	10
Weather	10
Biodiversity	10
Eco-tourism	8
Flooding	6
Beauty of Landscape	0

Of medium importance were soil and weather; these were recognised for their regulatory and supportive functions. The respondents demonstrated a good knowledge and understanding of how the provisioning services they use rely on regulating and supporting ES. Most people described the soil as being very important for the farm, as can be seen in the quote below from a younger man in a focus group in Annai:

> *"Soil is very important for farm and can be used to build homes out of it, and make pots".*

Participants also agreed that the tropical lowland forest (known as the 'high bush') of the area has more fertile soil and better 'air' compared to the savanna and gallery forest. By 'air' they were referring to what Western scientific approaches would call 'temperature'. They explained that the higher trees bring protection from the sun and thus create a more favourable microclimate.

Of lowest importance were biodiversity, eco-tourism, flooding and beauty of landscape. A similar homogeneity of the ranking among the different groups of local stakeholders was also found for this section. Even though flooding was ranked second lowest, it was described as "*being very good and bad at the same time"*. This contradictory perspective of flooding was explained: the occasionally high floods – which destroy their farms, as cassava rots in waterlogged soils – represent the negative aspect of flooding. The positive aspect of flooding, according to respondents, was that the fish populations depend on the floods to stay healthy, as can be seen in the quote below:

> *"If the river not flooding the fish will die. A few years ago river came up quick and then dropped quick, affected all the fish".* (Younger man, Yupukari)

Participants explained that the high water is necessary for the fish to feed and spawn in the savanna and in the forest. If the river does not flood the "*fish will be meagre and with bad worms inside*" (younger man, Massara). Other positive aspects related to flooding included "*travelling gets easier and it goes faster*" (older man, Kwatamang); in some cases the travel time was cut in half due to the shortcuts through the flooded forest and savanna. It is also "*easier to hunt as the animals are being trapped on islands*" (younger man, Rewa).

The results showed a greater difference in the responses between individuals from the same community compared to respondents from different communities. This is consistent with many other studies, which illustrate the generally accepted phenomenon that even in small communities people's values and opinions differ between individuals (see for example Bauer, 2003; and Picard, 2003).The similarities between communities could be explained by the fact that all five communities share a common settlement history, ethnicity and cultural customs in their use of ecosystems (Durand and Lazos, 2004). Furthermore, considering access to land and power relationship in villages, every participant said that all household uses resources in a similar way and that some did not use or get more than others. This is an interesting result as it was noted that it seemed to be a trend that the founding families have access to the best farming grounds (Field diary). There is clearly a logical explanation for this as they were the first to choose their agricultural land, and as no one reported any jealousy or expression of unfairness it might indicate that people feel that there is not an unbalanced power divide in regards to the land within the villages.

In regards to power relationship for fishers, it could be divided into people who own a boat or not and those that do commercial fishing more frequently. The commercial fishers were sometime seen as having a good status as being skilled in fishing is important in North Rupununi but in other communities this did not seem to be the case (Field diary).

4.2.2 National and international stakeholders' perception of ecosystem services in the North Rupununi

Stakeholders at the national (Georgetown) and international scale (international tourists in North Rupununi) valued the ES in the Rupununi quite differently to stakeholders at the local scale (see Table 4.4). According to the national and international stakeholders, biodiversity was the most important ES. In comparison, biodiversity was ranked in seventh place among the local stakeholders, which placed it in the section of lowest importance. The most common explanation for this high rank by national and international stakeholders was that it encompasses all other ES. The spokesperson for one development organisation used these words to describe the importance of biodiversity:

> *"Biodiversity no doubts, it involves so much in maintenance of forest and importance of livelihood to communities who rely on free meat, fauna and also flora which are used by local communities in their everyday life".*

Following biodiversity in importance were freshwater and fish, respectively. This ranking is not that different to the local stakeholders' valuation. However, the emphasis on why these ES were valued differed. Most national respondents recognised the importance of freshwater and fish for the biodiversity of the area first, and then the importance of these ES for the livelihoods of the communities living in the North Rupununi. The above quote illustrates this point. Although, it singles out biodiversity it also indicates a good understanding of the local situation, which is a positive indication in terms of inclusion of the local stakeholders in future initiatives.

Table 4.4: How stakeholders from different scales value ES by ranking between one and ten, where one is the highest rank and ten the lowest.

Ecosystem services	**Local scale**	**National scale**	**International scale**
Farm products	1	6	9
Fish	2	3	3
Wood	3	10	10
Water	4	2	2
Soil	5	8	7
Weather/Climate regulation	6	7	8
Biodiversity	7	1	1
Eco-tourism	8	5	5
Flooding/water regulation	9	9	6
Beauty of Landscape	10	4	4

Freshwater and the flooding were recognised as being an important factor regulating the landscape, as this quote shows:

> *"It [water regulation/flooding] determines the varying level of water throughout the year and contributes to biodiversity of the area"*. (Spokesperson from conservation organisation)

Both national and international stakeholders' ranked 'beauty of landscape' in fourth place, because as many expressed it "*fits together with eco-tourism and biodiversity*". A representative from Guyana Tourism Association expressed it with these words:

> *"It is an ES with little effort and you have pristine, untouched green clean environment."*

However, this result is very different to the local stakeholders' values, which ranked 'beauty of landscape' of least importance in tenth place. These results clearly illustrate the difference in perception and value of ES between stakeholders at the local scale compared to national and global scales. Garrity (1998) described similar results in South East Asia, where national and international stakeholders valued the conservation of biodiversity and regulation of water flow higher than local stakeholders, who valued the use of agricultural land and extraction of wood products the most. Baranzini *et al*. (2010) investigated the importance of tropical forest conservation from a general global perspective and found that people ranked carbon storage as the most important ES, followed by biodiversity. The last study is set in a slightly different setting, but even so the trends are similar to the findings of this research.

If these different values between stakeholders at different scales are not properly understood and accounted for it can lead to conflict in future development and conservation initiatives. However, the same mismatch in perception between national and international stakeholders cannot be seen (Table 4.4). Indeed, the opposite seems to be true, with national and international stakeholders sharing similar perceptions on these ES. This result will be further discussed in the next section.

4.3 Reasons behind stakeholder valuation of ecosystem services

Explaining why a stakeholder values an ES is important, because it allows for a deeper understanding of the stakeholder's personal values and priorities. As discussed earlier (chapter 2) it is assumed that a person's values together with other factors influence the decisions that they take (Dietz *et al*., 2005). Thus, from a natural resources management perspective this is important both at the national and the local scale. At the national scale the goal is to influence more pro-environmental decisions, and at a local scale it is important because the local people are the resource users and they make decisions every day that affect the natural resources. This means that a better understanding of how people value and perceive ES can lead to better collaboration between stakeholders at different scales.

Four themes have been identified which aid in explaining why the stakeholders value the ES the way they do; these will now be discussed below.

4.3.1 Influence of spatial scale

The first factor to consider when analysing the values of ES at different scales is to establish at which scale and to whom the benefits of an ES flow (Hein *et al.*, 2006). If considering the top four ES for the local stakeholders – farm products, fish, wood and water – the supply scale of these ES can be identified to be local if the focus is on their instrumental values. However, if focusing on the intrinsic values, fish biodiversity and freshwater habitats can supply benefits to larger scales, such as national and international stakeholders. This differentiation of value ground was apparent in the result reviewed in the previous section, indicating that, although freshwater and fish (which were valued second and third most important by the national and international stakeholders) provide ES locally, they also provide benefits to stakeholders at larger scales.

Considering the spatial scale of benefits from ES of medium importance (soil and weather/carbon sequestration), according to the local stakeholders, soil was ranked fifth; this can imply several ES, but the one the Makushi highlighted was the importance of fertile and dry soil, which can be categorised as a supporting ES providing benefit on a local scale. Considering weather, which was interpreted as carbon regulation, the ES benefiters are on multiple scales; as the atmosphere is transboundary, the benefits can be valued by someone on an international scale. However, the result here was a bit surprising: the local stakeholders valued this ES higher, than the national and international stakeholders, eventhough it has clear global benefits. A potential explanation for this is that many of the international tourists only saw the savanna part of the North Rupununi, and thus assumed that the contribution of the ecosystems to carbon retention and sequestration was small, compared to a forest. This can also possibly explain the result on the national scale, because not many of the respondents had actually been to the North Rupununi, even though they are involved in work that affects the area. One participant actually said that "*North Rupununi does not have much trees, so not so important for carbon regulation*" (spokesperson for one of the governmental bodies). This is clearly a misconception, as the area contains substantial amounts of forest and is not just made up of savanna.

The least important ES according to the local stakeholders were eco-tourism, biodiversity, flooding/water regulation and beauty of landscape. The spatial supply scale of these ES is mostly of multi-scalar pattern, which supply benefits to all three scales (local, national and international). The high ranking of biodiversity and beauty of landscape by the national and international stakeholders again illustrate the intrinsic values these type of ES supply. Several local respondents did say how much they loved Rupununi and how beautiful it was, but in comparison to the other life-supporting ES these types of cultural and more aesthetic ES lose out.

Examining on what spatial scale an ES supply benefits and to whom has explained many of the values given to the ten ES. However, not all rankings could be explained by looking at scale alone, and even if scale does explain the valuation to some extent, it is important to consider other factors that seem to have influenced this valuation exercise.

4.3.2 Basic needs and cultural values

The high values of the four provisioning ES (farm, fish, wood and water) among the local stakeholders can be explained by their use value. The communities are dependent on these four ES for their dietary and sheltering needs. Only a few of the local stakeholders have paid jobs, which mean that most rely completely on the environment around them for their livelihood. A young woman in Kwatamang explained simply why the farm was the most important to her:

> *"Farming most important because need food to survive",*

Whereas these two quotes described dependence on fish:

> *"If there is no fish in the river where can we go for food".* (Younger man, Yupukari)

> *"Everybody relies on fish. Very few people have guns so not much hunting. Depend totally on fish".* (Older man, Annai).

The above quotes illustrate the Makushi's dependence on these goods, but other responses revealed another factor, that of cultural identity and values in their practices and way of life. This can be seen in the quote below from an older man in Annai:

> *"It is our way of life, we live off the earth, we don't have jobs, only a little bit of money from fishing and from small short jobs".*

Fishing was something that almost everyone expressed a joy in doing, from young to old and men and women. It was also noted that being a good fisherman was something people were proud of and valued. A young man in Massara said "*I love fishing, fish every day*". When I spoke to him I told him other villagers had said he was the best fisherman in the village – he was noticeably happy and proud of this comment (field notebook, 20/03/2011). Chan *et al*. (2012b) state that cultural identity benefits are commonly associated with fishing, as they found that young people of Kyuquot-Checleset on Vancouver Island, Canada, lost a sense of their cultural identity when their opportunity to fish diminished. Chan *et al*.'s (2012b) study can be linked to the Makushi, who also have practised fishing for centuries, and for whom fishing is a major part of their culture; by practising fishing they help to keep their cultural identity and way of life alive (Jones, 2005; Roe, 2003).

Although the fishing techniques that were used have changed, traditional fishing with bow and arrow and by making traps when the water is going up or down are still practised; however the use of seine nets has increased markedly during the last 10-15 years. Most respondents were quite critical of the seine nets and blamed them for the decrease in fish abundance (which will be further discussed in the following chapters). Furthermore, fish provides another benefit to the Makushi, who are able to sell fish to generate a small income. They mainly sell within the village, but sometimes they get orders from people from Lethem, or from communities in the Pakaraima Mountains, or in the savanna that do not have access to such rich fishing grounds. Lastly, fishing also has a social benefit, as I was also told and witnessed several times families that went for a picnic on their day off, meaning the whole family goes on a fishing trip somewhere for the day to fish, grill and relax together. This seemed to be a very cherished and appreciated break in their hard working lives.

Farming can most certainly be classed as a basic need for the Makushi, but equally, farming cassava and other products is part of their cultural traditions. Cultivating cassava and the process required to prepare it to make cassava bread, farine, cassrip,[11] and/or curi[12] is seen as a vital part of their cultural identity, and essential to ensuring the viability of their way of life.

The use of wood for house-building, canoes, paddles and bows, firewood, medicine and material for craft work demonstrates its importance both in meeting basic needs and cultural activity. A younger man in Yupukari expressed the importance of wood:

> *"Wood is important because if no wood, would not have material for house or boat".* (Younger man, Yupukari)

Water was described as something vital, used for drinking, cooking, and washing, but also for transport. All communities have some type of borehole in the village which helps keep the water cleaner, and makes the job of collecting water easier, as they do not need to go to the river. However, some families still use the river for drinking, and most seem to drink the river water when out fishing or travelling along the river. An old man in Rewa explained the importance of water with these words:

> *"Water is for everyday living, born and grow with water"*

This quote also illustrates how integral the water is for the Rupununi landscape in the eyes of the Makushi.

[11] Cassrip is a black rather thick liquid that is extracted during the cassava to farine process and used as flavouring of food.
[12] Curi is the traditional alcoholic beverage made by fermenting cassava.

The cultural identity of the different Amerindian groups in North Rupununi seemed to be similar in relation to the ES reviewed. The majority of participants identify themselves first and foremost as a farmer and fisher second. However, there were a few people that identify themselves as fishers first, these people tended to do more commercial fishing than the average person. Only two men saw themselves as hunters and this was because they hunted all year round and not just during the wet season or ad hoc as the majority of the men.

The influence of cultural identity on the valuation of ES has previously been theoretically considered (Hoyos *et al*., 2009). Yet, empirical studies on the topic are very limited (Hoyos *et al*., 2009). Hoyos *et al*. (2009) provide some empirical evidence of the influence of cultural identity on how respondents in Spain valued natural resources using choice modelling techniques (see literature review for further explanation). They found that persons with a Basque cultural identity are willing to pay 28-33 percent more on average to protect an ES. They explained this rationale with the Basque's deep cultural roots, where mother earth has a central role (Hoyos *et al*., 2009).

4.3.3 Education level and conservation training

The similarities in how the local stakeholders valued the ES were shown earlier in table 4.2. Although similar averages were found between the communities and different stakeholder groups, there were still some individual differences, which could be linked to the person's previous level of education and conservation training. Barazini *et al*.'s (2010) study in Switzerland also found that education and income are two variables that can be used to explain valuation. Ojeda *et al*. (2008), who were looking at willingness-to-pay for ES in the Yaqui River Delta, Mexico, also found comparable results. They found that four key variables – education level, income, number of children in the household and initial bid amount – influenced how much monetary value people assigned to the ES. The first two of these variables will be discussed further, whereas number of children had no influence in this research (this was tested; the result was the same as the other stakeholders groups in Table 4.2 and thus not included in the already large table) and bid amount is not relevant to this study. The next section will discuss the influence of income, while this section will continue to discuss the influence of education and training. For example, as mentioned, most people in the North Rupununi valued wood highly because of its use value as a construction material, but there were some respondents who also acknowledged the importance of wood/trees for its carbon storage and how this service is linked to climate change as can be seen in the quote below:

> *"Forest has good fertilised soil, animals, materials, also good for the atmosphere, carbon in the trees for climate"*. (Older man in a Focus group, Annai)

This man and the few others (2 percent) that expressed this link between the forest and climate change either had a higher level of education and/or more training, due to either being in a position of power (Toshau or village councillor), or in a paid profession linked to tourism in which they have received further environmental training.

The highest ranking of biodiversity of respondents in Georgetown can also be explained by their higher education level, and the fact they are educated/trained in conservation (Garcia-Llorente *et al*., 2011). Their reasoning illustrates a better understanding of scientifically constructed hierarchical ecological systems, exemplified by this quote:

> *"It [biodiversity] comes first because I look at these (the other 9 ES) and see them as they fall within biodiversity, it covers all species, all habitats. Contributes largely to what the area is"*. (Spokesperson from a conservation organisation)

A similar ranking of biodiversity as the most important or second most important ES was only identified by a few (1 percent) in North Rupununi. What separated these respondents from the others was again a higher education level in combination with higher conservation training. A younger man in Yupukari described the importance of biodiversity in this way:

> *"Biodiversity is very important, we need it to do tourism, environment comes first, I think this covers most of the natural resources"*.

As argued, this valuation rating can be linked to education and training (Garcia-Llorente *et al*., 2011), but there also seems to be a link to tourism and the financial benefits it brings to the individual and the community. The quote also indicates that the person thinks biodiversity is important because they need it for tourism, revealing a value in utilitarian terms. A study focusing on the conservation attitudes of the Wapishana in South Rupununi concluded that most Wapishanas in these communities thought conservation was important, but mainly from a utilitarian point of view, and not conservation for its own sake (Henfrey, 2002). However, similar conclusions cannot be made in this study.

Another result linked to the difference in conservation and management attitudes between the communities found that Rewa had a higher positive attitude towards conservation and management than the other communities, as the following quotes demonstrate:

> "*We are not doing large-scale fishing, trying to conserve fish. Arapaima for example, we have lots of them in nearby pools"*. (Older man in Rewa)

> *"We have lots of forest don't want to destroy it, don't want to lose our carbon. Long time ago they used to waste wood, now trying to understand how to manage and use the forest in a sustainable way".* (Older man in Rewa)

These positive attitudes to conservation have led to certain areas on Rewa's titled land being set aside for conservation, particularly rich fishing ponds, which have been designated to serve as tourist attractions. Additionally, many respondents reported on a reduction in hunting, as they explained it was more beneficial to take tourists to see an animal several times than to kill it. So was this difference in attitudes due to Rewa's more isolated location compared to the other communities, or could it be other factors? Subsequently it became apparent that the language the Rewa participants used to explain why conservation was important revealed an influence from outsiders, which was linked to a prolonged level of conservation and wildlife training from conservation organisations, such as Conservation International and Iwokrama. Similar positive influences from environmental outreach work have been reported in other studies (such as Jacobson *et al*., 2006; Mehta and Heinen, 2001; Sodi *et al*., 2010). Jacobsson *et al*. (2006) found that in general, community support for conservation was enhanced where environmental outreach and basic formal education had been provided. Sodi's (2010) findings also support this argument; she found that environmental outreach programs appeared to positively influence people's views on protected areas in five forested parks in four countries (Mynamar, Indonesia, the Philippines and Thailand) of South East Asia.

Whilst it has been confirmed that Rewa has had many training sessions from conservation organisations, it does not fully explain Rewa participants' positive attitude, because most other communities have also had conservation training. However, the training has been undertaken alongside the development of the village's eco-lodge, which has slowly been developing since 2005, and with it increasing the financial benefits to villagers. Another potential explaining factor could be less competition of resources, as Rewa is still a relatively small, quite isolated community which means that even if an area is set aside for conservation the cost to the villagers is not as high as it might be for a community such as Annai, which has a large population and is located much closer to other communities. It is likely that these factors in combination could explain the Rewa participants' more positive attitude towards conservation (Mehta and Heinen, 2001).

This result is important as it demonstrates and verifies the positive effect conservation training can have on local communities' attitudes towards the environment, and therefore illustrates the importance of investing in awareness raising programs for conservation organisations. Additionally, it also supports the theory that eco-tourism can be an important tool to create positive attitudes and practices for conservation (Kiss, 2004).

4.3.4 Income and funding

The local stakeholder group with a paid profession differed the most from the other stakeholder groups in the value ranking (Table 4.2). Although the difference was only slight, and the sample numbers only small, interesting patterns were found in their responses. They revealed, as might have been expected, a slightly reduced dependence on fish and farming. This is most likely due to their income, which means they can afford to purchase some food instead of growing it or fishing themselves. This is illustrated in the quote from a working younger man in Kwatamang:

> *"I only fish once every two weeks as am busy working and buy the fish instead. Also using gas instead of wood for cooking, as got the money and it is easier in the rainy season".*

Another interesting result was that the overall ranking of eco-tourism, which was the industry most people worked in, was not higher in villages with an eco-lodge compared to the ones without. Similarly, people that worked full-time for an eco-lodge did not rank it higher on average than people not benefiting financially from tourism (Table 4.2). This is an interesting result, as in economic theory, income is seen as a top variable indicating what an individual should value the most (Brander *et al*., 2006; Sodhi *et al*., 2010). The explanation for this result is most likely to be a combination of two factors. First, even though eco-tourism generates income for these individuals and communities, the salaries and the village contributions are still too low to substitute for the other life-supporting activities such as farming and fishing (see quote below), which also generate some income if produced in surplus. The second factor is their strong ties to their cultural identity and traditions – they have strong traditions in farming and fishing and enjoy doing them, and therefore they mean more to them.

> *"Tourism benefits me by giving me money in my pocket plus money to the village council. Caiman catching salaries, village tour, people get some money for showing off what they got".* (Younger man, Yupukari)

> *"I'm working full time so do not have much time to do fishing and farming but love it and do it as much I can".* (Older man, Rewa)

The working schedule of one of the privately owned eco-lodges in the area permits their staff to work three weeks and then have the fourth week off to allow them to take care of their farm and go fishing. Regardless of eco-tourism's low ranking place (eighth, see Table 4.2) it is very much seen as the most desirable development path for all five communities (Field diary and notes). The communities with no eco-lodge expressed great willingness to develop one in the near future. No negative aspects or comments were recorded and everyone was positive for the tourism industry to grow within the area. The issue of not generating enough income to make a significant contribution to an improvement of life quality for the communities, which has been the main criticism towards eco-tourism as a conservation-development tool (Kiss, 2004), was not raised; the communities expressed patience and trust in the growth of their tourism industry.

> *"Tourism will be good in the future, it will generate jobs"*. (Younger man, Massara)

For the stakeholders in Georgetown the importance of money is not linked to personal income; instead it may be linked to organisational income, i.e. their funding sources, which seem to have an influence on how the organisation values its work. This is illustrated in the following quote from one of the conservation organisation's spokespersons:

> *"The carbon has become the thing because that is what we are being asked to think [from the Government and the international community], although I see more ES that we can look at, our national focus is carbon"*.

4.4 Understanding or mis-understanding of scale

Understanding the spatial extent of an ES is an issue researchers have battled with since the beginning of the ES concept, and it is still an issue that needs further investigation (Hein *et al*., 2006). However, most researchers have an idea of the scale an ES operates within. For example, carbon storage has benefits on a global scale, whereas retention of the soil (prevention of soil erosion) might be most valuable on the local scale – although potentially benefits could be felt nationally if the area produced substantial amounts of food for the nation. In the case of the Makushi, this seems to be different as the result shows that most (79 percent) of the respondents in the North Rupununi did not think that ES produced in North Rupununi had any benefits for people outside of this area. Half of the remaining respondents (10 percent) thought that people from Georgetown benefited by buying goods (fish, cassava bread, wild meat) from the North Rupununi or that they came as tourists. The last 10 percent recognised that some ES, such as tourism, carbon storage and biodiversity, have global benefits reaching far from the North Rupununi and beyond Guyana.

These results indicate that the Makushi's understanding of spatial scale in regards to the flow of ES might be different in comparison to how Western science produce scale. This could potentially be explained by the large scale outlook of the ES concept and/or that indigenous knowledge has had a tendency to focus on local scale and seldom on global scale (Bohensky and Lynham, 2005; Du Toit *et al*., 2003). Other studies (Bohensky and Lynham, 2005; Du Toit *et al*., 2003; Wohling, 2009) have found similar empirical evidence, which indicates that traditional ecological knowledge might not be so well adapted to analyse scale issues. The value of indigenous knowledge for biodiversity conservation in social-ecological systems is well known (Berkes, 2003). However, Wohling argues that “indigenous knowledge is not adapted to the scales and kinds of disturbance that present society is exerting on natural systems” (2009, p. 1). The result from this study does not support Wohling’s conclusion that indigenous knowledge is not well adapted to disturbances in the present society. However, it does indicate that there is a difference in scale understanding between the TEK of the Makushi and that constructed by physical scientists in relation to the flow of ES. It could either be regarded as a limitation for the Makushi due to a lack of understanding how spatial scale is constructed or it could be considered that the Makushi’s construct of spatial scale is just different to that of physical science. Either way this is an important result –the local communities in the North Rupununi appear to appreciate the spatial extent of ES produced in the area differently, which thus needs to be considered for any future management initiatives such as Government promoted REDD+ and maybe other PES schemes.

On the other hand, in Georgetown the stakeholders’ understanding of scale was also investigated, and they had a better understanding of the spatial extent of ES, particularly the ones which have global benefits, such as carbon storage and sequestration and biodiversity. However, when asked to identify the most important ES at the local scale there was a considerable mismatch to what the local stakeholders valued. Half of the stakeholders said that freshwater was the most important local ES, followed by biodiversity and eco-tourism. This was quite contrary to the Makushi’s valuation (Table 4.2), which put freshwater in fourth place, biodiversity seventh and eco-tourism eighth. This mismatch in scale of understanding the importance of ES for other stakeholders and the extent of ES is important. Again, for any management or development project this mismatch of interests and understanding has to be acknowledged before trust between the stakeholders can develop, which is a prerequisite for a successful project.

4.5 Constraints of the ecosystem services concept and the issue of valuation

Working with the ES concept proved rather more difficult than expected when engaging with local stakeholders. Explaining the ES concept and the valuation exercise was found to be challenging. The major barriers were identified to be the language of the ES concept and the notion of valuation.

4.5.1 The language of the ES concept

Prior to the data collection in the current study, workshops on ES had been held in the Rupununi by other researchers and NGO staff. Additionally, before each interview and focus group a presentation was held on what ES are and what the concept can be used for. Regardless of the time spent trying to explain the ES concept to the participants, for the majority it remained unclear and confusing. It was therefore felt that the interview and focus group process would benefit from the term ES being exchanged to 'natural resources' or just referred to as 'benefits' or 'use' of the forest, for example. By changing the terminology to improve understanding and facilitate communication, the process improved considerably. The research assistant later explained that the term 'natural resources' had also been new for the local people, but over the years they have learned and become accustomed to this term through research and work by conservation organisations.

Difficulties with using the ES language have been found in other studies (Defra, 2007; Tapella 2013; Fish, 2011). Even the UK Government has highlighted the potential for confusion due to the language associated with the ES concept (Defra, 2007). In the Defra (2007) report, which investigated the public's understanding of the ES concept and language, the term ES was found to be completely unfamiliar to most of the respondents. This unawareness was linked to the respondents not knowing what the term 'ecosystems' meant (Defra, 2007). The report concluded that "a significant degree of learning was required before ES can be a useful term, and at the moment it is meaningless and confusing to use, and will most likely distance people if used" (Defra, 2007, p. 40).

In the current research, the use of the term 'natural resources' instead of ES is thought to have improved the data gathered as it allowed for clearer communication. Other studies (Tapell *et al*., in press) working with indigenous people have come across similar difficulties. To overcome this issue it has been suggested to omit the ES term in the questioning and instead leaving the identification and categorisation of ES to the researcher after the data is gathered (Tapell *et al*., in press). MacDonald *et al*.'s (2013) study on a methodology to explore the values of community leaders in Australia assigned to multi-use landscapes also highlights the benefits of not using a strict interview script based on the ES approach. Instead, by only having a few categories for natural capital and ES, it allowed the participants to speak more freely, and they revealed a much more composite picture about the importance of ES (MacDonald *et al*., 2013). This approach was also used in this research to allow the participants to speak freely about what was important in their surroundings, what resources they used and other benefits they could identify that come from the natural environment.

Although there are some clear difficulties communicating the concept of ES, politicians around the world have openly embraced the concept (e.g. UK National Ecosystem Assessment and Guyana's Low Carbon Development strategy). Even though the ES concept carries technocratic connotations, which can easily lead to scepticism and critique, if the language was to be changed it would lose much of its analytical power (Fish, 2011). Fish (2011) argues that the ES concept needs its own, very particular, vocabulary because it is its non-conventionality that allows for new thought and connections to be made, which is something this study supports (Fish, 2011, p. 676). Even though there might be a need for the technocratic language of the ES concept, very few scholars have addressed this issue previously (Defra, 2007; Fish, 2011; Menzel and Teng, 2009). This thesis therefore highlights the language of the ES concept as a potential barrier when working with local stakeholders, and particularly with indigenous communities.

4.5.2 The issue of valuation

The second issue that arose from using the ES concept was the difficulty local stakeholders had in grasping the valuation exercise. Through this exercise it became apparent that the notion of valuation was something new and most found it a difficult task. An older man from Kwatamang expressed it in these words:

> *"Never thought about value really, used to using what we need. Never thought about how important the forest is for us."*

Others people expressed a difficulty in choosing between ES because *"they [ES] are all important"* and *"I have not thought about value in that way before".*

The Makushi's difficulty with valuation may be linked to their dependence on the ES. Because most of the ES they listed are crucial for their livelihood, choosing one over another is rather difficult. Similar valuation difficulty was found by Kenter *et al*. (2011), who studied the impact of deliberation on ES valuation in the Solomon Islands. There they found that "after deliberation key ES became priceless as the participants were unwilling to trade them off in the choice experiment scenarios, regardless of financial cost" (Kenter *et al*., 2011, p. 505). These key ES found in the Solomon Islands could potentially be compared to this study's top four ranked ES (farm, fish, wood, water), as these ES are crucial for the Makushi way of life. Although these difficulties with the valuation were observed, they were also overcome by allowing the participants further discussion and contemplation around the topic. This is supported by the similarity of the results found in the focus groups and interviews. However, these results illustrate how difficult it would be to put a monetary value on some ES, which is important to recognise when applying the ES concept in developing countries.

Another reason participants struggled with the valuation exercise may be because the ES concept is based on a Western expert-led worldview, as discussed earlier in the chapter, which is different to most indigenous people's worldview. The Makushi connection to nature is different to that of most Western scientists and to most people living a Western lifestyle. The degree of connectedness to nature affects how a person, and a society, construct and value nature (Wilson, 1984). Links can be made from these conflicting world views to Ehrlish and Moon's (1983) reasons to construct the ES concept. As discussed in Chapter 2, the ES concept was constructed to demonstrate humans' dependence on nature, which can be described by highlighting and categorising the wide variety of ES humans rely upon for their well-being. Just the necessity to have to remind people of the link between humans and nature demonstrates the lack of connectedness which exists in many societies today, mainly in the West but also in cities in the developing world. Nevertheless, for people whose lifestyle is still linked to nature, like the Makushi, no reminder is needed to illustrate their dependence on ES. Due to these very separate worldviews it can be difficult for indigenous and other local people whose lives are still linked with nature to understand the ES concept, which is a very fabricated and compartmentalised view of the world.

Menzel and Teng (2009) argue that the concept of ES as it is used today can hinder communication rather than facilitate it. They go even further and argue that the concept strengthens the position of those who hold the power to define ES (i.e. formally educated experts rather than the local users). They urge a resolution of this issue by including local human values and needs in ES projects by encouraging stakeholders within ecosystems under investigation to gather data, and to jointly identify and define ES in cooperation with natural and social scientists. Tapella *et al*. (in press) also used a similar methodology where the stakeholders were allowed to identify and value the ES in their own language. The research for this thesis was designed to allow for this process to take place; the benefits of using this approach have been illustrated by overcoming problems that arose.

Despite the difficulties expressed, the valuation exercise encouraged the respondents to reflect and articulate their opinions on what was important to them. Additionally, after the sessions many respondents expressed an appreciation for being allowed to voice their opinion and that an outsider was interested in what they thought and had to say. A comparable result was found by Sheil and Liswanti (2006) when they performed a similar scoring exercise in Kalimantan, Indonesia. Their participants were also appreciative that outsiders sought out and valued their opinion; they also said the exercise was helpful because they needed to learn how to better articulate their wants and concerns, especially to outsiders. This result thus demonstrates the usefulness of this type of valuation exercise to encourage empowerment, participation and the possibility to build trust between outsiders and local stakeholders.

4.5.3 Overemphasis on economic rationalism

The last and most common concern with the ES concept is its overemphasis on economic rationalism. There are clear benefits to using monetary valuation to inform policy decisions, particularly to highlight the potential economic benefits of sustainable ecosystem management and the use of future development scenario exercises (Daily, 2009; de Groot *et al*., 2003). However, according to Chee (2004), most methodologies used for valuation suffer from serious limitations, which can result in significantly different monetary values. In addition, many ES, particularly cultural ES, are difficult or even impossible to value (at least currently) in monetary terms, such as bequest values and traditional practices (Chee, 2004). The dominance of monetary valuation in the research arena and among NGOs can potentially be risky; as Jepson and Canney (2003) argue, assigning a monetary value to ES may remove conservation from the public realm and make nature a commodity, with a value that goes up and down according to the global markets instead of its value to the people.

Too much focus on monetary valuation can particularly threaten cultural ES, as they are very complex and difficult to value and thus risk being neglected or undervalued (Plieninger *et al*., 2013). Cultural ES can promote a sense of 'groundedness', security, identity, and spirituality, whose value is difficult to capture in monetary terms (Jepson and Canney, 2003). This can be related to the Makushi, who also place great value in practising their traditional customs on their titled lands; being able to live a traditional lifestyle ensures their identity and culture live on.

The participants also valued security, as they often mentioned that the North Rupununi is a safe place to stay, whereas many saw Georgetown as unsafe. Another type of security issue raised on numerous occasions was the ability to live for free in the North Rupununi, which means that they do not need money to survive. The comparison to living in Georgetown was also made several times, about how expensive and difficult it is to live there. Most respondents also expressed warmth and some even an outspoken love for their village or land.

> *"I love my village. That is where I born and grow".* (Younger man, Massara)

We also witnessed the sense of loss some felt by just leaving their village's titled land and trying to fish in another village's land. All of these examples could be interpreted as the Makushi's groundedness to their land and their way of life. These ES are, as Jepson and Canney (2003) observe, very difficult to capture in monetary terms and it becomes an ethical question: does everything that has a value need to have a monetary value?

Gomés-Baggethun and Ruiz-Péres (2011) argue that economic valuation can be a potent information tool when not used as a single decision-making criterion, and if used alongside other valuation methods that capture the non-economic value dimensions of nature. Their criticism is aimed at the idea that economic valuation can capture a comprehensive picture of nature's societal value, and at the belief that economic valuation can solve the problems and shortcomings of traditional conservation (Gomés-Baggethun and Ruiz-Péres, 2011).

Garcí-Llorente *et al*.'s (2011) findings on an economic valuation of aquatic plants in Doñana, Spain, also illustrate the potential risks of using an economic framework to capture the value of ES. They found that even though respondents were given ample information about the importance of certain species and habitats, the contingent valuation method still failed to capture the full value of biodiversity and ES, as they ignored the ecosystem's properties and the biodiversity underpinning them (Garcí-Llorente *et al*., 2011). Schkade and Payne (1994) also criticise the contingent valuation method for being highly sensitive to changes in the questions and in the instructions given to the respondents. Spangenberg and Settele (2010) argue very strongly against using an economic framework to value ES and highlight the risks of employing such a concept. They also stress the weakness of the basic assumptions that underpin the ES concept (discussed in chapter 2) – that the economic valuations are far from realistic when applied to human behaviour. They emphasise that the methods used for monetary valuation give widely divergent results, which implies that the calculated values for ES are not robust, and therefore should only be used as a contribution to the implementation process of policy development (Spangenberg and Settele, 2010).

The risk of valuation is to get the figures wrong, which is unavoidable according to Spangenberg and Settele (2010). However, the ultimate risk is that economic instruments become ends in themselves, which could jeopardise the conservation of ES or even lead to their demise (Bonnedahl and Eriksson, 2007). As this proposal from Köck (2008, p. 18) illustrates: ''In order not to unnecessarily restrict economic activities, it has been suggested to permit the destruction of a habitat if a certificate is presented confirming that an equivalent habitat has been created somewhere else. Making the certificates tradable would create a global market, supporting a flexible and cost-effective biodiversity protection''. The complete lack of ecological understanding in this suggestion clearly exposes the risk of commodifying nature and the need to develop an improved valuation process.

Many scholars are calling for an alternative valuation process (see for example Chan *et al*., 2012; Chee, 2004; Spangenberg and Settele, 2010; Spash, 2008), one which does not solely rely on one monetary measure, but instead uses several metrics (Chee, 2004). This could involve utilising a broader range of tools such as a citizen's jury, simulation modelling, probabilistic risk assessment, and/or multi-criteria decision analyses (MCDA) (Chan *et al*., 2012). Spangenberg and Settele (2010, p. 334)) advocate for a 'horizontal' MCDA, which results in a ranking of options, where the diversity of stakeholders' value systems is taken into account and "the purpose of the exercise is not to reach an 'optimal' solution, but creating a level playing field in terms of information access as an input into a political discourse processes". Bryce *et al.* (2013) also identify the MCDA as a good decision-making method that is transparent and structured, which can produce a systematic and visual representation of diverse stakeholder perspectives in complex situations where trade-offs are unavoidable. This approach is particularly useful to "evaluate how well alternative management options fulfil a range of criteria that reflect the values and objectives of stakeholders" (Bryce *et al.* (2013), p. 1).

It is not within the remit of this study to scrutinise monetary ES valuation. However, it is important to emphasise the limitations of such applications and highlight good alternatives, such as the approach used in this study. The scoring and ranking methods used demonstrated how useful this methodology can be to understand different stakeholders' perceptions, and a useful tool to quickly and relatively cheaply describe the value of ES for spatial planning and development (Klain and Chan, 2012). Similar results have also been found by Sheil and Liswanti (2006) and Klain and Chan (2012), who both encourage and prefer the use of these type of valuation methods.

4.6 Conclusions

This chapter illustrated that when comparing local, national and international stakeholders, the value of ES differ depending on the stakeholder's scale. A pattern could be seen whereby ES with a more local spatial distribution were valued higher by the local stakeholders compared to the national and international stakeholders, and vice versa. The ES valued highest by the national and international stakeholders tended to operate at larger spatial scales, a result that has been found in similar studies (Hein *et al*., 2006). I argue that it is therefore very important that the ES concept accounts for these differences in opinion and ensures stakeholders' perspectives at all scales are included and valued. How the different stakeholders' values should be weighed up and valued is a separate issue, and an area that needs further research and potentially the development of new frameworks and/or guidelines that ensure equitable representation of stakeholder values at different scales.

This chapter also demonstrated that stakeholders' perspectives and valuations of ES depend on factors other than scale. Considering the other themes (basic needs, culture values, education, and income) that were identified to influence stakeholders' valuation allowed, or at least provided the opportunity, for outsiders to try and understand the value grounds and way of life of the local communities in the North Rupununi. A better understanding of local communities' underlying values and way of life has been shown to be one of the most important factors for the success of conservation and management projects (Berkes, 2003).

Another important finding reported and discussed in this chapter was the dominance of provisioning services in importance and identification by the Makushi. As discussed earlier, the question is: is this because of a utilitarian view of nature, i.e. the products from nature that can be used by the people, or is it because of lack of western ecological knowledge, the nature of humans or different worldviews? Henfrey (2002), who conducted research in the South Rupununi with the Wapishana people, found that the utilitarian aspect of species and ecosystems seemed to be prioritised in comparison to more intrinsic value grounds. However, other literature suggests that indigenous people are more connected to nature in their societies. Many indigenous people do not see themselves apart from nature, as people in many Westernised countries do; instead they see themselves as an integral part of the ecosystem. Still, some studies suggest a provisioning ES dominance or favouring, as discussed in the chapter. Issues such as knowledge level of the ES concept and ecology and instinct to value products that ensure survival were all discussed as factors most likely to influence the value a stakeholder at any scale might give an ES. It is difficult to draw a conclusion other than it might be inappropriate to draw conclusions regarding the Makushi's relationship with nature based on a ES concept analysis, as the two might not be compatible.

Some of the constraints of the ES concept have also been discussed where language, the social/human dimension and the need for an alternative valuation approach have been highlighted. This study has also provided support for the applicability and benefits of using a non-monetary method such as scoring and ranking for the valuation of ES.

The next chapter will explore the condition and trends of the freshwater ES in the North Rupununi. Investigation into how temporal scale affects the ES will be explained and issues around ES and spatial heterogeneity will be discussed.

Chapter 5

Ecosystem services in the North Rupununi: their status, and the effect of temporal scale and spatial heterogeneity

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The previous chapter discussed perspectives and values of ES, illustrating how dependent the local communities in the North Rupununi are on the ES the natural landscape produces, regulates and supports. In the light of these findings, the importance of these ES and their status is evident for the local communities. The ecosystems producing these ES need to be healthy, well-functioning systems to secure the well-being of the Makushi people. It is therefore essential to establish baseline data where this is missing, and collect data to enable assessment and monitoring of the ES in the area. Furthermore, a better understanding of how both temporal scale and spatial heterogeneity from a physical scale perspective affect the status and distribution of the ES is needed to maintain well-functioning ecosystems (Koch *et al*., 2009). This chapter will focus on these topics, which are linked to the second research aim, which is 'To assess the status and trends of ES and explore how they vary over temporal and spatial scales'. The implication of these research findings will be briefly discussed at the end of the chapter, but a more thorough examination will take place in Chapter 7, where the research findings will be linked to different management options.

The high diversity of the North Rupununi and the multitude of ES produced have been discussed earlier (chapters 2 and 4). In this chapter, the focus will be on the ES produced, or linked, with the Rupununi River, its tributaries and remnant lentic water bodies. These ES are both rare and endangered systems that provide crucial ES for communities living a subsistence lifestyle, like the Makushi in the North Rupununi. Locally, the most important ES the river produces are the aquatic food webs and the abundant availability of good quality water, as illustrated in the results described in chapter 4. These rich aquatic food webs produce a high quantity and diverse number of fish, which is one of the main provisioning ES the North Rupununi supplies to the local population. Nationally and internationally, the most important ES in the North Rupununi is its high biodiversity. It hosts more than 400 species of fish

(Wetlands Partnership, 2006a) and is home to many endangered large mammals, as discussed in chapters 1 and 2. High biodiversity ensures resilient ecosystems that can provide many values and services to people both locally and globally (Holling, 1974). An example of such a service is eco-tourism, which is developing and has expanded well in the North Rupununi. The developed eco-lodges provide much needed economic benefit to the communities. Another important ES is the buffering of the hydrological changes (both annual flood pulse and multi-year cycles) this wetland provides. During the annual floods, the Rupununi's savannas and forests store a large portion of the floodwater; some of this water is evapotranspirated and some recharges the groundwater supply. All communities and towns along both the Rupununi and Essequibo Rivers (which the Rupununi River flows into) benefit from this buffering effect of the floodplain. The flood pulse changes the landscape dramatically, as discussed in chapter 2 (section 2.7), and it is therefore important to investigate how this annual event affects the delivery of ES in the North Rupununi. This chapter will discuss the status of three ES in detail: the water quality and quantity for the area, food webs represented by the fish fauna, and the biodiversity represented by the Black Caiman (*Melansuchus niger*). Biodiversity might not strictly be an ES but it supports the provision of other ES and therefore, in this study, it is regarded as a supportive ES.

In the first part of the chapter, spatial heterogeneity in the landscape will be discussed, demonstrating how the waterbodies differ in their physico-chemical properties and how this affects the water quality, fish fauna and the biodiversity. The second part will discuss the importance of temporal scale, focusing on seasonality. How the dry and wet season affect the water quality and quantity, and how this influences the fish fauna and the Black Caiman population are two of the main themes. The third part will focus on long-term temporal scales and will examine how the water quality, fish fauna and Black Caiman populations have changed over a decade and the possible explanations for these changes. A discussion around the major findings will conclude this chapter.

5.1 The effect of spatial heterogeneity on the provision of ecosystem services

In South America, the principal criterion used to classify rivers is the amount of suspended sediment in the water (Meade, 1994), as discussed in chapter 2 (section 2.7). The Rupununi River is classed as a whitewater river, which means that it is brown muddy in colour, and carries a lot of suspended sediment making the transparency low (Watkins *et al*., 2005). Some creeks in the Rupununi are classed as blackwater creeks, meaning the water is virtually free of sediment under natural conditions, which makes the transparency very high. The water is black due to the fulvic and humic acids which are dissolved in the catchment area's acidic soil. In the

North Rupununi, Simonie Creek and Bat Creek, among others, are classed as blackwaters (see Map Appendix 3 and 4). There is also a third class called clearwater, which is intermediate in its transparency and colour (Meade, 1994). The Rewa River in the North Rupununi has been classed as a clearwater river (Watkins *et al*., 2005).

There are many different types of waterbody habitats (oxbow lakes, permanent and seasonal ponds, creeks, swamps, inlets) in the North Rupununi. These different types of habitat provide their own physico-chemical characteristics which might influence the water quality, fish fauna, and biodiversity. This section will examine the diversity of freshwater habitats in the Rupununi landscape and how this affects the flow of ES.

5.1.1 Water quality and its differences across habitats in the North Rupununi landscape

The results demonstrate that some of the water's physico-chemical properties vary quite considerably when comparing four different water habitat types (Rupununi River, blackwater lakes/creek, permanent ponds, and creeks; see Map 3.6 for water testing sites), whereas others remain relatively similar (Table 5.1). All the water parameters tested, apart from phosphate, indicate that the natural water bodies are in good condition (Table 5.2; EPA, 2001; WHO 1998). The phosphate concentration in most habitats is higher than anticipated for a relatively pristine system such as North Rupununi; this result will be further explored later on in the chapter. The results for some of the wells indicate different types of pollution, as the values of ammonia and phosphate (nitrate) are elevated in comparison to the World Health Organisation's criteria (WHO, 1998).

First, the longitudinal differences of the Rupununi River's physico-chemical properties can be viewed in Figure 5.1. Here the different parameters have been analysed with a principal component analysis (PCA), which is a multivariate statistic used to visualise how different sites are related or not, and which parameter differs the most between the habitats. The analyses show that turbidity is the strongest variable to explain the difference between the sampling sites. The result also shows that the Rupununi River's water by Yupukari and Massara are the most similar among the different sampling sites, and that these sites have the highest turbidity values; this is explained by both of them being up river to the other two sampling sites, and closer to the source of the river, which is the Kanuku Mountains in the dry season and the South Rupununi savannas in the wet season. However, Rewa did not have the lowest turbidity, which might be expected as it was the furthest downstream sampling site. Instead it was Kwatamang, which most likely depends on the slower velocity around this site, as large deposit areas were confirmed both shortly upstream and downstream from the sampling site. For the Rewa water sample it seems to be the higher than average phosphate concentration that makes this site differ from the others, and it might be the high volume of water entering the Rupununi River by the creek tributaries which causes the slightly higher turbidity. For the water sample by Kwatamang it appears that both turbidity and pH are the dominating variables explaining its difference in comparison to the other water sampling results.

Table 5.1: Mean water quality values for four natural waterbody types and for well water

Waterbody type	**Season**	**Rup. Riv.**	**Ponds**	**Black water Po.**	**Creeks**	**Wells**
Turbidity (NTU)	Dry	25.1(±4.8)	34.5(±11.5)	2.8(±0.7)	10.8(±10.5)	0.9(±0.2)
	Wet	8.5(±3.9)	10(±1.4)	10.2(±1.2)	9.1(±4.1)	6.1(±3.2)
EC (μS/cm)	Dry	25.6(±2.5)	30.3(±8.2)	28.9(±0.6)	24.9(±9.2)	68(±16)
	Wet	19.1(±0.7)	20.1(±1.2)	19.8(±0.5)	20.3(±1.2)	62.5(±12)
pH	Dry	6.8(±0.23)	6.6(±0.2)	6.2(±0.05)	5.9(±0.3)	5.9(±0.8)
	Wet	6.2(±0.1)	6.3(0.2)	6.4(±0.1)	6.3(±0.1)	5.9(±0.9)
Temp. (^{0}C)	Dry	29.9(±0.6)	30.8(±0.7)	25.9(±0.3)	28.7(±1.8)	29.3(±1.6)
	Wet	28.6(0.7)	28.8(±0.5)	28.8(±0.2)	28.8(±1.5)	28.8(±1.1)
Ammonia (mg/l)	Dry	0.06(±0.01)	0.08(±0.01)	0.04(±0.01)	0.18(±0.05)	0.13(±0.06)
	Wet	0.06(±0.01)	0.11(±0.05)	0.08(±0.04)	0.08(±0.06)	0.07(±0.03)
Nitrate (mg/l)	Dry	0.14(±0.04)	0.04(±0.03)	0.09(±0.03)	0.05(±0.04)	4.58(±4.2)
	Wet	0.06(0.05)	0.05(±0.04)	0	0.05(±0.04)	3.78(±1.3)
Phosphate (mg/l)	Dry	0.48(±0.2)	0.32(±0.13)	0.16(±0.1)	0.2(±0.05)	0.67(±0.8)
	Wet	0.37(0.1)	0.26(±0.07)	0.3(±0.06)	0.26(±0.08)	0.85(±0.8)
Iron (mg/l)	Dry	0.28(±0.08)	0.46(±0.1)	0.26(±0.08)	0.34(±0.1)	0.27(±0.4)
	Wet	0.77(0.1)	0.96(±0.2)	0.64(±0.1)	0.76(0.1)	0.24(±0.3)

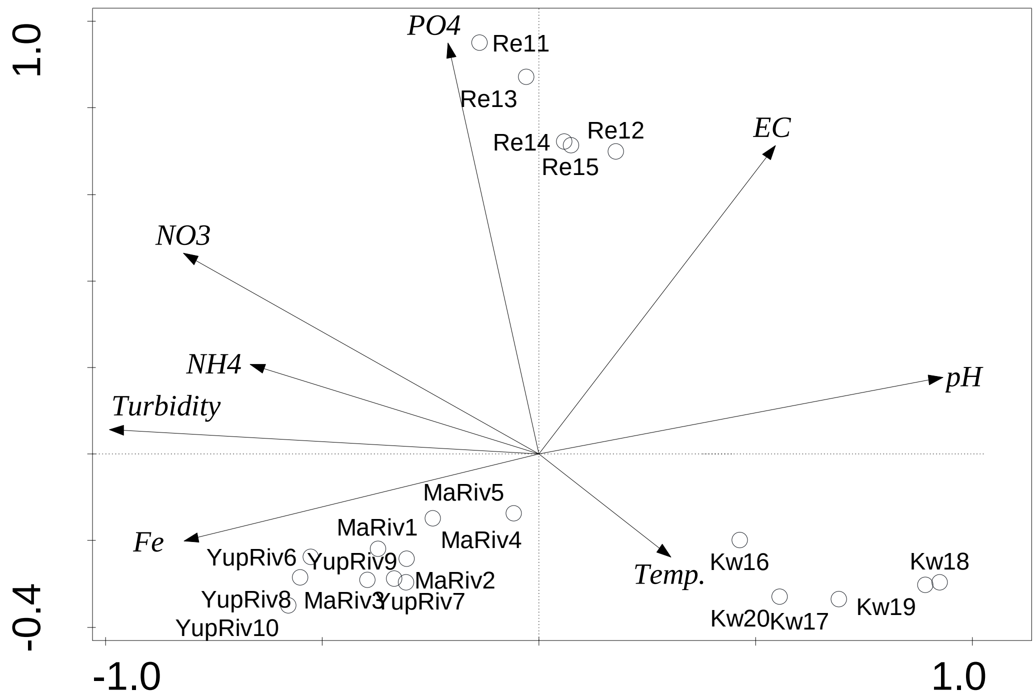

Figure 5.1: PCA diagram of Rupununi River physico-chemical parameters in the dry season (see Table 5.3 for total variance and Eigenvalues)

It can also be concluded that the turbidity values were rather stable in both seasons, with a mean of 25.1 NTU (± 4.75 NTU) in the dry season and 8.5 NTU (± 3.96 NTU) in the wet season. However, the differences between seasons are quite high, which will be further discussed later on in this chapter.

Ponds were the waterbody type with the highest turbidity and conductivity values (Tables 5.1 and 5.2). Out of these it was Moby Pond that had the highest turbidity in the dry season (Map 3.6) and Simonie Lakes the lowest. The conductivity values were overall rather low and particularly low for a whitewater river such as the Rupununi River, which had a mean value of 25.6 µS cm $^{-1}$ (±2.48). In the Amazon River, another whitewater river, the electrolyte content has a range of 40-80 µS cm $^{-1}$ and a turbidity range of 50-100 NTU (up to 1000 NTU) (Junk, 2005). However, the Orinoco River, which like the Rupununi River is located on the Guiana Shield, has lower conductivity values (10-50 µS cm $^{-1}$) and turbidity (30-200 NTU) compared to the Amazon (Junk, 2005), which is more in line with the Rupununi's values. The reason for these lower values in the Guiana Shield is most likely due to the slow erosion rates of the bedrock. The Guiana Shield has amongst the slowest erosion rates on earth: a metre per million years on the flat tops of mountains such as Roraima and Auyan Tepui, and only a few metres or tens of metres per million years over substantial areas of the shield (Meade, 1994).

Another process that might also be responsible for the turbidity result, which was explained by the Makushi and observed in the fieldwork, was that several ponds became milky in colour towards the end of the dry season. This was because the ponds become disconnected from the Rupununi River or the creek they were part of due to the reducing water level, and subsequent disturbance of the sediment, either by the wind or by fish caused the whitening (increased turbidity) of the water. McConnell (1964) also observed similar patterns in her exploration of the Rupununi. This 'whitening' effect was noted to occur in several ponds: (i) all the ponds along the Bononi Creek, except Bononi Pond, which remained connected to the River, as the part of the creek closest to the river had burst the banks a few years earlier (Field notes 18/03/11); (ii) Moby Pond; (iii) Awarekru Pond; (iv) Kwatamang Pond; and (v) Takatu Pond (see Map Appendix 1-5). More ponds may have gone milky in colour but these ponds were the ones observed. It was also noted that it took between 1-4 weeks from the pond becoming disconnected to the colour changing to milky, depending on the size of the pond; the smaller the pond, the faster the process and vice versa (Field notes 10/04/2011). However, there were also ponds that became disconnected but did not undergo this marked transformation in colour, such as Devil's Pond and Grass Pond. These are ponds of darker waters and lower turbidity (Table 5.2), and thus contain fewer particles/sediment to be stirred up. The explanation for this is most likely the difference in drainage area – the 'whitening' ponds were mainly drained by savanna, whereas the non-whitening ponds were located in the forest or at least had a higher proportion of forest in their drainage area. As the ponds became milky their ability to produce good quality ES were reported to decline, thus indicating a temporal and spatial pattern between the savanna and forest ponds.

To compare the different habitat types another PCA analysis was performed (Fig. 5.2); as can be seen in the diagram, turbidity is the parameter that explains the difference between the habitats the most. It is also apparent in the PCA diagram that there is a physico-chemical difference between some of the waterbody types, as a few waterbody types are grouped separately in the diagram. The creek samples, for example, can be found in the right hand bottom corner, with no other habitat types nearby. This is most likely due to their clear water (low turbidity) and low pH (Table 5.1 and 5.2). However, not all water types are grouped together, indicating physico-chemical difference within the same water body type. For example, for the ponds it is most likely the turbidity that divides the group, where there is a mixture of clear and more 'muddy' coloured ponds; the group of pond samples seen in the upper right square of the diagram represent values from Devil's Pond, which has clearer water than most of the other ponds. Again, a similar pattern can be seen for the Rupununi River samples where the Massara and Yupukari samples are grouped together, as seen in Fig. 5.1, whereas now Rewa and Kwatamang's water samples have grouped together as being more similar when comparing to other habitats. Although the PCA result for the dry season illustrates and supports what the other results show, caution has to be taken as the total variance value (Table 5.3) is a bit high to indicate fully trustworthy results. Still, the PCA results for the wet season (Fig. 5.3) also support the described results above, and the total variance is within a good range (Table 5.3), which is a positive indication that the results are trustworthy.

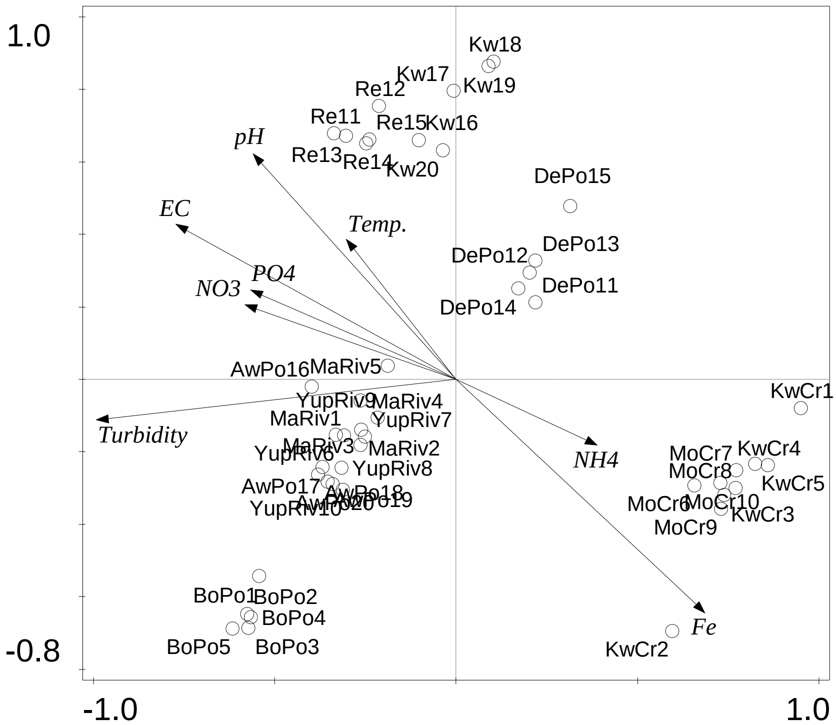

Figure 5.2: PCA diagram showing how the different water habitats differ physico-chemically in the dry season

The Rupununi River had on average a slightly acidic to neutral pH 6.8 (± 0.23) making it the waterbody with the highest pH (Tables 5.1 and 5.2). This result is in line with other healthy South American rivers which also have a slightly acidic to neutral pH (Roberto *et al*., 2009; Junk, 2005). The creeks were found to be the most acidic waterbody type with a mean pH range of 5.9 (± 0.25). This low pH is due to the leachate of organic material in the creeks' catchment, which is much more concentrated in creeks as they contain lower water volume compared to rivers (Wickland *et al.*, 2012).

Comparing the black and white lentic waterbodies, the blackwater lakes were more acidic, as expected, with a mean pH of 6.2 (± 0.05). Other blackwater tributaries in South America have a pH range of 4-5, a conductivity range of 6-20 µS/cm $^{-1}$ and a turbidity of less than 5 NTU (Junk, 2005). This indicates that Simonie is not as acidic nor has as low conductivity as most other blackwater tributaries. The reason for this is probably the mixed landscape surrounding the

Simonie creek and lakes, which is a result of the different soils making up the North Rupununi. On the savanna, mostly white sands are found, which dominate along the Rupununi River (Eden, 1964; Sarmiento, 1983) and the west side of the Simonie creek and lakes. In contrast, on the east side of Simonie, it is mainly lowland tropical forest which is found on more silty soils (Hawkes and Wall, 1993). It is therefore likely that the mixed soil and landscape surrounding Simonie Lakes and creek is the cause of this result.

The chemical properties of the water were quite variable between most of the water body types. The highest phosphate and nitrate concentrations were obtained in the Rupununi River. The lowest phosphate concentration was found, as expected, in the blackwater lake of Simonie, whereas the lowest concentrations of nitrate were found in ponds. Overall, iron was obtained in rather high concentrations (Table 5.1) and ponds were the waterbody with the highest values. The high concentrations are thought to come from the iron rich latosol soil of this area, and the concentration was higher in ponds that mainly receive drained water from the savanna compared to blackwater lakes (Eden, 1964; Hawkes and Wall, 1993; Sarmiento, 1983). The forests filter the water more efficiently and the water also contains fewer soil particles, as the roots of the trees are more efficient in keeping the soil in place compared to the savanna (Eden, 1964; Hawkes and Wall, 1993; Sarmiento, 1983).

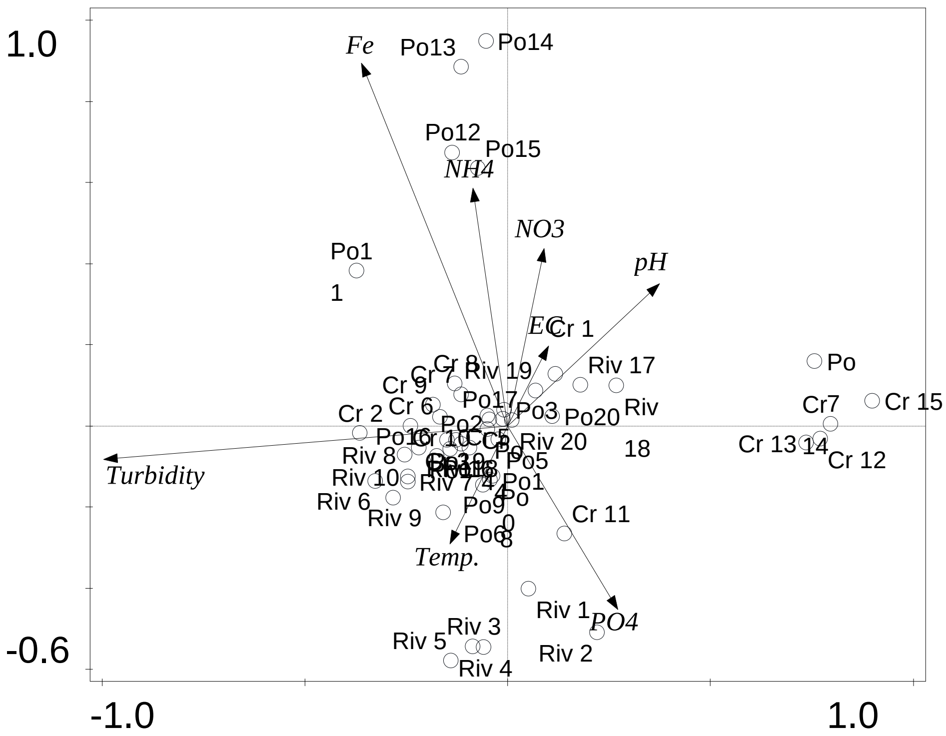

Figure 5.3: PCA diagram showing the physico-chemical characteristics of the different water bodies (Riv- Rupununi River, Po – Pond, Cr – Creek) in the wet season

Table 5.2: Mean values of main limnological parameters measured in habitats of the Rupununi River floodplain

Type of water body	Waterbody	Turbidity (NTU)		EC (µS/cm)		pH		Temp. (°C)		Ammonia (mg l^{-1})		Nitrate (mg l^{-1})		Phosphate (mg l^{-1})		Iron (mg l^{-1})	
		Dry	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
River	Rup. Yup	28.4	12.1	22.2	19.0	6.7	6.1	29.7	28.5	0.08	0.04	0.17	0.01	0.46	0.13	0.31	0.72
	Rup. Ma	27.2	9.2	25.6	18.9	6.7	6.2	30.5	28.7	0.05	0.05	0.15	0.02	0.39	0.52	0.38	0.61
	Rup. Kw	19.7	9.3	25.8	19.6	7.0	6.3	30.1	28.9	0.04	0.06	0.07	0.10	0.35	0.32	0.18	0.85
	Rup. Re	24.9	3.3	28.8	19.1	6.8	6.0	29.4	28.0	0.07	0.07	0.17	0.13	0.72	0.49	0.24	0.91
	Rewa Riv.	22.3	10.4	22.3	18.9	6.7	6.1	28.6	27.4	0.05	0.07	0.40	0.27	0.38	1.46	0.33	0.98
Ponds	Moby	47.8	9.3	43.0	18.9	6.6	6.3	30.8	28.8	0.08	0.10	0.04	0.00	0.45	0.23	0.71	0.70
	Bononi	38.5	10.3	25.7	21.6	6.7	6.3	30.3	29.3	0.07	0.07	0.06	0.05	0.42	0.33	0.42	0.83
	Devils	17.3	10.5	22.1	19.7	6.8	6.5	31.3	28.3	0.09	0.15	0.03	0.10	0.11	0.21	0.24	1.34
Lakes in creeks	Awarekru	30.5	10.2	27.4	19.7	6.5	5.9	30.1	29.5	0.1	0.0	0.11	0.01	0.30	0.14	0.37	0.76
	Simonie	2.8	10.2	28.9	19.8	6.2	6.4	25.9	28.8	0.04	0.08	0.09	0.00	0.16	0.30	0.26	0.64
Inlet (Rup. Riv.)	Awarmie	16.5	3.4	24.9	18.6	6.6	6.2	26.8	27.9	0.05	0.07	0.07	0.07	0.34	0.62	0.28	0.63
Creeks	Annai	1.7	5.6	18.7	20.5	6.0	6.5	29.3	29.1	0.08	0.06	0.03	0.06	0.20	0.32	0.22	0.61
	Kwatamang	19.2	10.5	33.1	19.5	5.8	6.3	30.6	28.3	0.39	0.13	0.02	0.01	0.20	0.29	0.38	0.85
	Mouri	11.6	11.1	22.9	20.8	6.1	6.2	26.3	29.1	0.08	0.05	0.09	0.07	0.20	0.17	0.43	0.82
Wells	Yup	0	0	161.9	160.0	7.5	7.3	29.8	28.0	0.02	0.03	0.18	0.19	2.32	2.58	0.00	0.00
	Ma	0	0	65.0	53.3	4.9	5.1	31.1	30.5	0.02	0.11	11.66	9.33	0.49	0.76	0.06	0.00
	An	0.4	0.5	30.8	22.0	5.9	5.6	28.7	29.4	0.05	0.02	1.46	1.32	0.21	0.21	0.03	0.08
	Kw	1.7	15.1	40.5	44.7	6.0	6.2	28.1	28.3	0.03	0.07	0.15	0.18	0.28	0.28	1.10	0.83
	Re	2.6	15.0	41.7	32.8	5.2	5.2	28.7	27.6	0.52	0.10	9.42	7.89	0.06	0.41	0.15	0.31

The higher than expected values of phosphate, with a mean of 0.48 mg l^{-1} (± 0.2) in the river and a range of 0.075-0.45 mg l^{-1} in the other habitats are surprising. The American Environmental Protection Agency's (US EPA) water quality criteria state that phosphate should not exceed 0.05mg l^{-1} in flowing waters (US EPA, 1986) however phosphate concentrations in the Amazon River has been measured at 0.25mg l^{-1} (Gibbs, 1972). Although levels of 0.08 to 0.1 mg l^{-1} orthophosphate may trigger periodic blooms, long-term eutrophication will usually be prevented if total phosphorus levels and orthophosphate levels are below 0.5 mg l^{-1} and 0.05 mg l^{-1} respectively (Dunne and Leopold, 1978). These guidelines are for temperate freshwaters, so the risk of algae blooms might not be the same in the tropics, where nitrates are in limited availability; water bodies on the Guiana Shield are generally very nutrient poor, as discussed earlier. However, it could potentially lead to an increase in macrophytes and floating vegetation in lentic environments, which could then cause deoxygenated environments due to the breakdown of the organic material, which could increase fish mortality. In a lotic environment, such as the Rupununi River, it is not the availability of nutrients that commonly are the limiting factor in primary production; it is the availability of light (Winemiller, 1990). This reduces the risk of algae blooms, but it has been shown in previous studies that tropical waters are more vulnerable to eutrophication then temperate ones, so it may be a serious issue that potentially could lead to a deterioration of the habitat and the ES the area produces (Winemiller, 1990).

When high phosphate concentrations are detected it may indicate fertiliser runoff, domestic waste discharge, or the presence of industrial effluence or detergents (EPA, 2001). However, in the Rupununi, fertilisers are not used on a regular basis. I was only told once that a community further upstream had used it recently when a shipment was sent from a governmental body (Field diary, 18/06/2011). It is therefore doubtful that fertilisers could be the source of the higher concentrations of phosphate. Neither are any industrial effluences present in the area. The only possible non-natural source of phosphate is from domestic wastewater and detergents. All the communities have pit latrines and many use the closest waterbody for their personal washing and for their clothes, which will cause some level of pollution; however, as the concentration is not lower in either moving water or the wet season it seems unlikely that such a small population (6000) can cause these values consistently. Other explanations could be technical faults with the equipment. However, since higher than expected results were detected, extra care and more than double replication of the test was done and concentrations stayed similar, indicating that the procedure was performed correctly. The last explanation for this result is that it comes from a natural source, as phosphorus occurs naturally in geological formations and varying degrees of leaching occur under different conditions, so it could potentially be the source. The unusually high concentrations of phosphate (Table 5.2) in the well water in Yupukari do indicate that the source is natural and comes from below the ground.

Moreover, it has been found that fire on the savanna increases the leaching of phosphate from the litter layer to the mineral soil and to a deep (1m) soil layer, where it is retained (Resende *et al*., 2011; Richie *et al*., 2011). Repeated savanna fires, which are lit to improve the grazing for the cattle and are part of the traditional culture in the Rupununi savanna, may have led to translocation of phosphate from the litter layer to the clay minerals in the deep soils. These fires often spread, and at least three of the ponds forming part of the study were affected with fires, engulfing the vegetation along the water line. Thus, a hypothesis would be that these enriched clay layers have come in contact with salty waters, which causes the fixed phosphate to leach out into the waterways. Chase and Sayles (1980) found that when sediment from the Amazon River reaches the seawater substantial quantities of soluble phosphorous are released from the natural suspended sediment. Unfortunately, salinity was not measured in this survey but conductivity values can be used as a substitute, and the much higher conductivity values in Yupukari's well water (Table 5.2) indicate that it is possible the source of phosphate comes from below ground. Additionally, the interview with the healthcare worker in Yupukari revealed that people have complained about the salty flavour of the water from the well, which supports the hypothesis that the source of the phosphate might come from below the ground.

Table 5.3: PCA analysis values of all habitats in both dry and wet season and the particular values for the Rupununi River in the drey season.

Site	**Total variance**	**Explained variation (cumulative)**			
		Axis 1	**Axis 2**	**Axis 3**	**Axis 4**
Dry season - All habitat types (Riv., Po. And Cr.)	10.21	84.31	91.53	97.22	99.09
Wet season - All habitat types	3.81	70.17	85.00	94.19	9.57
Rup. Riv. Dry season	0.93	59.59	91.15	97.89	99.55

The above discussed results for the natural waterbodies indicate a wide range of limnological environments (e.g. pH, turbidity) which produces water habitats with diverse physical and chemical properties (Roberto *et al*., 2009). This wide range of abiotic conditions indicates great habitat diversity, which is linked to high species diversity and thus partially explains the high biodiversity in the Rupununi floodplain (Agostinho, 2000; Roberto *et al*., 2009). Habitat diversity is an important factor for species richness of several assemblages in wetlands (e.g. Rolon *et al*., 2008; Tockner *et al*., 2000). In terms of conservation this result means that to maintain the Rupununi's high biodiversity all different types of waterbodies are important and need to be prioritised.

Shifting the focus from the natural water bodies to the man-made wells, the results show that some of the chemical variables have higher concentrations than would be desirable (Table 5.2). It is clear that the well in Rewa has higher than recommended concentrations of ammonia 0.52 mg l^{-1} (± 0.13) compared to the EU Directive for drinking water, which is 0.5 mg l^{-1} (EPA, 2001). Rewa's well also has higher nitrate levels (9.42 mg l^{-1} (±2.1) than most other communities, although it is safely below the 50 mg l^{-1} guidance limit (WHO, 1998). Both of these results indicate slight contamination, most likely of faecal kind. It was found that the wells were located closer than the minimum recommended 30m from any hand dug pit latrine (depth 3-4 m), which most likely is the source of these elevated values (WHO, 1998).

Another well result with higher than average values were the nitrate concentration 11.66 mg l^{-1} in Massara (Table 5.2). This water is pumped from a mechanically drilled well with a depth of about 30-35m, and it is piped out to all the households in central Massara (the main hill where most of the people live). A potential explanation for these values is the high number of cattle that graze, or grazed, on this hill in the recent past. The cattle had already been identified as a contamination problem by the Toshao, and the majority of them had been moved to other high grounds further away from the community. Additionally, this area of the Rupununi has been a cattle ranching centre for a long time, which potentially also contributes to the elevated nitrogen values. The high nitrate concentrations could potentially be dangerous for young babies under the age of one if the concentration goes over 50 mg l^{-1}, as there is a risk of blue baby syndrome (WHO, 1998).

As discussed earlier, the highest concentration of phosphate (Table 5.2) was found in Yupukari; it is also a mechanically drilled well, 30-35m deep, supplying the households on the main hill with water. The values of phosphate were not high enough to cause any health risks (WHO, 1998). However, there were some problems with the storing tanks as algae developed and gave the water a foul taste, according to respondents.

The pH values for four out of the five wells were also more acidic than the recommended pH 6.5 according to the EU Drinking water directive. Extreme pH values can cause red eyes, skin and mucus membrane irritation, but the pH has to be below 4 to cause negative effects in humans. However, a low pH is corrosive and thus needs to be considered when installing water wells with distribution systems to minimise damage and to ensure longevity.

The last well data that stand out are the high iron concentrations in Kwatamang's well (Table 5.2). Both Kwatamang and Rewa's wells are hand dug, which means they are much shallower compared to the mechanically drilled ones and most likely more permeable as well. It is therefore believed that Rupununi's iron rich soil leaches easier into these wells compared to the lined deeper ones. There can also be localised geological differences which make Kwatamang extra rich in iron, as the last sample revealed an exceptionally high concentration of 2.1mg l^{-1}. This sample was taken towards the end of the dry season when the water level in the well was very low, which most likely contributed to this result. High concentrations of iron do not cause any health risks but may discolour the water and can negatively affect the taste (WHO, 1998).

5.1.2 The condition of the fish fauna in the North Rupununi

Like other tropical waterways, in the North Rupununi it is difficult to estimate the abundance of fish, and much remains to explore the full extent of the rich fish diversity of the area (de Souza, 2012). To my knowledge, no quantitative study on of the abundance of fish in this area exists, which makes it difficult to estimate the condition of the fish population. To overcome the difficulty of establishing fish abundance and to estimate the fish population's status, this study explored the knowledge of the local indigenous communities. The people of the North Rupununi have fished in these waters (Plate 5.1) for at least a century (Forte, 1996), which makes them local experts and well-equipped to assess the status of the fish populations in the area.

Plate 5.1: Local fisherman catching Lukunani in Taraqua (Source: photograph taken by author)

5.1.2.1 Quantitative results on fish abundance and diversity

The diversity of the fish fauna in the North Rupununi is exceptional, as discussed earlier (Watkins *et al*., 2005). However, to what extent this diversity is reflected in the fish the Makushi use was not known. The data from the community monitors revealed that a similar high diversity could be found in the number of species of fish the Makushi use – during the six month monitoring period a total of 1582 fish were caught belonging to 50 different species (Fig. 5.4), and when including the observational fishing trips a total of 73 fish species (Appendix 8) were recorded. There were probably more, but due to the difficulty in accurate identification some species might been overlooked.

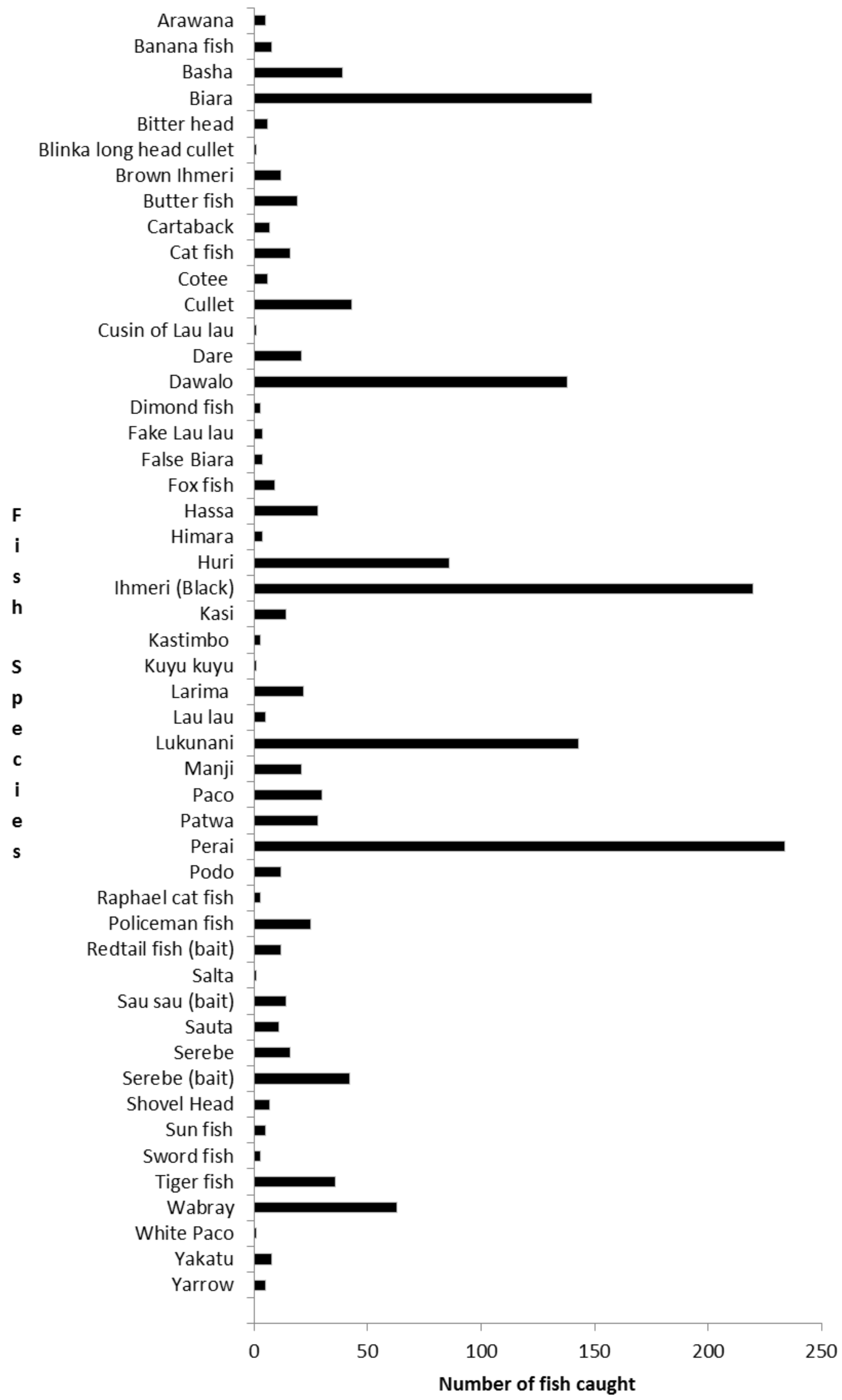

Figure 5.4: The total number of fish caught during a six month period by four fishermen in different communities along the Rupununi River

The results (Fig. 5.4) also reveal that although there is high diversity in the fish catches, there are a few species that clearly dominate. These are primarily: Perai (*Pygocentrus natteri*), Imehri (*Trachycorystes trachycorystes*), Baiara (*Rhapiodon vulpinus*), Dawalla (*Ageneiosus ogilviei*), and Lukunani (*Cichla ocellaris*), which can be seen in Plate 5.2. These five most caught species represent 56 percent of the total catch, and the ten most caught species (Table 5.4) represent 73 percent of the total catch. Furthermore, out of the 50 species caught 23 species (46 percent) were caught only 10 times or less (Table 5.5), whereas the five most caught species were caught more than 87 times. The presence and utilisation of a high number of fish species is good from a resilience point of view, as a broad resource base allows for flexibility in the species they target. However, the results also indicated that the Makushi rely on a quite limited number of fish species for the majority of their food supply, which could potentially make them vulnerable to population changes of these fish species.

Table 5.4: The ten most common fish species caught and the total number of catches for each species by the community monitors

Fish species	No. of Fish
Perai	234
Imehri	220
Baiara	149
Lukunani	143
Dawalla	138
Houri	86
Wabray	63
Cullet	43
Serebe	42
Basha	39

Table 5.5: The frequency at which a fish species were caught both in numbers and percentages of species

Frequency of fish	No. of species	% of species
< 10	23	46
10 < 20	9	18
20 < 30	7	14
31 < 86	6	12
87 <	5	10

The dominance of these five species (Perai, Baiara, Dawalla, Imehri, and Lukunani) could be due to their high population numbers, or to these species being the favoured food fish of the local communities, or, as the results indicate, a combination of both. In the case of the Red-bellied Perai most fishers observed tried their hardest not to catch it, because it does not contain that much flesh and some people said they did not like the taste of it, as the quote below from a woman in Yupukari illustrates:

> *"Black and Red Perai are plenty in numbers, people eat them but not so much, it's a sweet fish"*.

The Perais are also notorious for taking the bait and damaging the fishing line. However, due to the Red-bellied Perai's high prevalence and predatory behaviour it seemed impossible to avoid in many instances. As an example, on one of the observational fishing trips on the Rupununi River (Field notes, 28 January 2011), the two fishers caught a Perai every five minutes for the duration of an hour. After this they decided to stop fishing until the sun had gone down, as the Perai rest during the night. Despite some of the negative sides of fishing Perai it was noted that in the wet season the reliance on Perai increased, as it becomes harder to catch other fish. The Perai then become an important staple that at least give a bit of food, even though not to the preferred taste.

For the Lukunani the situation seemed different, because when asked during the focus groups and interviews which fish they preferred to eat most people rated the Lukunani as the tastiest fish (Arawana came second) and the one they would prefer to catch and eat. This is illustrated by a quote from a younger man in Rewa:

> *"Lukunani is the tastiest fish and it is easy to catch, other fish species are harder to catch".*

Another quote from a man in Yupukari might illustrate the difference in fish availability as it contradicts the previous quote:

> *"Most frequent fish to catch is the Perai, second most common is Houri. Least frequent fish to catch is catfishes, and have to throw 50 times to get Lukunani".*

This meant the fishers might go fishing particularly for Lukunani, which did not seem to be as prevalent for the other four top species. However, these quotes also indicate that there might be spatial differences in the abundance of the Lukunani across the landscape, as the man in Rewa said it is easy, whereas the man from Yupukari thought it is a difficult species to catch. This result will be further discussed in the following sections.

a)

b)

c)

d)

e)

Plate 5.2: The most caught fish species in both the dry and wet season (a) Perai (*Pygocentrus natteri*) (b) Imehri (*Trachycorystes galeatus*) (c) Lukunani (*Cichla ocellaris*) (d) Baiara (*Rhapiodon vulpinus*) (e) Dawalla (*Ageneiosus ogilviei*) (Source: photographs taken by author)

5.1.2.2 Qualitative results on fish abundance

Most of the respondents fished at a frequency of every day to every third day, with a tendency to fish more frequently in the wet season (mostly every day) compared to the dry season. Their frequent fishing activity together with their TEK put them in an excellent position to estimate the abundance of the fish population. The fish abundance results from both the focus groups and the questionnaires can be seen in Table 5.6. It illustrates the frequency with which the Makushi catch each fish species out of the 25 most common fish species they use. From the result, three categories could be identified: 44 percent of the fish species are rated as common or abundant, which might mean that these species are easy to catch (healthy populations) and/or these are species they target specifically because of taste preference or market demand. However, 24 percent of the fish species are rated as rare or occasional, which might mean that these fish species have smaller populations and/or they might just be harder to catch, due to particular habitats or feeding requirements. However, there is also a group of species (32 percent) where the responses from the focus group and the questionnaires did not match. Potential explanations for the differences in result could be: strong seasonality of species, different habitat requirements, local extinctions, and different fishing methods and fishermen skills.

Strong seasonality of some species from this group (the mismatched one) proved evident as it was mainly a wet season species, e.g. Paku, Cartaback, Dare, which make them common/abundant in the wet season but rare/occasional in the dry season, illustrating a temporal pattern found for several of the species. This pattern was explained during the focus groups, as groups occasionally marked both rare and abundant for these species. Other explanations could be particular habitat requirements, local extinctions, or at least much reduced populations of certain species dependant on location. For example, Haimara are only found in a few locations today in the North Rupununi and their number was reported to have reduced quite sharply in the last 10 years. The Haimara prefer blackwater creeks and rivers but can be found in other waters too. Today it seems that this species is confined to a few areas where the fishing pressure is low and the preferred habitat requirements are met.

Table 5.6: Fish species abundance rating according to both the focus groups and questionnaires

Fish species	Majority result	
	Questionnaires	Focus groups
Arawana	Occasional	Occasional/Common
Baiara	Common	Common
Banana fish	Rare	Common
Basha	Occasional	Rare
Butter fish	Rare	Abundant
Cartaback	Rare	Abundant
Cullet	Common	Abundant
Dare	Occasional	Abundant
Dawalla	Common	Abundant
Haimara	Rare	Abundant
Hassar	Common	Abundant
Houri	Common	Abundant
Imheri	Common	Abundant
Kassie	Common	Occasional
Lau lau	Rare	Rare
Lukunani	Common/Abundant	Abundant
Manji	Common	Abundant
Paku	Rare	Abundant
Patwa	Rare	Common
Perai	Abundant	Abundant
Policeman fish	Common	Abundant
Sword fish	Rare	Occasional
Tiger fish	Rare	Rare
Yakatu	Common	Abundant
Yarrow	Rare	Abundant

Another potential reason for this result could be access to different fishing methods and fishermen skill differences. As not everyone is equally skilled in fishing, the more skilled can get larger catch sizes, and not everyone has access to seine nets or boats, which will both aid the fishing result. Lastly, the results indicate a tendency for the focus group results to rate species as more abundant (64 percent of the species) compared to the questionnaire result, which only rated 8 percent abundant. Adding the common and abundant ratings together with data from the focus groups indicates that 76 percent of species have high numbers, whereas the result from the questionnaires estimated that 48 percent of fish species were common or abundant. It is a marked difference in result. The difference could potentially be explained by peer pressure or other group dynamics in the focus groups to estimate more positively than is actually the reality. As discussed in the methodology chapter, in some focus groups there was a real sense that commenting negatively on the fish status might lead to regulation from the outside, and that was something most people were against. Still, these results need to be investigated further before concluding that it is the focus groups that overestimate the results and not the other way round.

To allow for further analyses of this result comparison between the communities were made using the questionnaire data, which shows that the rating of abundant fish species is much lower for most of the communities than that indicated by the focus group results (Fig.5.5). Figure 5.5 also shows that there are some great differences in abundance number between some communities. The most prominent result from the graph is that Rewa has the highest fish abundance, with 82 percent of the fish species rated as common or abundant, compared to Kwatamang which only rated 19 percent of the species to be abundant or common. The other three communities rated the fish abundance quite similarly: about 60 percent (56-62 percent) of the fish species were rated as either common or abundant, whereas about 40 percent (38-43 percent) was seen as rare or occasional.

This quantitative result mostly corresponds well to the qualitative data that was also collected. People in Kwatamang definitely made it clear that there had been a marked decline in the fish numbers in recent years. Similarly, people in Rewa knew they still had good fish numbers, albeit they had also noted some declines, particularly in favoured fishing locations nearby. Moreover, In Kwatamang and Annai, many people described the waters around Rewa to be excellent fishing grounds. However, the result from Annai, which does not indicate any lower fish numbers compared to Massara and Yupukari, has to be treated with care. Many people described the decline in fish numbers both in formal and informal interviews, and as its location is so close to Kwatamang it seems rather doubtful that Annai's water would be that much richer in fish than Kwatamang's. Despite this ambiguous result I believe that the qualitative data supports the result from the questionnaires much more than the result from the focus groups. Consequently, this result may indicate that interviewing fishers by themselves rather than in a group will produce more reliable data.

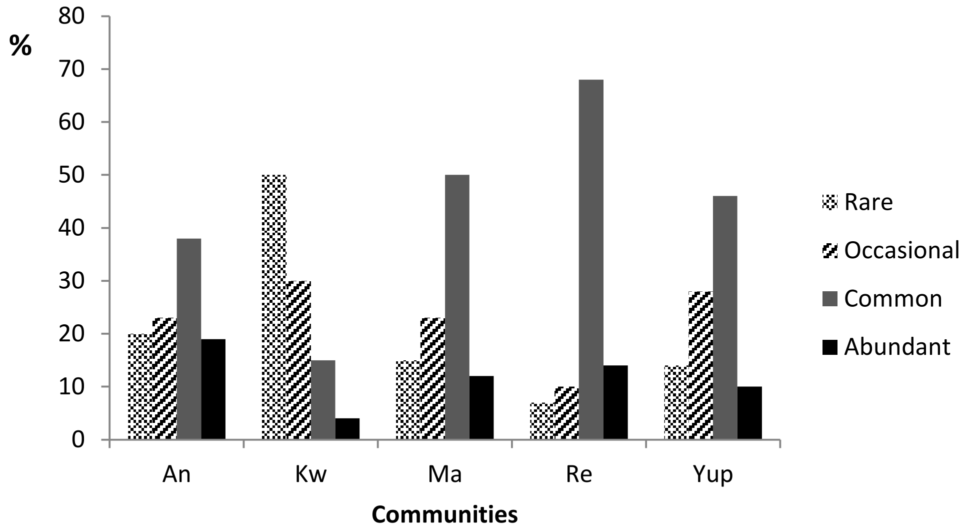

Figure 5.5: How the different communities' fishers rate the 25 most common fish species numbers

5.1.2.3 The size of the fish

The length of fish can be used to estimate the status of fish populations (Welcomme, 1985). If the majority of the fish in a population are small, it may indicate a too high fishing pressure. If fish are taken too early, they may not have reached fecundity age, and it can lead to more drastic declines in the populations as reproduction is prohibited (Welcomme and Petr, 2004). During the 16 observational fishing trips that were undertaken during January to July 2011, the length of each fish was measured and allocated to a size category based on the Makushi fishermen's knowledge. Most of the fish caught (50 percent) were classed as belonging in the medium sized category (Fig.5.6), which is a positive result for the health of the fish populations. However, the distribution between the large and the small size category was not as positive, as only 10 percent were classed in the large size category, whereas 40 percent were classed as small. The loss of large sized specimens from a population is often a sign that the fishing pressure is too high; if the same high pressure is sustained for long periods, it has been found that the trait for growing large can disappear from a species, and then even when the fishing pressure is reduced the fish size does not return (Hsieh *et al*., 2010).

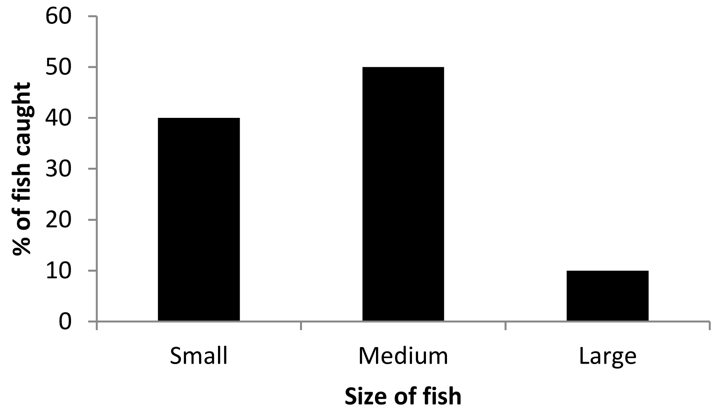

Figure 5.6: Percentage of fish caught divided into three size categories depending on each species maximum size

A decrease in the size of fish was also confirmed in the data from the FG and interviews. Many people reported that the fish had decreased in size during the last 10-20 years. The quote below from a man in Annai illustrates this phenomenon:

> *'Fish are smaller now, I used to catch 3 fish in the river and they would weigh 40lb about 20 years ago, now have to catch plenty fish to get 40lb'.*

The selective disappearance of larger fish species and specimens are in line with exploitation curves in other fishing locations (Welcomme, 1985). This pattern tends to be due to people's preference to consume large individual fish, as well as for larger species' lower capacity to sustain high mortality levels within the population. When the large species are gone, the fishers continue to fish on the intermediate-sized fish and successively push the fish assembly from 'k' dominance[13] to 'r' dominance (Welcomme, 1985), which leads to reduced resilience, as all evidence indicates that altering size (age) and spatial structures makes fish more prone to catastrophic shifts (Hsieh *et al.*, 2010). Spatial structures refers to the metapopulation concept (Levins, 1969) in which if there are several populations of the same fish species, if one encounters adverse environmental conditions, the other populations have hopefully coped better. This means that even if local extinction has taken place the fish species can recolonise and recuperate (Hsieh *et al.*, 2010). It is therefore important that any management approach ensures both the conservation of the age (size) of the fish and spatial heterogeneity, in addition to viable spawning biomass (Hsieh *et al.*, 2010).

[13] A 'k' and 'r' species is an ecological description used to categorise species according to their main reproduction and growth characteristics.

5.1.2.4 Habitat grouping of the fish fauna

According to previous research in the Rupununi (McConnell, 1964, 1987) and other research in similar wetlands in South America (Winemiller, 1990), different habitat types host different fish assemblages (Arrington *et al*., 2005; Granado-Lorencio *et al.,* 2005). To examine if the same pattern exists for fish that serve as an ES further investigation was done on the location where fish species were caught. The results show that 32 percent (Table 5.7 and Fig. 5.7) of the fish species caught were found in all the different types of habitat (river, ponds and creeks). In this 'all habitat' category (river, ponds and creeks), four out of the five most frequently caught fish species were found. However, a strong spatial pattern could also be found: 22 percent of the species were only ever caught in ponds; 21 percent of the species were only caught in the Rupununi River, and 7 percent only caught in creeks. This result indicates that about a third of the fish species the Makushi use are found in most habitat types. It also illustrates that although there are species that are generalist, which can live in many different types of habitat, the majority, 68 percent of the species, have preferred habitat requirements. Out of the top ten most frequently caught fish species, half of them are generalist, but the other half can only be found in ponds or creeks. Results from the interviews support this finding, as respondents described fish species habitat preference. The quotes below describe some of these:

> *"In creeks, and ponds, where it's shallow water, you find Houri, Patwa, Hassar, Arawana and Lukunani. Perai you find everywhere".*

> *"Baiara go up river to spawn into South Rupununi when the water is rising from the Essequibo".*

These results highlight the importance of maintaining high habitat diversity in the landscape to ensure a good supply of fish for the Makushi, and to safeguard the fish diverssity of the area.

Table 5.7: Presence (P) of fish species in different habitats

Fish Species	Rupununi River	Ponds in rainforest	Ponds in gallery forest	Ponds in Savanna	Creeks
Arawana	P	P	P		
Armoured catfish			P		P
Banana fish	P	P			
Basha	P	P	P	P	
Baiara	P	P			
Bitter head		P			
Blinka long head cullet					
Bon bon					
Brown Imehri	P	P			
Butter fish	P			P	P
Button fish		P			P
Cartaback		P	P		
Cascod		P			
Cat fish	P				
Cotee					P
Cullet	P	P	P	P	P
Curali	P				
Cusin of Lau lau	P				
Dare	P	P	P	P	P
Dawalla	P	P	P	P	
Dimond fish	P	P			
Dog fish		P			
Fake Lukunani					P
False Biara	P				P
Fox fish		P	P	P	P
Giri giri	P	P			
Hassa			P		P
Himara		P			
Houri		P	P	P	P
Houri sp.2				P	
Imehri (Boots)	P	P		P	P
Imehri spotted					P
Johnny sp	P				
Kasi	P	P			P
Kastimbo		P			
Kuyu kuyu	P				

Fish Species	Rupununi River	Ponds in rainforest	Ponds in gallery forest	Ponds in Savanna	Creeks
Larima	P				
Lau lau	P				
Logo logo			P		
Lukunani		P	P		P
Manji	P	P			
Mud eel			P		
Needle fish			P		
Paco	P				
Patwa			P	P	P
Perai arti		P			P
Perai Black	P		P		P
Perai Erti (spotted)		P			
Perai lataja				P	
Perai sorokoli		P			
Perai white	P				P
Piab	P	P			
Podo	P				
Policeman fish	P				P
Raphael cat fish	P				
Red tail	P				
Red-bellied Perai	P	P	P	P	P
Redtail fish (bait)			P		
Salta	P			P	
Sau sau	P	P			
Sauta	P				
Serebe	P				
Shovel Head	P	P			
Silver fish	P				P
Sun fish			P		P
Sword fish	P				
Tiger fish	P	P			
Wabray		P			
White Paco	P				
Yakatu		P	P		
Yarrow					P

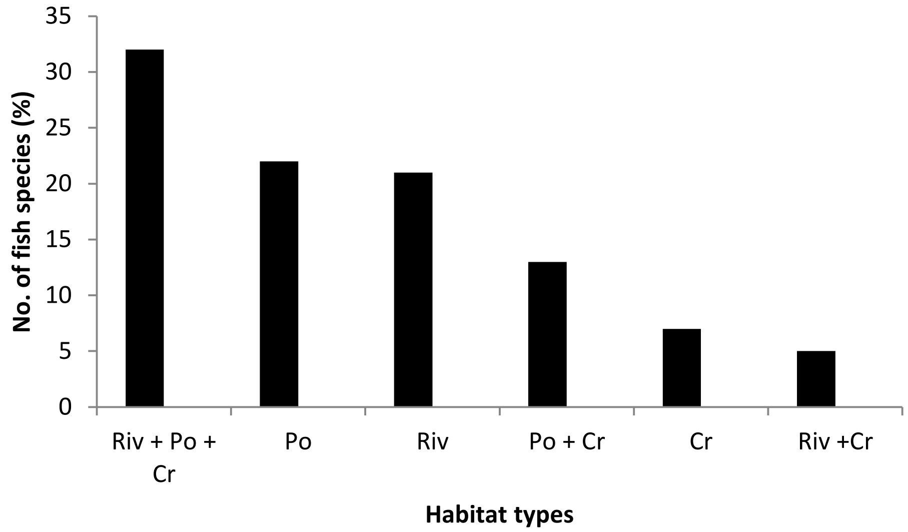

Figure 5.7: Percentages of fish species the Makushi use found in different habitats

5.1.3 Status of the Black Caiman

The Black Caiman population appeared to be in a good condition, as 40 percent of the participants reported that the number of Black Caiman has increased in the last 10 years. The Black Caiman is rated as endangered on the IUCN Species index. This result is therefore positive for the conservation status of the species, as the numbers were very low 50-60 years ago when the trade of Black Caiman skin was still legal. The positive trend was reported in all the five communities and Black Caimans were spotted in all of the communities. However, uneven spatial distribution patterns were noticed, as certain areas had a higher abundance than others. It was noted that Yupukari had the highest number of Black Caiman sightings. It was also confirmed in interviews and informal talks with personnel at the Caiman House[14] that these spatial hotspots occurred. However, they were not sure why the Black Caiman preferred this area compared to further downstream. During the interviews and focus groups, certain habitats were highlighted as being particularly preferred by Black Caimans to nest and for the juveniles to grow up. These were rather small ponds in the forest that had a quite large part of the waterbody covered with floating vegetation (20-80 percent), offering protection to their offspring. One of these favoured breeding grounds was Devil's Pond, which could be verified in the spot counting, where almost half of the sightings were juveniles less than 3 years of age; a total of 25 Black Caimans were counted here in the dry season, which is the highest count of any site (Table 5.8).

[14] Caiman House is the Eco-lodge based in Yupukari, which also undertakes Black Caiman research.

Table 5.8: Mean number of adults and juveniles of Black Caimans in four different habitats in dry and wet season

Site	Dry Season		Wet Season	
	No. of Adults	**No. of Juveniles**	**No. of Adults**	**No. of Juveniles**
Rewa River	3.5	4.5	1	1
Simonie Lakes	2.5	5	2	1
Devil's Pond	14	11	5	8
Rup Riv Yup	7	4	1	2

In other studies, it has been found that Black Caimans prefer blackwater rivers compared to whitewater rivers, which Spectacle Caiman prefer (Aguilera *et al*., 2008). This preference could potentially be linked to lower conductivity, as Aguilera *et al*. (2008) showed that conductivity could be a useful indicator to predict good Black Caiman habitats. The findings in this study correlate well with this theory, as the Rupununi River by Yupukari has the lowest mean conductivity of all the communities. It is further supported by the result from Devil's Pond, which was the site with the highest number of Black Caimans and the pond with the lowest conductivity. Simonie Lakes is another site that was said to be preferred by the Black Caimans, and it also turned out to have lower than average conductivity. However, in this study only a few Black Caimans were counted in this area, but this was most likely due to the unseasonal high water level which all the local guides verified. Consequently, the result from this study supports Aguilera *et al*.'s (2008) theory and indicates that the Black Caiman distribution and abundance could be linked to conductivity in the North Rupununi as well.

5.2 Seasonality of the ecosystem services

In the Rupununi floodplain, the annual flood pulse causes an exchange of materials between the terrestrial and aquatic ecosystems, which affects the proportion of suspended and dissolved components in the water and its physico-chemical characteristics. The flood pulse process was described in chapter 2 (section 2.8) and how it changes the water quality for both the fish and the people who use it (Affonso, 2011). It also affects the amount of available dry land and the connectivity in the landscape, which leads to seasonal patterns that will be discussed in this section.

5.2.1 Freshwater

5.2.1.1 Seasonal water level fluctuations and the effects on ecosystem services provision

> "*The colour of the water changes in the river when it is getting higher. This is because get water from the mountains*". (Older man, Kwatamang)

The average water level difference between the seasons in the Rupununi River was found to be 5 metres (Fig. 5.8). The mean dry season depth was 4.6m (± 1.7m) and the wet season mean depth was 9.7m (± 1.3m). There is limited existing data available on rainfall and water depth data for the Rupununi. McConnell (1964) was one of the first scholars to monitor the fish and water levels in the Rupununi and she reported a 5m water level difference between the seasons at Karanambo (eco-lodge north of Yupukari), which evidently corresponds well with the result of this study. However, changing trends have been observed on larger scales. Climate change is being linked to intensification and changing patterns of the El Niño Southern Oscillation (ENSO), and it has been shown that the amount of rainfall in Guyana is directly linked to the ENSO events (Hammond and ter Steege, 1998), where La Niña causes the highest flooding, and El Niño the worst drought (Mol *et al*., 2000). Hence, it is likely that the uncertainty of the seasons and their intensity will continue to change long-term as the climate changes. Some studies (Betts *et al*., 2008) suggest that the Amazon is drying whereas recent evidence indicates a wetting trend (Gloor *et al*., 2013). Gloor *et al*.'s study also illustrates that the intensification of the hydrological cycle is concentrated to the wet season, leading to gradually greater differences in the maximum and minimum water level in the Amazon (Gloor *et al*., 2013). The pattern that Gloor *et al*. (2013) describe sounds very similar to what both local people and organisations been reporting (as the quote below indicates from one of the conservation organisations), indicating that this pattern might be true for the Rupununi as well. Clearly, more research is needed to establish climatic trends, but there still might be a need to develop adaptation strategies for the area.

> *"Floods in my experience have been regular but I've seen great difference in amount of rainfall".*

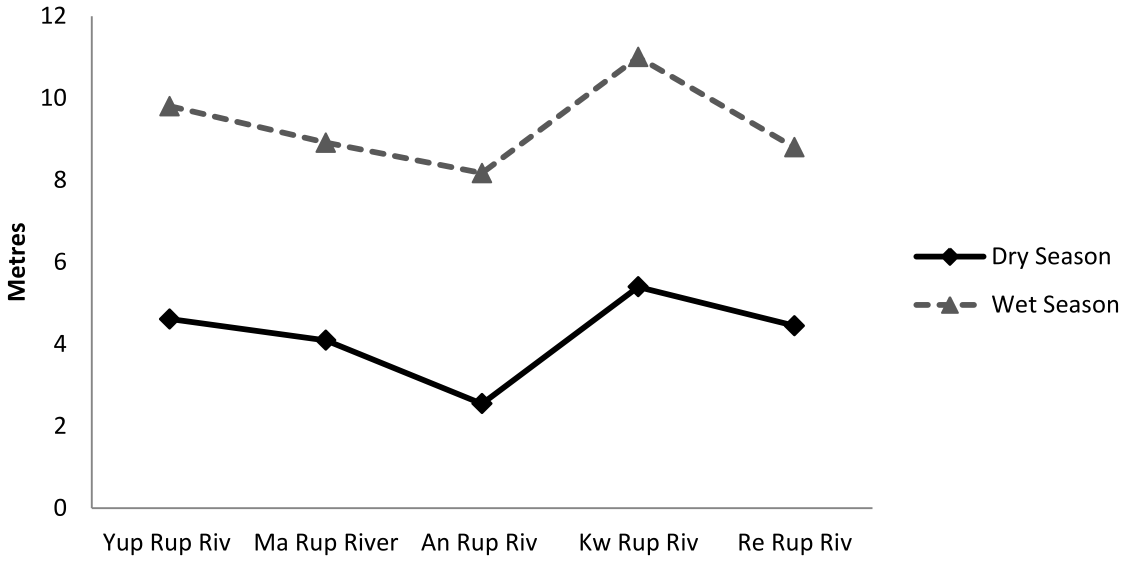

Figure 5.8: Mean Rupununi River depth in both the dry and wet season in all five communities

The ponds in the North Rupununi evidently experience a similar seasonal water level difference to the Rupununi River but with a slightly lower mean depth difference of 3.94m (Fig. 5.9). The ponds are located near the Rupununi River and were identified as very important fishing areas during the focus groups and interviews, as the quote from a man in Kwatamang illustrates:

"The ponds are equally important as the river in terms of fishing grounds".

The depths of the 15 ponds described and monitored in this study varied greatly. For example, Grass Pond near the community of Rewa had a mean depth of 5.63 (±0.71m) in the wet season and in the dry season this was reduced to 1.23m (± 0.48m). This is a difference of 4.4m, which greatly affects the water quality and the fish assemblages that live in this environment, something that will be further discussed later in this section.

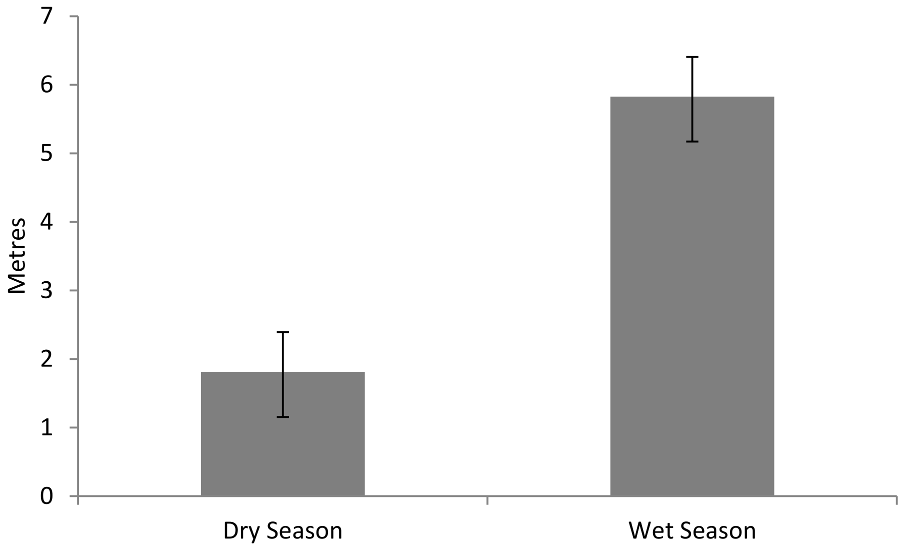

Figure 5.9: The water depth difference between the ponds along the Rupununi River

The creeks identified as either important fishing sites or important spawning areas experienced potentially the most prominent difference between the seasons with a range of completely dry to a max depth of 6.3m (Fig. 5.10).

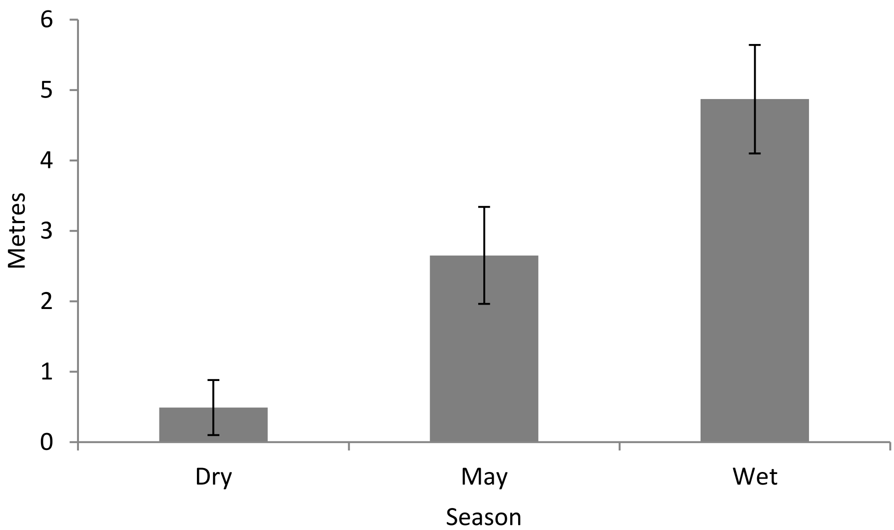

Figure 5.10: Mean water depth difference in creeks between the seasons in metres

The floodplain extent and depth varies throughout the landscape depending on topography and distance from the river. The mean depth of the flooded area around the communities was 1.4m (Fig. 5.11). The lowest flooding level was measured in the Massara savanna with a mean depth of 0.77m and the highest depth (3.9m) was measured in the varzea forest by Bat Creek (or Bad creek as people in Rewa now call it) near Rewa.

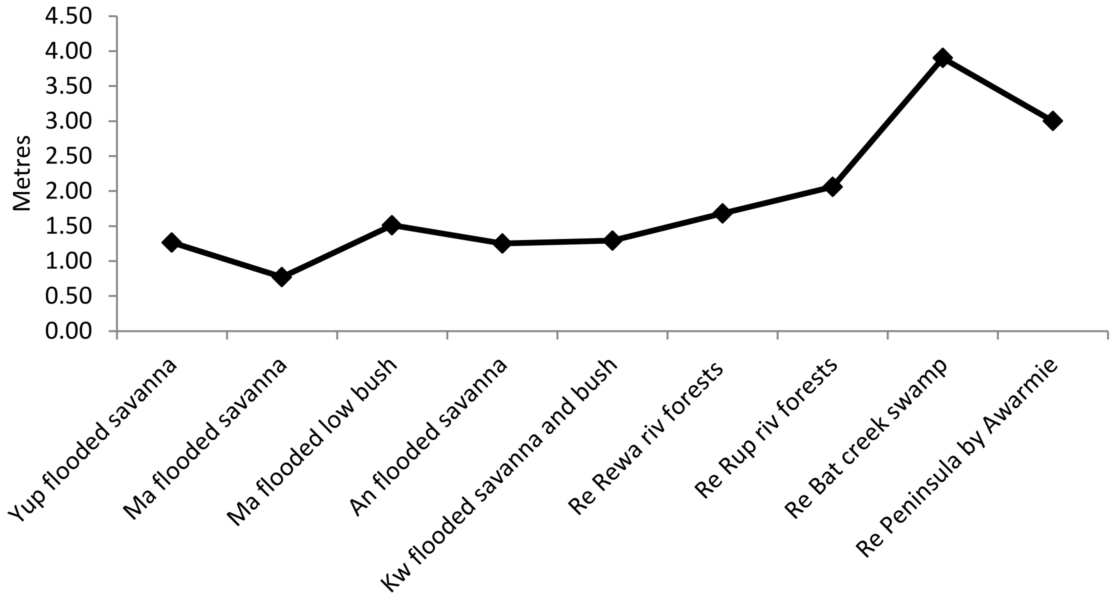

Figure 5.11: Average depth of flooding water following longitudinal the floodplain of Rupununi River

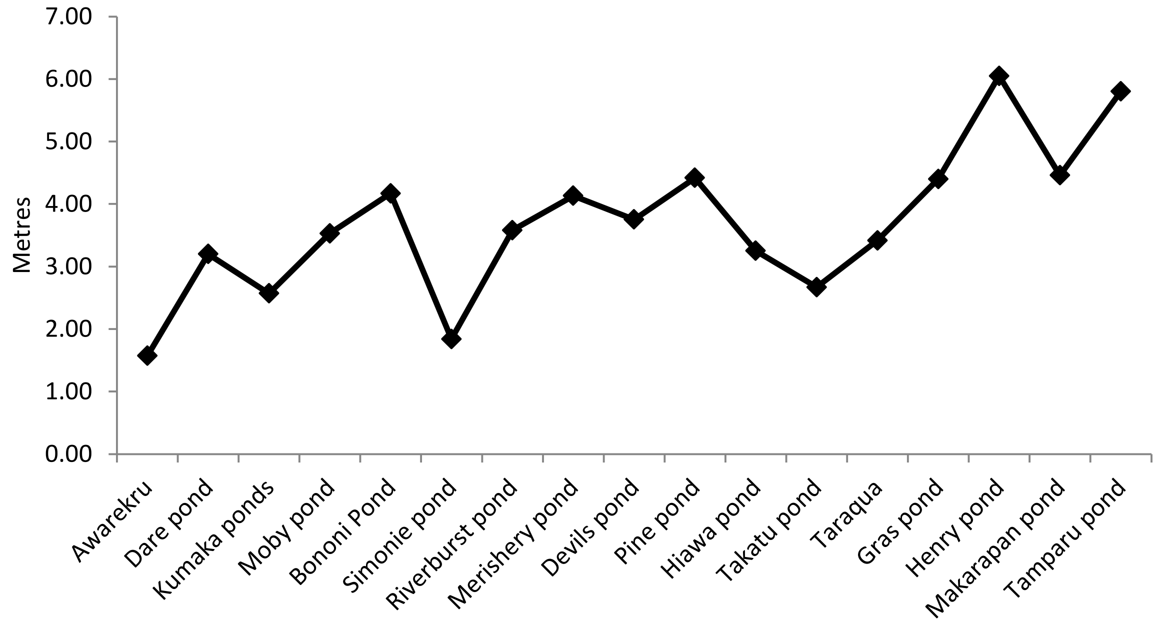

Figure 5.12: Mean difference in water depth in ponds along the Rupununi River

A slight trend might be detected when analysing the flooded areas' depth and the depth of the ponds. Both of these graphs (Fig. 5.11 and 5.12) indicate a small increase in water depth the further along the Rupununi River the measurement is taken, which is the expected result of the longitudinal effect. These deeper flooding waters might partially explain the higher fish abundance around Rewa, as deeper water usually indicates a longer period of flooding, which means longer time for fish to feed. This was identified by the local communities to be important for the health of the fish, as the quote from an older man in Massara indicates:

> *"If the flooding is too short there is not enough time to eat and breed for the fish".*

5.2.1.2 Seasonal effects on the physico-chemical properties of the water quality

When comparing the dry and wet seasons' water values for the natural water bodies (see Table 5.1 in the first section of this chapter), a clear pattern can be seen over most of the values. The results show that the differences found between different waterbody types in the dry season had almost disappeared in the wet season. This is due to the homogenising effect of the added rain water, which means that more habitats, if not all, are connected, mixing the water from the different waterbody types (Thomaz *et al*., 2007). Another general seasonal trend that was found among the physical variables was that most of the values decreased in the wet season compared to their values in the dry season. For example, turbidity and conductivity values for all the water bodies, apart from Simonie Lakes and Annai creek, went down. The conductivity values only showed a slight decrease, but for the turbidity values the reduction was considerable (Fig. 5.13). This increase in transparency of the waters is attributed to the large amount of rainwater being added to the system and to the low erosion rate of this area, which means that only a small amount of suspended particles is added to the water when the landscape is flooded. It also means that the water in all the water bodies becomes diluted as the rain water is added.

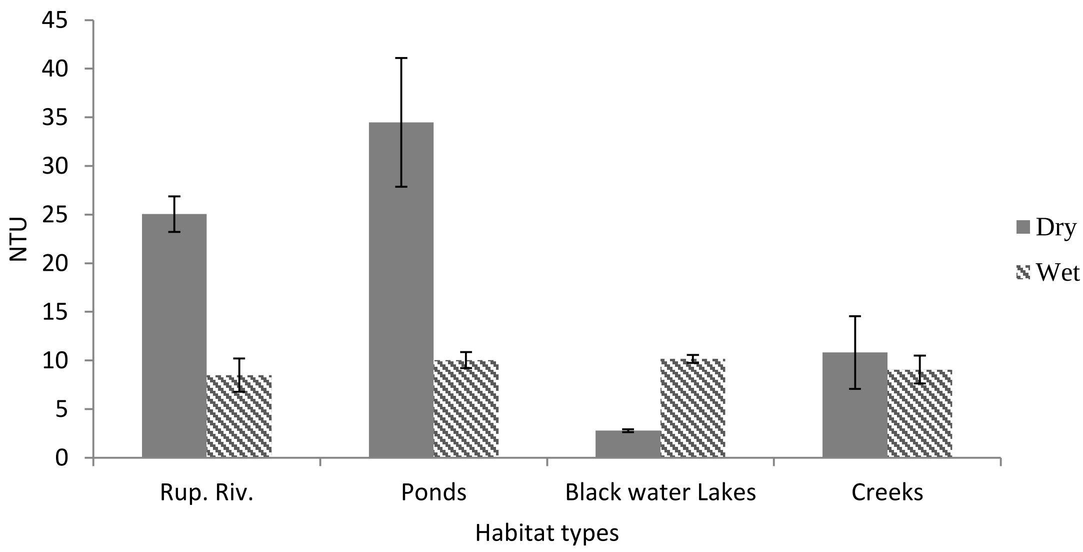

Figure 5.13: Turbidity values (NTU) for all the different habitat types in both seasons

This result corresponds well with what was recorded in the interviews, where respondents said that the Rupununi River turns darker in the wet season, which is what happens when the water becomes clearer. The colour change was particularly noticeable in Rewa, as this is the community located furthest downstream. Similar results have also been found in other studies. In some of these previous research studies a dilution effect was also found on the chemical variables, but in this study this trend was not so clear for all waterbody types. A potential dilution effect might be detected in the nitrogen, phosphate and ammonia values for the river and some of the ponds. For the other types of waterbodies the concentration rose slightly, but only to reflect the mean concentration of the river and ponds. This can be explained by the homogenising effect mentioned above, where the landscape is much more connected in the wet season. The homogenising effect that has been found also means that the water heterogenity in the North Rupununi is reduced in the wet season and thus supports Thomaz *et al.* (2007) findings that floods as a process reduce spatial variability.

For the pH values a slight seasonal trend might be seen in Figure 5.14, which indicates that the majority of the water became more acidic in the wet season compared to the dry season. There are two exceptions though: the blackwater lake of Simonie and Annai creek. These waterbodies became less acidic in the wet season because they were more acidic then average in the dry season. This general trend of acidification depends most likely on the addition of rainwater, which normally has a pH of around 5.8 (Charlson and Rodhe, 1982).

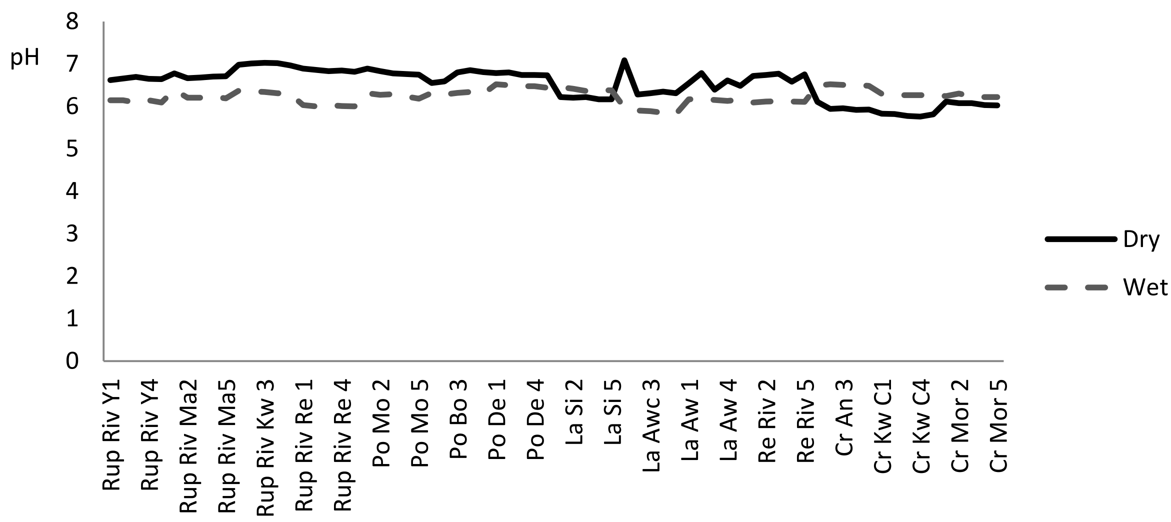

Figure 5.14: pH values in different waterbodies in both dry and wet season in North Rupununi

The iron concentrations are the only parameter that had an increasing trend in the wet season, and this trend can be seen in all the different water habitats (Fig. 5.15). This increase is most likely due to leachate from the iron rich latosol soil. First when it is flooded, more iron particles becomes suspended in the water and later in the flooding season the iron becomes more soluble from the ground, due to the anoxic conditions which often form in these flood waters as so much plant material is being broken down.

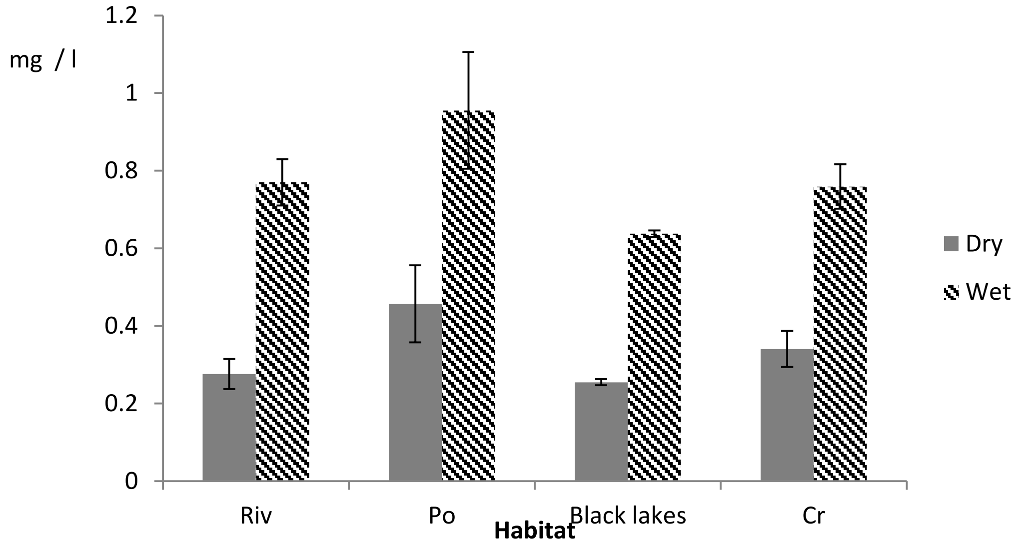

Figure 5.15: Mean iron concentration in different waterbody habitats in both the dry and wet season (mg l^{-1})

The well data does not show any consistent seasonal variation. The most noteworthy result is probably the increase in turbidity values from the dry season to the wet season. This increase can most likely be explained by the close link the rising river water has to the water table. As noted in the field diary (6/6/2011), the wells' water level in Rewa and Annai followed the water level of the Rupununi River very closely. This was also reported during informal interviews with community members and later measured, which showed on average a difference of 1.8m between the seasons from the ground to the water surface of the well. This result can have severe consequences for the communities; the quality of the well water deteriorates, as the water no longer goes through the cleaning process of seeping through the sand of the savanna (Kiptum and Ndambuki, 2012). An increase in stomach related illnesses during the wet season was confirmed by the health worker in all the communities during the interviews. This pattern was particularly common if the households did not have access to a drilled well. The Red Cross had distributed chlorine tablets to add to the water tanks for cleaning purposes but no other analyses were made to check how clean the water was, which means that the wet season negatively affects the quality of the drinking water for the people in the North Rupununi.

5.2.2 Effects of the seasons on the fish fauna in the North Rupununi

The annual flood pulse that can be predicted to start from April-May through to July-August is vital to the system, as discussed earlier. This is the time when the larger fish migrate upriver to spawn in the swamps of the south savanna and the smaller fish migrate laterally by swimming up streams and creeks to spawn on the savanna and in swamps throughout the Rupununi. The fish which migrate to spawn are called total spawners, which means they only spawn once a year and they rely on the hydrological cycle to do so (McConnell, 1964). Partial spawners can spawn several times in a year and thus appear less dependent on the rains to maintain a healthy population. However, the partial spawners, such as Lukunani, also depend on their lateral migrations onto the savanna and/or into the forest to feed. The increase in feeding that the flooding allows leads to many of the partial spawners breeding just before the rains start to maximise the food availability for their offspring (McConnell, 1964).

5.2.2.1 Seasonality and fish abundance

The increased availability of food during the wet season means that it is a time of plenty for the aquatic food web, but for the Makushi this is a period of hardship. Everyone that participated in the research confirmed that the wet season, with its larger volumes of freshwater, means it is much harder to catch fish. This is because the fish move out from their normal habitat in search of food and spawning locations, and then occupy a much larger area making catching them much harder.

In the dry season the average catch was calculated to be 18lbs per fishing trip and in the wet season this was reduced to 6lbs, based on interview and focus group data (Fig.5.16). This means that the availability of food for the Makushi is greatly reduced during this period. The result is supported by previous work in the North Rupununi by Mistry *et al*. (2004), who found that the Makushi catch around 20lb in the dry season and 5lb in the wet season.

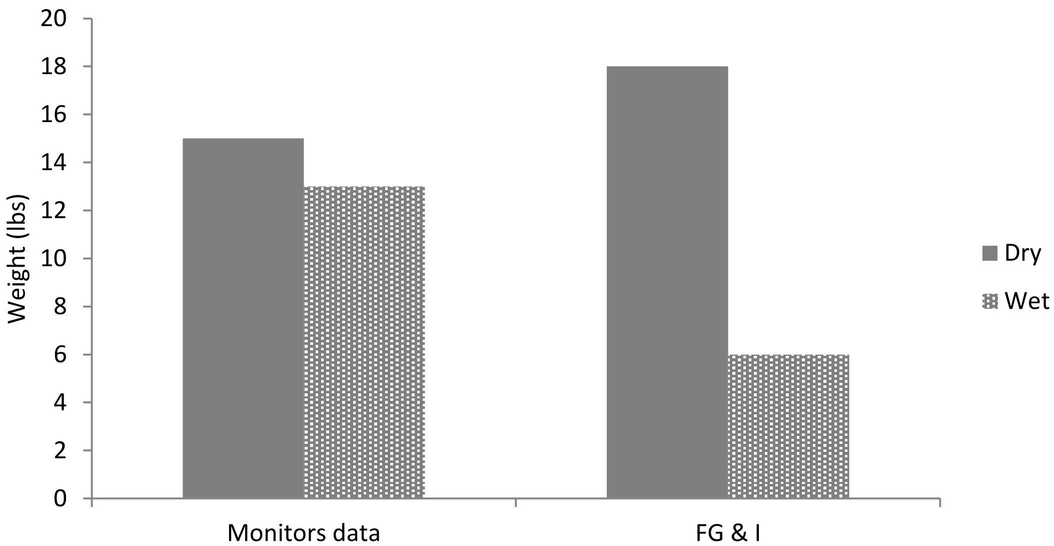

Figure 5.16: Seasonal average fishing catch, in weight; data from fish monitoring and focus groups and interviews

Data from the 162 fishing trips done by the community monitors indicate a slightly lower average fish catch in the dry season than the results from the focus groups and interviews (Fig. 5.16). The result also shows that the mean weight per fishing trip in the wet season is more than double the value which was given in the interviews and focus groups. There are some potential explanations for this result. Firstly, the data from the wet season might have been slightly skewed due to time limitations of this study, which meant that most of the fishing in the wet season took place in May and June and only two fishing trips were done in July. While May is classed as the wet season, the availability of fish is still rather good because the fish are migrating upriver, and up the creeks, which makes it a good time to fish. Therefore these values might distort the result slightly and make the wet season look more abundant than it really is in its entirety. Another potential explanation is the vast number of fishing trips (Table 5.9) the monitor in Massara did during the wet season. This man loved to fish, which meant that he fished most days and sold any surplus. It is therefore possible that his high fishing effort may have skewed the numbers.

Table 5.9: Fishing effort of each fisherman participating in the fish monitoring

Community	**Total no. of fishing trips**	**No. of fishing trips**	
		Dry	**Wet**
Massara	72	28	44
Rewa	38	28	10
Kwatamang	36	18	18
Annai	16	13	3

5.2.2.2 Seasonality and fish diversity

In the previous section it was shown that the amount of fish the Makushi catch declines in the wet season. In this section, results will be discussed that look at how and if the species of fish that are available as an ecosystem service change with the season, and if so, in what way.

Results from the focus groups and questionnaires reveal that 20 percent (Fig. 5.17) of the most commonly caught fish species are only available in the dry season, and about 16 percent is only available in the wet season. The remaining species (64 percent) can be caught in both seasons. This means that wet season species are almost as numerous as dry season species, and therefore the seasonality of fish should only slightly reduce the number of species available for the Makushi. This result is supported by the results from actual numbers caught by the monitors, which showed a very similar division of species seasonality (Fig. 5.17). In addition to this, the total number of fish species caught in the dry season was 43, in comparison to 35 in the wet season; this result also supports the above conclusion that there is only a slight decrease in the diversity of fish species caught.

The reasons why some fish species (16 percent) are only available during the wet season is that they represent the migratory fish that come from the Essequibo River. The other group of fish species, the 20 percent, which is only available in the dry season, do not actually disappear, but they become so dispersed that they become almost impossible to catch during this period. These explanations mean that the total number of species in the area actually increases during the wet season, but not from an ES point of view.

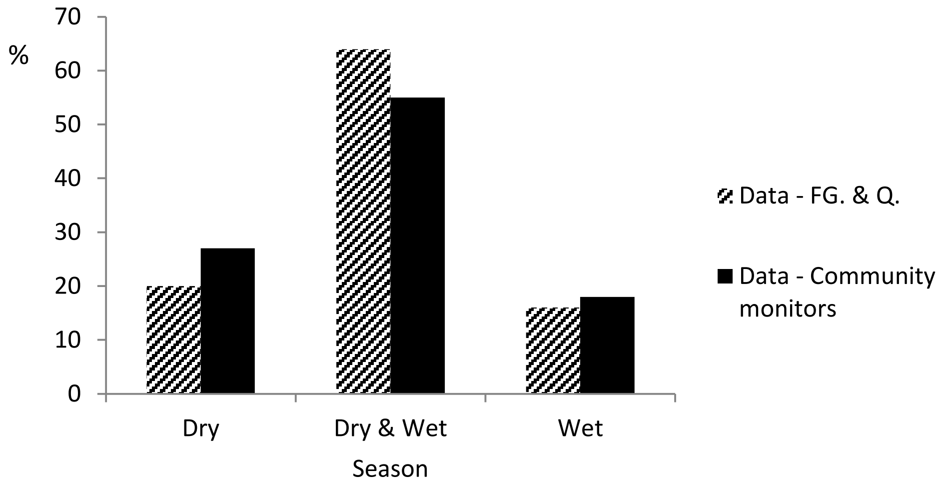

Figure 5.17: Fish species seasonality (percent of species used) from both actual fish numbers caught by monitors and from focus groups and questionnaires

Even though the number of fish species available is similar between the seasons, there is a difference in the species composition. In Figure 5.18 and 5.19, the total biomass of the fish caught by the community monitors is shown. The dry season graph show the dominance of the five most caught species, as discussed earlier (Fig. 5.4). The graph for the wet season shows that four out of the five dominant species in the dry season are still caught in high amounts but it can also be seen that the dominance of a few species has reduced to some extent. The Baiara is the fish species which provide the highest biomass in both the dry and wet season. However, if considering the numbers of fish (Table 5.10) and difference between the seasons it becomes clear that a ‘high water’ fish, as the Makushi call fish species only available during the wet season, tops the list. The Imheri also contributes the second most biomass in the rainy season, whereas in the dry season they can only be caught if the fishers dive for them as they hide in rocks and burrows. The other species that is only present in one season is the Houri; it was confirmed the Houri is not caught in the wet season as it hides in the savanna grasses, indicating this species' seasonality for the Makushi but not from the ecosystem.

Table 5.10: Top five most frequently caught fish species in both seasons.

Fish sp.	Dry season No. of fish	Fish sp.	Wet Season No. of fish
Perai	97	Imehri	176
Dawalla	97	Perai	127
Lukunani	83	Baiara	70
Houri	79	Lukunani	60
Baiara	79	Dawalla	41

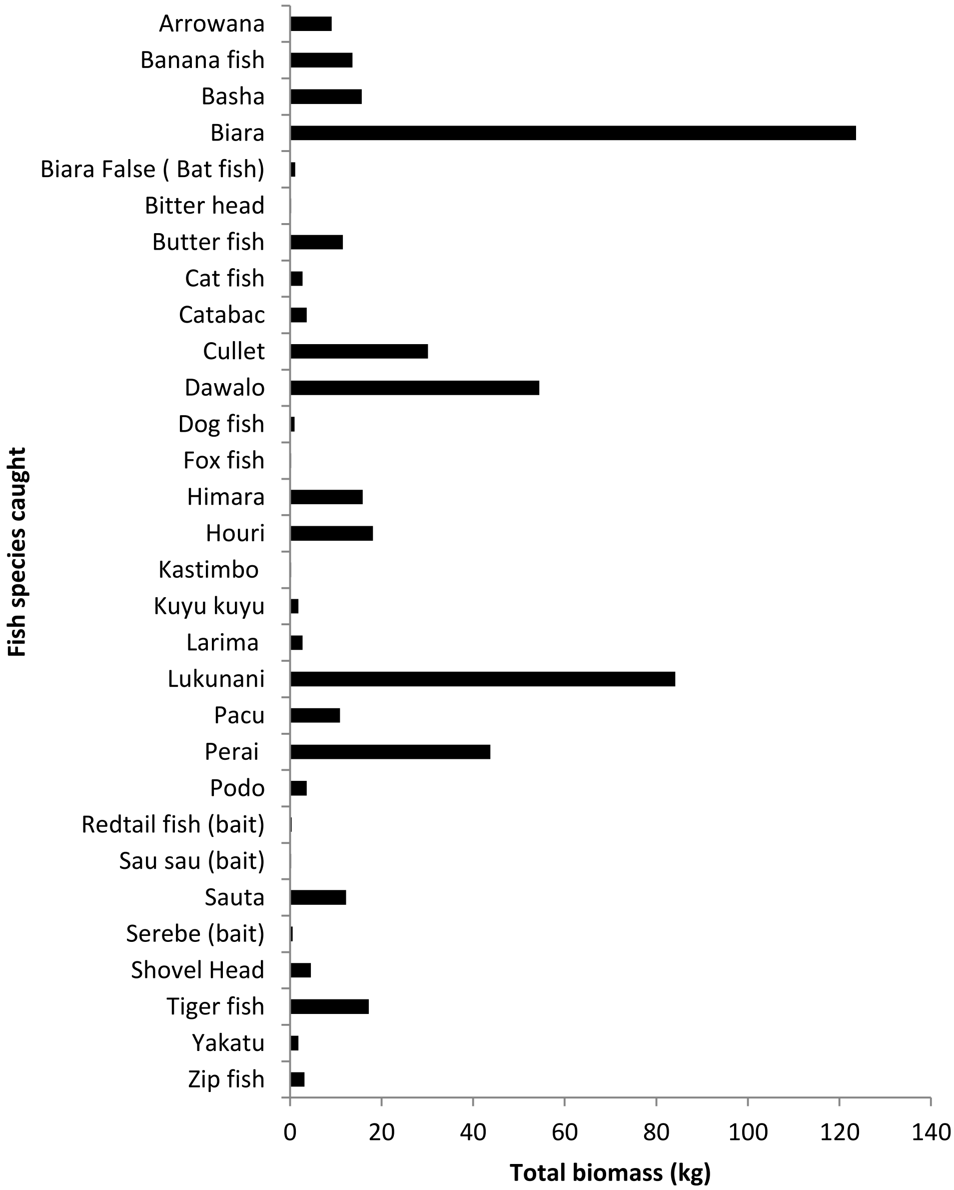

Figure 5.18: Total biomass of fish caught by the four community monitors in the dry season

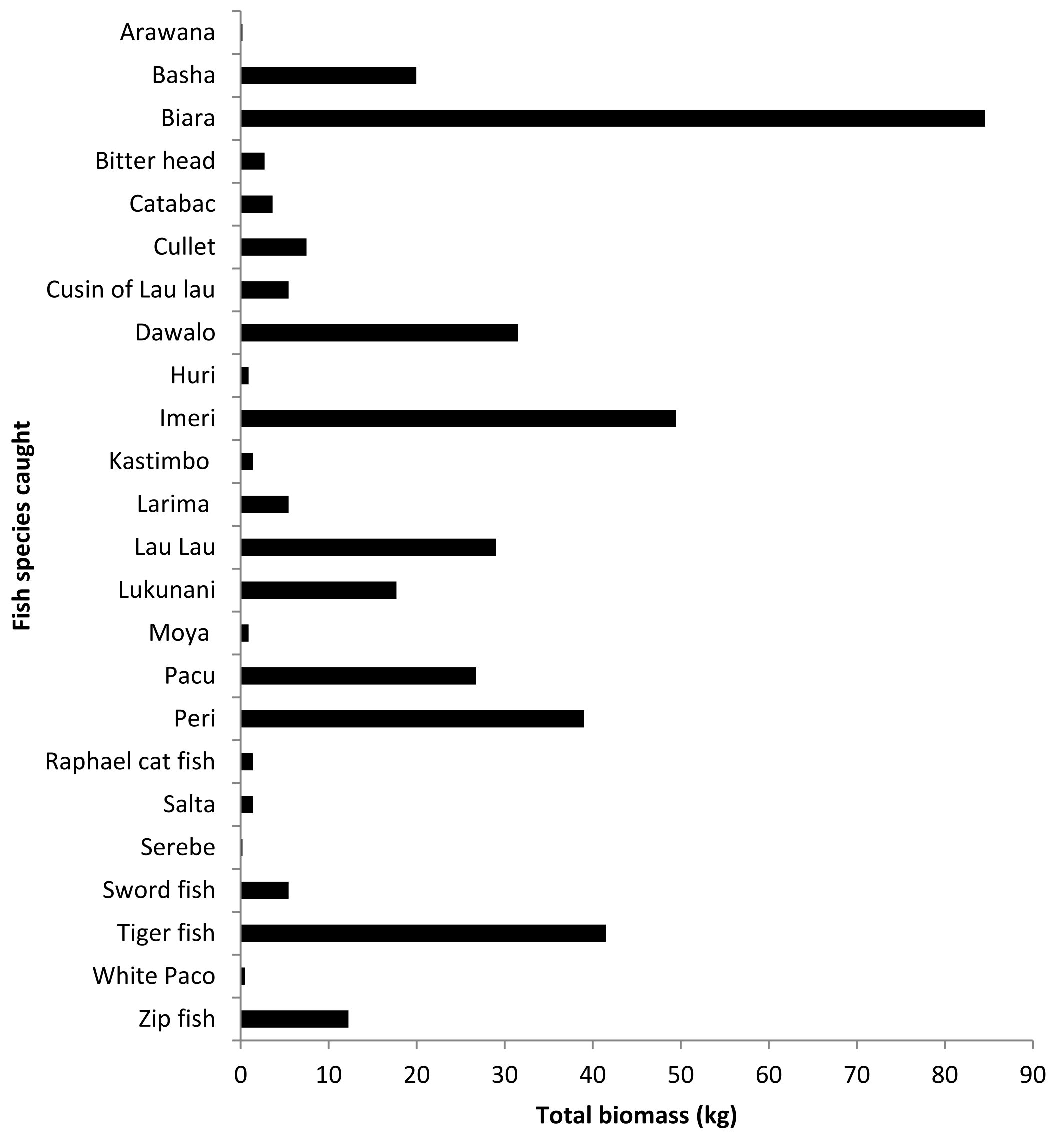

Figure 5.19: Total biomass of fish caught by the four community monitors in the wet season

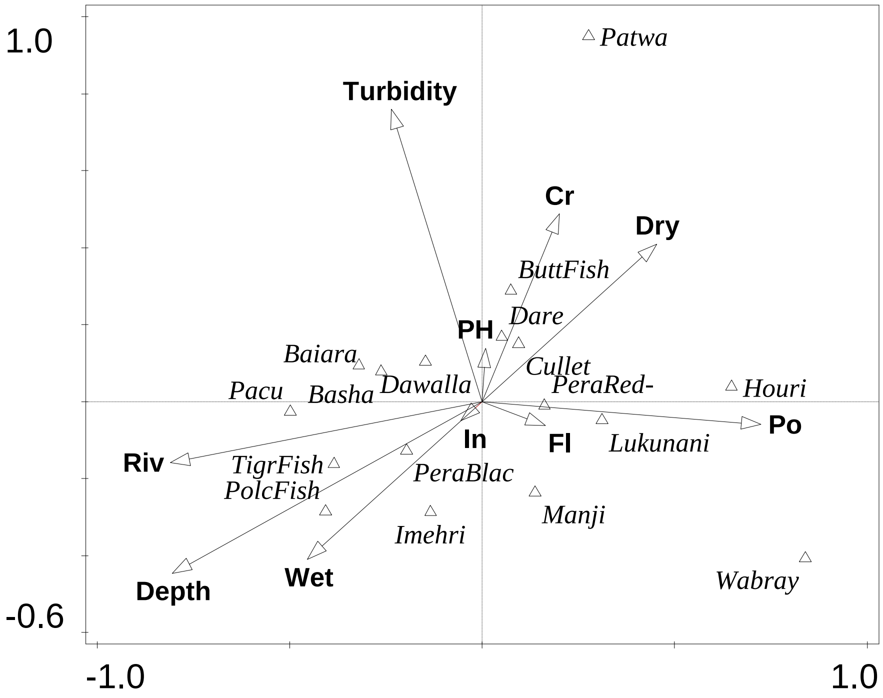

Figure 5.20: CCA on fish catches with environmental variables using CANOCO 5.0

To explore the data further a canonical correspondence analysis (CCA) (using CANOCO 5.0) was performed on the 17 most abundant fish species, using quantitative data from the fish observations and community monitor data. The results diagram (Fig.5.20) shows how the species fit well along the gradient of different habitat and season preferences. The total variance was 5.85 and the Eigenvalues are listed in Table 5.11, which indicate that these values are acceptable. This quantitative result thus supports the previous discussed qualitative result, as similar patterns of preference to season and habitat can be seen. However, the diagram also shows that the habitat seems to be the strongest factor explaining the species distribution/composition, as the river and pond arrows are longer and closest to axis number one. Turbidity is the variable with the longest arrow and is close to axis two, which indicates that this factor is the second most important in influencing the fish distribution and numbers. As discussed earlier, turbidity showed the strongest seasonal difference among the variables and is thus strongly linked to the influence of the seasons on the fish.

Table 5.11: Eigenvalues from CCA analyses

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.4007	0.1927	0.1566	0.085
Explained variation (cumulative)	6.9	10.22	12.92	14.38

5.2.3 Seasonality and Black Caimans

The Black Caiman follow a similar seasonal migration pattern to the fish, moving into the forest and onto the savanna as soon as the water level allows them to follow the fish to secure their food. This pattern is demonstrated in Fig. 5.21, which illustrates that the Black Caiman numbers are higher in the dry season compared to the wet season. This seasonal pattern, where Black Caiman numbers are negatively affected by rising water levels, has been previously observed (e.g. Da Silveira *et al*., 2008). The Black Caiman move out from their normal dry season territory to feed but also to find terra firma, as they need ground to rest on. Even though the Black Caiman follow a similar seasonal spatial distribution to the fish, the wet season represents a more difficult time for them as their prey is further dispersed over a larger area, which means they face similar difficulties to the fishermen in the area. The migration of Black Caimans, which follows the littoral zones, means they get closer to the communities, which has been proven to be dangerous for the local population. Several stories were told where people had been attacked and dogs taken by Black Caimans.

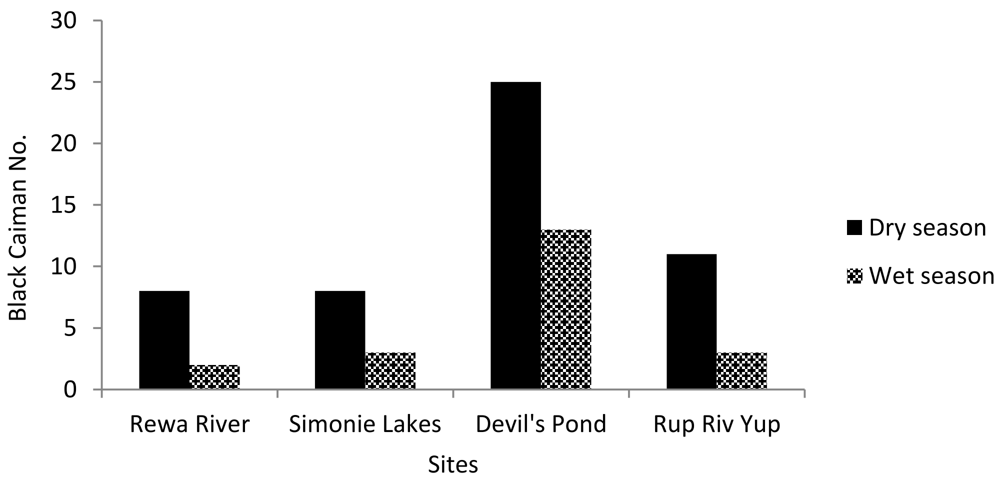

Figure 5.21: Black Caiman counts in the dry and wet season in four locations

5.3 Long term trends in ecosystem services

Monitoring data on water quality and fish abundance is very limited for the North Rupununi. However, some data is available from the Wetlands Partnership (2006a, 2008) and work by individual researchers such as R. Lowe-McConnell, E. Eigermann, J. Mistry *et al*., and G. Watkins. These scholars and others have provided some data allowing for larger temporal scale comparison of the health and/or trends of water quality, fish fauna and Black Caiman populations.

5.3.1 Trends in water quality over the past decade

The water quality in the Rupununi does vary seasonally as discussed in the last section. However, the water quality is expected to stay rather constant between years unless some anthropogenic pressure has been added to the system. To investigate if there has been any temporal change in the water quality during the past 11 years, the results from this study were compared with data from Mistry *et al*. (2004), which was collected in January 2000. Table 5.12 reveals that the water quality has changed to some extent in the Rupununi River and in the wells of three communities.

Table 5.12: Comparing water quality data from 2000 with 2011 data

Water Parameters	Water Source							
	Rup River		An Well		Re Well		Kw Well	
	2000	2011	2000	2011	2000	2011	2000	2011
Turbidity (NTU)	5	25.1	4.85	0.43	1.33	2.6	5	2.8
EC (μS/cm)	22.8	24.1	41.31	29.78	22.67	28.3	36	40.5
pH	6.3	6.8	5.3	5.9	5.1	5.4	5.8	6
Temperature (C°)	26.2	29.9	27.3	28.6	25.7	28.7	28.3	27.5
Ammonia (mg/l).	0.01	0.06	0.09	0.05	0.02	0.48	0.01	0.03
Nitrate (mg/l).	0	0.13	0	1.46	0	9.4	0	0.15
Phosphate (mg/l).	0	0.4	0	0.21	0	0.06	0	0.03
Iron (mg/l).	0	0.3	0.03	0.03	0	0.15	0	1.09

First, the most substantial change in water quality can be seen in the chemical parameters: the ammonia, nitrate, phosphate and iron concentrations. All of these values were nil, or very near nil, in 2000, whereas today these values have increased considerably. In the river the increase of phosphate and nitrate concentrations are the ones to be concerned about. As discussed in 5.2.1, there is no reported use of fertilisers among the communities, nor any industrial effluent that can possibly explain this increase in concentration. Higher values of the same variables are also found in the well data. Yet, these results are easier to explain as it has already been established that both pit latrines and cattle are the most likely sources for this contamination.

Second, the turbidity in the Rupununi River is much higher in the 2011 study compared to 2000. For the wells this pattern is not as clear. Differences in turbidity may be caused by logging and mining and other destructive land use activities. However, neither of these were observed, or reported as being a problem, which makes it difficult to believe that there has been such a considerable change. The other point is that an average turbidity of 25.1 for a whitewater river is already considered low, whereas a turbidity value of 5 would indicate a blackwater river. It is important to remember that the samples taken in 2000 were only meant to be indicative, as they were only taken once in the dry season. Therefore, it is difficult to draw any conclusions from this result beyond a potential fault with either of the machines – indicating a greater temporal difference than actually exists – or that the conditions when this sample was taken were temporarily different for some reason. However, the result of the chemical parameters supports earlier conclusions that at least the phosphate concentrations have increased in the past decade to levels that are higher than expected in a relatively pristine system.

Could it be that the Makushi practice of slash and burn cultivation is causing this result? In Mistry *et al.* (2004), it was concluded that the slash and burn practices did not have a significant impact on the water courses. Could it now mean that the population has increased so substantially that the forest and savanna fires they purposely light cause these elevated nutrient values and extra sediment load? Considering the spatial scale of their agricultural practices it seems unlikely. Or could it be the mining activity further upstream in one of the tributaries to the Rupununi River? Or the suggested explanation for this result as discussed earlier (section 5.2.1)? Unfortunately, the conclusion must be that a clear answer to this result is not within the remit of this thesis. However, a strong recommendation can be made to investigate this result further, because if these elevated levels are sustained it can have substantial health consequences on the waterways, fish fauna and the communities of the North Rupununi.

5.3.2 Temporal changes in fish populations

In the past decade the majority (54 percent) of the most common fish species caught by the Makushi appears to have remained at a similar abundance (Table 5.13). However, 33 percent of the species show a decline in abundance and 13 percent of the fish species show an increase. These results support the statements from the interviews, where 86 percent of the participants said that the fish numbers had decreased during the last 10 years if not over an even longer period. As this quote from an older man in Annai illustrates:

> *"Fish were abundant in 70s, 80s. Then population grew 80-90s and new communities such as Crashwater were established. In the 90s people started to use seine nets to catch fish, before it was bow and arrow. Now people use even more nets and it takes twice as long to fish as it used to. And we can't find big fishes."*

Table 5.13: Comparing fish estimated abundance between 2011 to 2000 data

	Dry Season			Wet Season		
Fish species	**Annai 2000**	**Rewa 2000**	**2011 Mean data**	**Annai 2000**	**Rewa 2000**	**2011 Mean data**
Arawana	3	3	2	4	3	
Baiara	3	3	3	1	4	3
Banana fish	4		2	4		2
Basha	3		2	4		1
Butter fish	4		4	4		1
Cartaback		4	1		4	4
Haimara		4	2		4	1
Hassar	2		3	1		
Houri	3		3	1		1
Imehri (black)	1	1	1	4	3	4
Kassi	4		3	2		2
Kullet	4	4	4	4	4	3
Lau lau	1		1	4		1
Lukunani	3	3	4	1	4	3
Manji	1		3	3		
Paku	1	3	1	3	4	4
Patwa		4	3		1	1
Perai	2	2	4	4	2	4
Policeman fish	1		2	4		4
Sword fish	4		2	4		1
Tigerfish	4		1	3		1
Yakatu		4	3		1	
Yarrow	3		2	3		2

Note: 1 equals rare, 2 occasional, 3 common, and 4 abundant

When comparing Table 5.13 to Table 5.6, the results also show that the fish judged to have low abundance belong to the same group of fish species in Table 5.13 that has reduced abundance over time. This indicates that the estimated low numbers in Table 5.6 are linked to reduced populations and most likely not due to natural variability of fish species' population size or habitat, as speculated earlier.

The participants explained that they are still able to get enough fish, as can be seen when comparing average catches in this study to Mistry *et al*.'s (2004) data (see section 5.3.2.1), which only differed by 1-2lbs. However, the decline of fish results was both witnessed and documented; the Makushi have to travel further and spend more time fishing to get the same amount of fish as in the past. The effect of this decline on their lives is indicated by the quote above and the following from a younger man in Yupukari:

> *"The further you go from the village the better the fishing is"*.

A young man in Massara explained that when he was a child, about 15 years ago, it would be enough to fish for half an hour in the morning to obtain all the fish they needed for a day or two. Today you need to fish at least half a day, sometimes a whole day, to get the same amount of fish.

From the data in 2000, Mistry *et al*. (2004, p. 127) concluded that the result "implies that the fish communities present in the North Rupununi are some of the most unaffected in the neotropics and indicates little impact from either the Makushi or outside forces". While this is still true for the majority of the fish species, there is now also a significant number of fish species that show patterns of declining populations and a reduction in size.

The reason for the decline, according to 80 percent of the participants, was the increased population in the area and the use of the seine net. The populations in the five communities have increased by 44 percent from 2002 to 2011 (Guyana Statistical Bureau, 2002; NRDDB, 2011), and the average annual growth rate has been almost 5 percent (Fig. 5.22). This is a high population growth rate, which may indicate that the health of the people in North Rupununi is improving. However, the downside is that the resources now have to be shared between more people.

In regards to the use of seine nets as the cause of fish decline, people explained that with the use of seine nets people can take up many more fish, and faster, than by using hook and line or bow and arrow. It also means that all sizes of fish that get caught are harvested, while in the more traditional fishing methods the smallest fish could be released, or avoided altogether, by using the right sized hook or just shooting the bigger fish. Other explanations given for the decline were: fires which have destroyed vegetation along the riverbanks and around ponds, leading to less protection and food for the fish and potentially also a source for higher turbidity and phosphate values; otters, for eating too much fish, and causing the decline in some locations; and, according to a few people, selling fish commercially to outsiders.

The last two explanations given were gold mining and oil drilling. The gold mining is taking place in a tributary further south near the Kanuku Mountains, and more mining would have taken place in the past, but it is difficult to find data on exactly where and when and to what scale. The oil drilling mainly takes place on the' hunting' oil site, which has been on-going for several years. An event about 3-6 years ago was reported by all the communities where suddenly there was a massive fish kill. Very large fish were found floating on the surface and it was reported to the Environment Protection Agency, but nothing was done or investigated, to the participants' knowledge. A new drilling site was made and tested near the head waters of the Piarara River, by Dimond W, during the first few months of 2011. However, this site was closed down due to insignificant finds. Yet, a large area had been created by bringing in lots of soil very close to the flood line, which will thus most likely lead to some increases in suspended particulate matter. Moreover, this was done all without proper village consultation, resulting in mixed emotions among the local communities. Some were angry, and others were not sure what to believe or think, as most did not have a good understanding of what oil drilling was and what it could do to both the ecosystem and the job market.

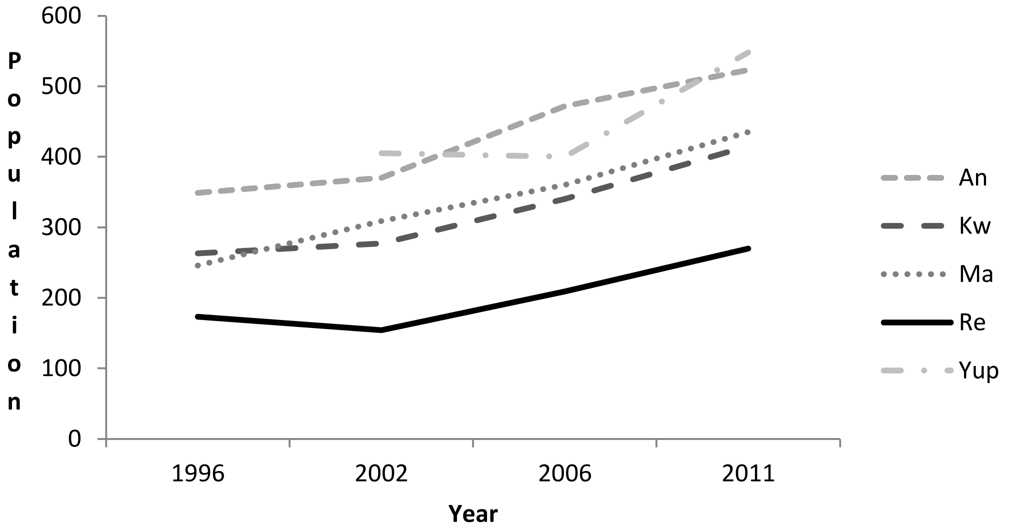

Figure 5.22: Population numbers increase from 1996 to 2011 for the five communities (Source: Forte (1996), Guyana Statistical Bureau (2002), Wetlands Partnership (2006), NRDDB (2011) and complemented by figures collected through interviews with health workers in the communities)

Going back to the results table which compares the fish abundance from 2000 to 2011 (Table 5.13), one of the three species that actually increased in abundance according to the Makushi's result was the Perai. The high abundance is also supported by the monitored fish data, which rank it as the species caught with the highest frequency, and described in the quote below by an older man in Yupukari:

> *"Thirty to forty years ago Perai wasn't as plenty as they are now".*

What could be the explanation for this perceived increase? The first explanation could be that Perai are seldom the fish the Makushi want to catch as they prefer other species to eat. However, due to their high abundance, now catching them is inevitable. Another potential explanation could therefore be that twelve years ago the people that participated did not want to admit to catching and eating so much Perai as they are not regarded as highly. The quote below from an older man in Annai describes this:

> *"People eat Perai but not so much, not so nice"*.

Another potential explanation is that the Perai have increased in abundance during the past 11 years. It could also be that other fish species have gone down and thus people accept taking up the Perai more now than they did 11 years ago. An increase in Perai numbers has been recorded in other sites such as Brazil (Rincon, 2003). This study found that it was the increased number of dams in the system that created more slow-moving or lentic water bodies, which then allowed the water hyacinth to increase, and this is the habitat the Perai larva prefer to live in and be protected by. There are no dams in the Rupununi, but the meandering of the river has changed quite considerably since the base maps were made in the 1960s, resulting in large areas of the river being cut off and thus creating more slow or still moving waters.

It was also recorded that there had been more deposition in the river, as areas that had been deep enough for boats to pass in the dry season were now difficult to pass due to their shallowness. However, any increases in the amount of water hyacinth were neither seen nor reported. Large fluctuations between fish species are also common in these types of waters and could potentially be the explanation (McConnell, 1964), or the increase of Perai might indicate a change in the food web – it was suggested that when larger predatory fish species like the Haimara decline it may result in Perai increasing in numbers. Still, not enough data is available to draw any conclusion on this matter, but it might be an area for future research.

5.3.3 Biodiversity and long term temporal change in the North Rupununi

Comparing the study's Black Caiman results with data from 2005-2006 (Fig. 5.23) illustrates that the result varies considerably between sites. Two out of the four habitats show no real difference in numbers between the years, while the other two habitats, Simonie Lakes and Devil's Pond, indicate a substantial difference. In Simonie River/Lake a much higher number of Black Caimans were counted in 2005 compared to 2011. This is most likely due to the higher than normal water level that was recorded throughout the 2011 dry season. It is established that high water levels result in lower numbers of Black Caimans when using the spot counting method (Da Silveira *et al*., 2008). To aid analyses of this result, questions were asked to the Caiman House research team in Yupukari, and they confirmed that no noticeable decline in

Black Caiman numbers had occurred during this time period in that particular area (Simonie River). Table 5.14 separates the juveniles and adults out of the total number and it can be seen that a much higher number of Black Caimans in Devil's Pond in 2011 could be due to the high number of juveniles. Perhaps Devil's Pond was not favoured among the Black Caimans as a nesting site in the past, whereas now it is proven both by this data and from interview data that it is a site which holds many juvenile Black Caimans.

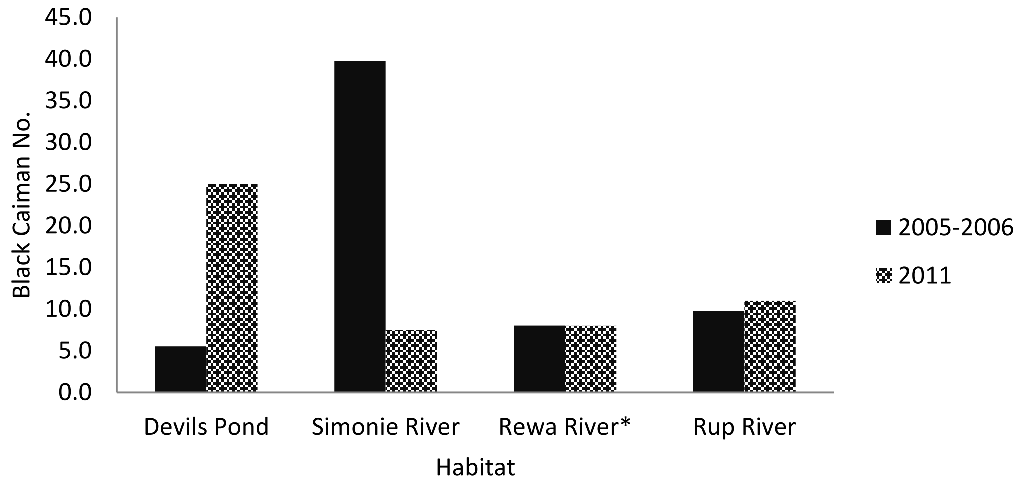

Figure 5.23: Comparing Black Caiman numbers between years and habitats

This result may also indicate that the population has recovered from the very hard hunting pressure which took place in the 1960s and which reduced the population substantially. This result is similar to Mistry *et al*. (2009) and Watkins (2002), who also found an increase in Black Caiman numbers in a similar area. However, looking at the quantitative results (Fig. 5.23) no general trend of increased numbers can be proven during this time period. The population of Black Caimans may just have stabilised again after the hard hunting pressure of the 1960s. However, in addition to the point counts data on a 1000 m stretch, additional data was collected for the Rewa River which gave an abundance of 3.1 Black Caiman per km; this can be compared to Watkins's (2002) average river data for the entire region which was 1.8 per km and 4.2 per km in lakes. These figures indicate an increased abundance supporting the qualitative data, but Rewa River is only one location and cannot be compared to the entire region Watkins's (2002) study assessed. So before any firm conclusions can be made on whether the Black Caiman numbers have increased again, more research is needed and longer time series of data would be useful to enable better conclusions to be made. Still, this result indicates that the population of Black Caimans in the North Rupununi has either gone up in numbers or stayed the same, which are both positive considering the tragic past for this species. However, the human Caiman conflict is an issue; stories of children and hunting dogs being taken need to be taken seriously and the population needs to be monitored to ensure the best possible solution.

Table 5.14: Comparing Black Caiman numbers between 2005-2006 and 2011, indicating age category of the Black Caimans

Site	Year	Mean no. of Black Caimans		
		Juveniles BC	**Adults BC**	**Total**
Devil's Pond	2005-06	1.3	4.3	5.5
	2011	14.0	11.0	25.0
Simonie Lakes	2005-06	28.8	11	39.8
	2011	2.5	5.0	7.5
Rewa River	2005-06	3.0	5.0	8.0
	2011	3.5	4.5	8.0
Rup. River	2005-06	5	4.8	9.8
	2011	7	4	11

5.4 Conclusions

It is clear that temporal scale and spatial heterogeneity of the landscape affect the condition of the three ES discussed in this chapter. The most severe changes in the landscape are clearly the large amount of water that is added to the system through the main rainy season from May to July every year. However, interestingly the findings show that it is not the depth of water or the season that seem to have the strongest effect on the spatial distribution of the fish, or more correctly, the species composition of the fish catch – instead it is habitat. Comparing this result with other studies, McConnell (1987) characterised the fish assemblage in tropical waters to be stochastic, although more recent findings have shown that deterministic mechanisms seem to structure floodplain fish assemblages, at least during low-water periods (Arrington, 2002; Hoeinghaus *et al*., 2003; Winemiller, 1996). This study's findings provide new insights into the issue of fish spatial and temporal dynamics by focusing the scale of enquiry on the fish species that are considered an ES, which to my knowledge no other study has done before.

The factor that differentiated the habitats the most was turbidity, which is linked to the classification of white or blackwater habitats. The results also showed that the number of species that prefer either the river or the pond habitat was of equal percentage, about 20 percent each, and only a third of the fish species could be found in all habitats. These results thus indicate the importance of protecting the heterogeneity of the landscape, and that all different types of habitats are important for a continued supply of fish.

The assessment of the local communities' fish catches in terms of fish abundance and diversity supported previous findings in small-scale fisheries, which is that the diversity of the fish catch is high and that the abundance of fish catches declines in the wet season. However, this study investigated the composition further and found that although a high diversity of fish is consumed, the majority of the catch comes from a rather small number of species. Six species (Lukunani, Perai, Baiara, Houri, Imheri, and Dawalla) in particular were found to contribute disproportionately to the fish catch. The reason for this dominance was discussed earlier, and seems to be a combination of high fish populations and the favoured food fish, which Lukunani and Houri seem to represent, whereas the other three seem to be more eaten because of their high availability. This study is unable to compare this data with previous years as no fish monitoring has taken place in the area previously.

Fish populations are known to fluctuate quite markedly between years, making it hard to say if these species are the dominant ones every year. However, through informal interviews it was confirmed that these species are the main food species for the communities. Although some fluctuations exists as it was reported that Lukunani numbers had been down a few years before, but because of the good flood which took place in 2010, the population seemed to have recovered to an extent. As mentioned, Lukunani is for many the most favoured fish to eat. They are partial spawners, which mean they have the capacity to reproduce throughout the year and do not rely on flooding, but due to the food shortages it has been documented that they also depend on the flooding to reproduce in decent numbers (Fernandes *et al*., 2009). So even if the lack of flooding affects them too, they seem to have the capacity to bounce back quickly, which is most likely linked to their partial spawning behaviour. This result also brings up the issue of vulnerability of the ES users, the Makushi, as a high dependence on a smaller number of species might mean that they are more vulnerable to changes in those fish species' numbers. Fortunately, this discussion is mainly theoretical as the species in question seem to have healthy populations; due to their generalist behaviour, five out of the six species live in all the different habitat types identified, and should be more resilient.

Fernandes *et al*. (2009) found that species composition and relative abundance differed between the dry and the wet season, when they studied the cichlids assemblages in 11 lagoons in Pantanal, Brazil. The result from this chapter, found similar result as the abundance of fish consumed also differed between the seasons. There were also some species compositions differences found, as about a fifth of the species the Makushi use were only available in the dry season and about as many (16 percent) were only available in the wet season. This thesis finding can thus conclude that some seasonal difference in species composition occurs when studying fish as an ES, but that the overall diversity of fish use stays similar between seasons.

One of the most striking findings of this chapter is the decline in the fish numbers in the North Rupununi. It was shown that about 33 percent of the fish species the Makushi use has declined in number during the last 10 years. It is a quite sharp decline, and seems to have already affected the size of some of the fish species, as there were far fewer large fish caught compared to small. This was also confirmed in the interviews where many described the lack of big fish around the communities and that they had to travel far to find large fish now. A spatial difference was also found in the decline, whereby one community reported much more reduced fish numbers than the other four, which was Kwatamang. It was also confirmed that the area around Kwatamang does not have as much fish as it used to, whereas Rewa was found to still have a mostly good supply of fish. These spatial differences can be due to several factors, but it is thought the much higher population of people around Kwatamang is most likely part of the reason. However, there might also be more biophysical explanations which will be further discussed in the next chapter.

Using local people to assess the fish abundance is a quite novel way of monitoring fish abundance and I believe the rigour in these findings support it as a potential alternative method to assess fish abundance, or at least be complementary to standard assessments, which is raked with difficulties in remote tropical waterways. I believe that it needs to be done in combination with community owned fish catch monitoring. Because in this way it provides the local communities with the capacity to assess their own fish populations, which hopefully builds more ownership of the resource and changes their attitudes to be more supportive to ensure healthy populations of fish.

The results also demonstrated time and again that Makushi knowledge and reliability can be trusted, as their information has been compared and confirmed with actual observations and/or scientific samplings. Comparison between focus groups and questionnaire results (Table 5.6) illustrates that the majority (68 percent) of the data correlated well and supported the quantitative data collected, indicating that the information gathered was reliable. Again, the fish abundance and season table results based on the community monitors data confirmed the estimated data provided in the interviews and focus groups. The results from the fishermen conducting the monitoring were also very encouraging, as their data was also verified through the focus groups data and through the observational fishing trips. This result is very promising, as much monitoring will most likely need to take place in the future due to both the REDD+ scheme, which requires a monitoring and verification process and for any community-led fish monitoring programme.

The next chapter will demonstrate and discuss in more detail how spatial scale impacts the supply and distribution of ES. It will particularly focus on fish and how the Makushi fishing pattern and strategy reveal source and supply areas in the North Rupununi. Important connectivity site will also be identified and their significance to the health and continued supply of ES will be discussed.

Chapter 6

The importance of spatial scale for ecosystem services in the North Rupununi

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The previous chapter discussed the effects of temporal scale and spatial heterogeneity on the condition of the ES. This chapter will follow on from this, focusing on the spatial aspects of the ES identified by the Makushi. Analysing space can be beneficial both for indigenous communities and for conservation. Mapping indigenous lands has proven to be a valuable tool for indigenous communities in their fight to secure land tenure, manage natural resources and aid development decisions (Chapin *et al*., 2005). Creating land maps can also further reveal how indigenous people view their land (Smith *et al*., 2012). However, there are issues of power with cartography that need to be considered, particularly when working with indigenous communities, because the 'power' from the map could potentially be used against them if the data is shared with the wrong people (Chapin *et al*., 2005).

Still, there is a great need to improve the understanding of ES spatial patterns and to create maps visualising these patterns. As discussed earlier (chapters 1, 2, 4) it is important to identify which areas in the landscape are responsible for the delivery of different ES and to what areas ES are supplied. Due to the heterogeneous nature of landscapes there are areas that provide more ES than others; there are also areas that ensure the flow of ES to other locations and scales, and these are particularly important connectivity sites (van Jaarsveld *et al.*, 2005; Amorors and Benettte, 2002). Mapping of these key ES sites allows for a better understanding of the spatial extent and pattern of ecosystem processes and population distributions, which is considered vital for management plans to be successful and to enable the linkage between conservation activities and human well-being (Fisher *et al*., 2011).

This will address the last research aim, which is to establish spatial patterns of the supply of ES and key connectivity sites between ES at different scales, linking this with how seasonal changes affect the spatial patterns. The chapter will start by describing the Makushi's fishing patterns and discussing the factors that influence their fishing strategy and associated spatial pattern. The second part will describe and discuss the importance of spatial connectivity in the landscape in regards to the waterways. Lastly, the spatial distribution of farm lands and hunting grounds will be discussed to reveal spatial patterns of these two important ES in the landscape.

6.1 Fishing patterns of the Makushi

To establish the spatial pattern of the supply areas of fish on a landscape level for North Rupununi the fishing pattern of the Makushi needed to be explored. The results reveal that the purpose of fishing trips, together with biophysical and cultural factors, control where the Makushi choose to fish.

6.1.1 Spatial aspects of the fishing practices of the Makushi

The most striking result from the interviews and focus groups was the identification of two different types of fishing, 'everyday fishing' and 'commercial fishing activity' (see Map Appendix 1-5 to see identified fishing sites). The difference between these two types was the purpose of the fishing trip, as the name suggests. The characteristics that separate these two types of fishing were the distance travelled to the fishing site, time away and the amount of fish caught. The most important fishing type was referred to as 'everyday fishing' by the local people, which since then has also been given the term subsistence fishing in the North Rupununi Management plan, which was produced towards the end of 2011 (Jafferally and Haynes, 2011). This study has thus taken the decision to use the same terminology to facilitate communication. The subsistence fishing type was described as the fishing necessary to stay alive. The respondents described it as 'the day to day fishing' that has to be convenient, thus preferably near the community; catches average around 5-20lb per fishing trip, depending on household and family size.

The commercial fishing type refers to fishing trips that result in financial gains for the fisher and are typically done further away from the community. Figure 6.1 clearly demonstrates the large difference in distance travelled between 'subsistence fishing' and 'commercial fishing' sites.

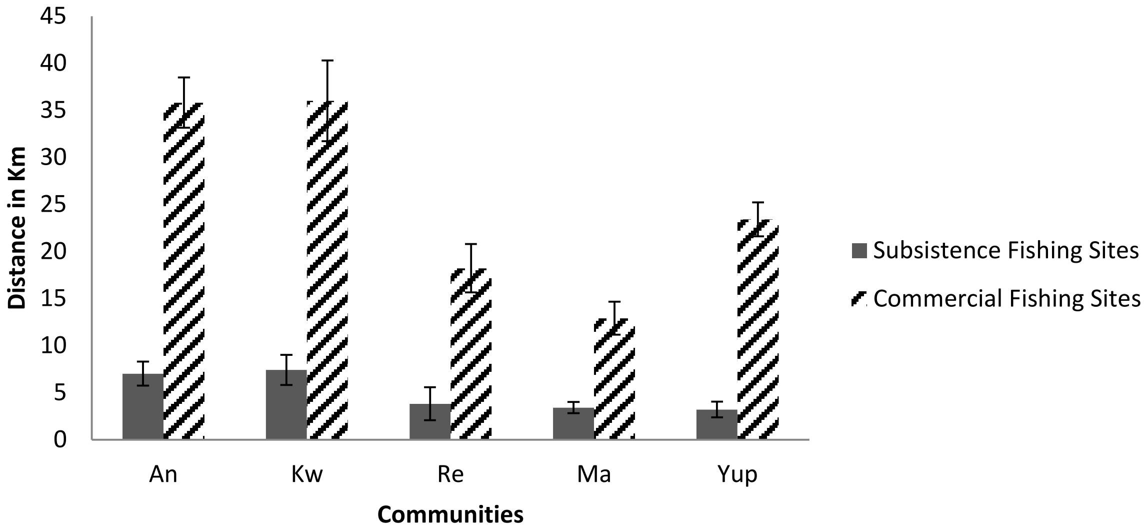


Figure 6.1: Mean distance to fishing sites for the five different communities, divided into subsistence fishing and commercial fishing sites

The spatial analyses of the different fisheries types (Fig. 6.1) show that the mean distance to the subsistence fishing sites is only 4.96 km. This is five times less than the mean distance to the commercial fishing sites, which is 25.26km. Several reasons were given for this behaviour. First, the lack of large and abundant fish populations of the market-desired species (such as Lukunani, Cullet, Arawana, Basha, and Tiger fish) explain to some extent the behaviour of traveling far for commercial fishing, as the quote below from a man in Kwatamang indicates:

> "*I and most other people catch fish near to the village but it is smaller fish. Has to go further to get big fish. Apoteri has huge fish, but need engine to go there"*.

Second, there was a strong sense and agreement within the communities that fishing for monetary gains should not negatively affect the essential subsistence fishing, and thus commercial fishing needs to take place away from the community. Third, many people did not have access to a canoe or a boat, which made it practically difficult to travel far for fishing, and thus restricted subsistence fishing to nearby fishing locations, as the quote below from a focus group in Annai highlights:

> *"There is a shortage of boats, therefore we used to go fishing in the creeks but you cannot get as much fish there now like you used to"*.

Begossi (2006) found similar results among artisanal fishers in Brazil, where access to only paddle or small engine canoes led to restrictive mobility, thereby favouring fishing sites nearby. Even though the same fishing pattern was documented in all the five communities (Fig. 6.1) it is clear that two communities, Kwatamang and Annai, have to travel much further than people from Massara and Rewa to reach good fishing sites. This relates to both the subsistence fisheries but most prominently to the commercial fisheries. Comparing this graph with the results from the interviews and focus groups, it is suggested that the distance to the fishing sites could be a good proxy of fish abundance (Morenco-Baez and Orr, 2010). This might suggest that Annai and Kwatamang have the lowest abundance of fish on their titled land, corresponding well to results discussed earlier (chapter 5) that highlighted a marked decline in fish species abundance and size for this area. However, it has to be taken into account that these two communities are located further away (at least 1-2 km more) from the river in comparison to the other communities. Thus, the further location from the river may explain the difference in distance in subsistence fishing sites, but the distance travelled for the commercial fisheries is so much greater that the more likely explanation is that the waters around Annai and Kwatamang are poorer in fish compared to the other communities.

Reasons given by the Makushi for the lower abundance of fish, as discussed in chapter 5, identified an increase in population as one of the two main causes. Population pressure could definitely be an important factor in the reduced fish numbers in Annai and Kwatamang, as another three communities utilise similar fishing sites. Yet, other possible explanations will be discussed below and further on in the chapter, which suggest that biophysical features could potentially partly explain why this area is more vulnerable to population pressure.

Another pattern that became clear through the interviews and focus groups was that subsistence fishing took place for the most part on the communities' titled land whereas commercial fishing more often took place on another community's titled land. For example, Kwatamang fish predominantly downstream on the Rupununi River and in the associated ponds and creeks along this stretch of the river from their landing site. Whereas people from Annai fish upstream from their landing, which is located only 1800m from Kwatamang's landing. Massara shows similar respect towards Yakarinta's (the closest community to them on the other side of the river) ponds, which are located near their main river landing and thus only use them occasionally. This unwritten agreement seems to be upheld by all communities to respect each other's subsistence fishing sites. However when it comes to commercial fishing, the rules seem to be different. For most communities it means they go far from their community and titled land, but then often end up using another community's fishing grounds. Still, this pattern was accepted as long as it only happened occasionally, the person had a letter from their Toshao, and had the permission from the 'host' community's Toshao. Nevertheless, some negative comments were noted in regards to this informal rule of respect – for example in Rewa, many fishers come from upriver savanna communities and fish on their titled land. There two older men were noted (Field Diary, 29 January 2011) to comment negatively about one particular man who had fished several times without asking for permission, which they were upset about; they had discussed the issue with their Toshao to resolve the situation. Maccord *et al.* (2007) found a similar result with artisanal fishers off the coast of the Atlantic Forest in Brazil, where a division of the fishing sites near the communities was evident, whereas fishing sites located further away and used only occasionally were shared. Cordell (1989) also observed and mapped similar informal rules of respect and of reciprocity concerning fishing sites by artisanal fishers of Bahia state in Brazil.

The commercial sites also seemed to be regarded as so rich that they could sustain higher fishing pressure. Yet, it was the supportive and fair community spirit that seemed to explain the reciprocial behaviour the most. Most respondents seemed to see themselves first and foremost as Amerindian, and second as their individual community identity (Field diary 5 April 2011). They thus regarded the Rupununi's titled land to belong to all its indigenous inhabitants and believed that it therefore should be shared with respect.

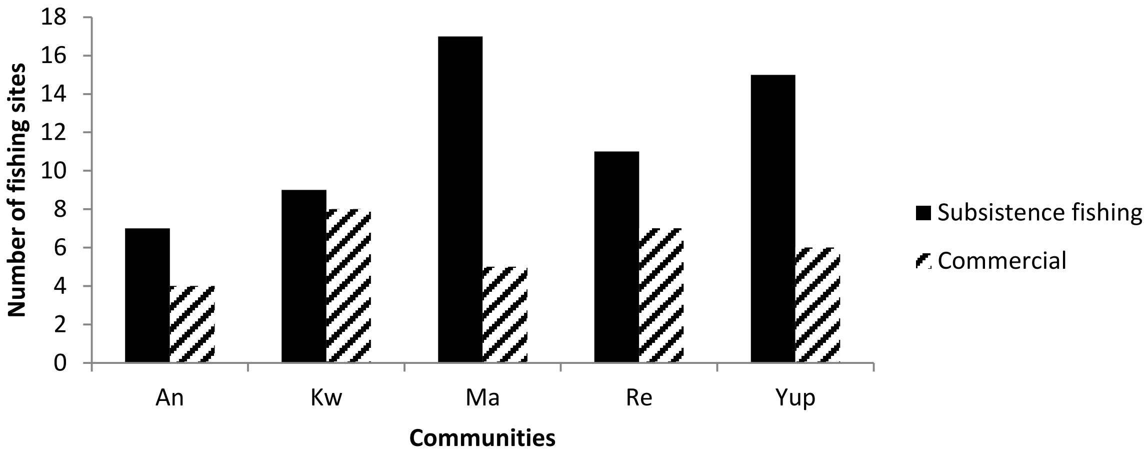


Figure 6.2: Number of subsistence and commercial fishing sites per community

The result of the Makushi's fishing pattern also reveals that 89 fishing sites are used by these five communities (Fig. 6.2, maps of fishing sites in Appendices 1-5 and list of fishing sites in Appendix 10). Again it is Annai, which has the lowest number of fishing sites in comparison to the other communities. This result supports the earlier suggestion that the fish resources around Annai and Kwatamang might be naturally less rich as not as many subsistence fishing sites are located there. The more even numbers of commercial fishing sites across the communities could be explained by the fact that some Annai and Kwatamang residents travel far down to both Rewa and Apoteri (another community about 20km further downriver from Rewa) to fish in their richer waters, meaning they often share commercial fishing sites (see Map Appendix 1-5).

In addition to the subsistence and commercial fishing sites, a third type of fishing site has been marked on the maps (Map Appendix 1-5) called 'occasional fishing sites', these are areas that are only used occasionally as the name suggest. They were only identified in the field as sites which are not so rich in fish but still used sometimes depending on water level or if passing for other reasons (Field notes 28 January 2011).

6.1.2 The habitats where the Makushi fish

The Makushi have a great range of habitats to choose from when they decide where to fish. Many of the respondents said the Rupununi River (see Plate 6.1) is the main fishing site, and the ponds and creeks (see Plate 6.1) are mostly used when they prefer a different type of fish such as Hassar or Houri, which are species normally found in ponds. The Rupununi River with its annual flood pulse regulates and rejuvenates most of the other water bodies such as the ponds and creeks. Yet, regardless of the river's magnitude the ponds are considered by many to be equally important. The ponds are particularly important for people who do not own a canoe – they can still have access to these fishing sites as they can wade out in the water (to throw cast nets or use seine nets) or fish from the sides.

Further analyses from the five communities found that a total of 42 ponds were identified by the Makushi as important fishing sites (Map Appendix 1-5). The average size of these ponds was fairly equal between the communities (Table 6.1) with a mean size of 11.4 ha. The smallest permanent pond was Paddle Pond in Massara with an area of 0.4 ha and the Simonie Lakes were the largest with a size of 50.6 ha.

Plate 6.1: Photos of Rupununi River in both dry (left) and wet season (right) (Source: photograph taken by author)

Nolan (2009) found in the central Amazon, Brazil, that the longer the distance from a pond to the river, the higher yield could be expected. However, the same result could not be found in the Rupununi. Nolan (2009) identified the greater ease of access if ponds were located nearer the river as an explanation for this pattern. For the Rupununi it is believed that the closer access to the Georgetown-Lethem road has more impact on the fish population, as outsiders can more easily access the river and/or it is easier for orders to be made to the community for fish if they are located near the road.

Table 6.1: Mean size measurements of the ponds in the North Rupununi and the distance from the pond to the Rupununi River

Communities	Pond size (ha)	Length (m)	Width (max, m)	Width (min, m)	Distance to Riv (m)
Yup	12.8	845.8	142.5	32.0	551.8
Ma	9.5	611.0	122.8	61.0	787.9
An	11.6	912.4	215.4	89.6	234.1
Kw	11.3	401.4	587.5	92.4	326.6
Re	11.9	878.8	139.3	78.6	356.1

To better understand the spatial landscape the ponds have been categorised into three different types dependent on their size (Fig. 6.3). Again the lower number of ponds around Annai and Kwatamang support the suggestion that these communities have fewer fishing areas, which could explain the reported lower abundance of fish compared to the other communities.

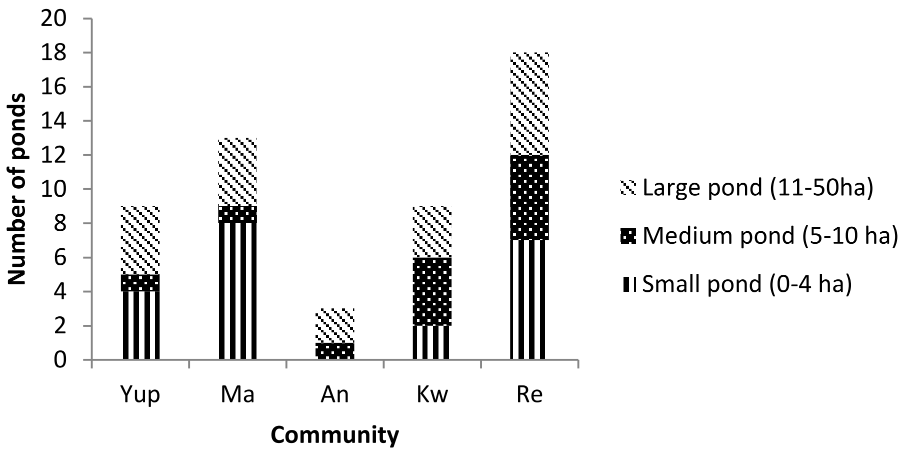


Figure 6.3: Number of ponds per community divided into three size categories

6.1.3 Fishers' behaviour and strategy related to key landscape features

Fishers' behaviour and strategy was explored to improve the understanding of the factors that influence the source and supply areas of the fish distribution. Opaluch and Bockstael stress that "the fishermen's decision as to allocate effort level is perhaps the most important type of behaviour to be understood" (1985, p. 3). It is particularly critical for any management plan to comprehend the fishing behaviour and strategy of the resource users (Béné and Tewfik, 2001).

Through both the formal and informal interviews three main factors could be identified to influence where the local communities in North Rupununi fish: traditional knowledge, biophysical factors (such as water level, transparency, vegetation and habitat features, season, stock behaviour) and cultural factors (further discussed in section 6.1.5). Some of these factors are in line with Béné and Tewfik (2001), who also identified the same factors in their study on Turks and Caicos Islands in the Carribbean.

Further investigation was done to establish if the respondents knew of particular habitat features that might indicate essential fish habitats. The fishers in the Rupununi displayed a rich and detailed knowledge of the biophysical environment they live and fish in. They knew the water depth of the water bodies they use and how they change throughout the year, which meant they knew exactly what month of the year a pond had the right water depth to maximise their yield. Furthermore, they knew that with the changing water level different species were attracted to different water bodies and thus choose their fishing location accordingly. They also displayed knowledge of where particular features such as rocks were located in the landscape, where the preferred fruit trees of some fish species were located, and when to seek them out to maximise their chance of catching the fish species which like to feed on the fruits, as this quote from a younger man in Rewa demonstrates:

> *"Fish need fruit trees, like at Makarapan pond and Old lady pond, there is also weed and giant water lilies there, which makes fish like the area"*.

This place-specific knowledge seemed to have been passed on through generations, and could not be easily transferred to other places. For example, on one of the fishing trips along the Rupununi River I asked two fishermen to fish in a location outside their community's territory as food was required on the journey. The two men appeared slightly disorientated as they could not find a good fishing spot and ended up asking me for advice. Consequently, only one Perai was caught during the 6 hour long fishing trip, which was extremely rare. In comparison, 18 fish were caught on an earlier fishing trip to the same location, but with a man from the community whose titled land it was on. The difference could, therefore, be related to place-specific knowledge, rather than stock levels.

Another example of the Makushi's in-depth knowledge of the fish fauna is the list of biophysical characteristics identified by most respondents as indicators of good fishing habitats for either particular species, or more generally for all types of fish (Table 6.2). Four out of these five characteristics are known to create good habitat for fish. However, 'black water' is known for its low productivity although high biodiversity has been found, these waters are normally associated with lower fish biomass compared to white waters (Fittkau *et al.*, 1975; Goulding *et al*., 1988; Handerson and Crampton, 1997). Yet, evidently in the Rupununi these dark waters are seen as indicators of the richest fishing grounds. For example, a man in Rewa observed:

"If the water is black it carries most fish. It also looks healthier and taste better. In muddy areas fishing not so good".

Many of the commercial fishing sites that people travel far to reach are of these dark water habitats, such as Simoni Lakes/Creek, Bat Creek, Blackwater Pond, Rewa River, Tarraqua and Gobi Pond (Map Appendix 1-5).

Table 6.2: Biophysical characteristics that constitute good fish habitats according to the Makushi

Biophysical characteristics	**Reason**	**Location and Time**	**Fish species**
Fruit trees (e.g. Wild Ginipot, Wild Cockrit, Wild Palm Fruit , Wild Passion fruit, Wild Guava, Lana, Wild Cherries)	*"Fish like these fruits so people go to areas with fruit trees when they are producing. Once the fruit is gone the fish go back to the Essequibo falls".*	Along the river but also other water bodies – fruit ripen mainly in wet season.	Mainly Pacu, Carteback and Imehri
Black water	*"Fish like clear water".*	All through the year, e.g. Simonie, Bat creek, Rewa, Mapare River, Blackwater pond.	All fish species
Deep pools	*"Fish like deep water".*	Deep pools are created where the Rupununi River bends and is most important in the dry season as it provides refuge.	Basha, Cullit, and other catfishes
Shading vegetation (water lilies, overhanging vegetation)	*"Fish like shading, because they can hide there".*	Makarapan Pond and Old lady Pond, Grass Pond, Moby Pond, Dare Pond, exists both season but most important in dry season when fish are confined to these spaces.	All fish species
Rocky areas	*"Fish like to feed on the algae which grow on the rocks. Also like to hide among the stones".*	Kwatamang pool, Riverburst pool, mainly used in dry season but the rocky ares are stable.	Catfish and Imehri

Of the five described biophysical characteristics (Table 6.2) two show a temporal dynamic whereas the other three characteristics are more stable. It is the fruit trees and the shading vegetation which varies temporally. The fruit trees have a familiar annual cycle which means that most of the fruit the fish like to eat are ripe for the wet season. The fruit provide important nutrients for the fish and the fish aid the fruit trees by dispersing the seeds. When it comes to the temporal pattern of shading vegetation, at least two types can be identified: the first is rather stable, which is the trees along the river, creeks and pond banks, providing the overhanging shading vegetation. The temporal changes that affect these important landscape features were human made fires which had escaped. As previously reported, the Makushi burn the savanna grass to improve the quality for the cattle. These fires have been reported to have spread and caused quite large-scale damage, or at least long-term negative effects. Sites where this was reported to have occurred included: (i) along the north bank of the Rupununi River to the east of Kwatamang; (ii) Kwatamang Pond; (iii) Devil's Pond; and (iv) Grass Pond. The respondents all said that there had been a severe decline in the amount of fish in these habitats afterwards, as the quote below from an older man in Rewa indicates:

> *"All that side burn, used to get big fish and plenty, plenty after that things change, not as much fish".*

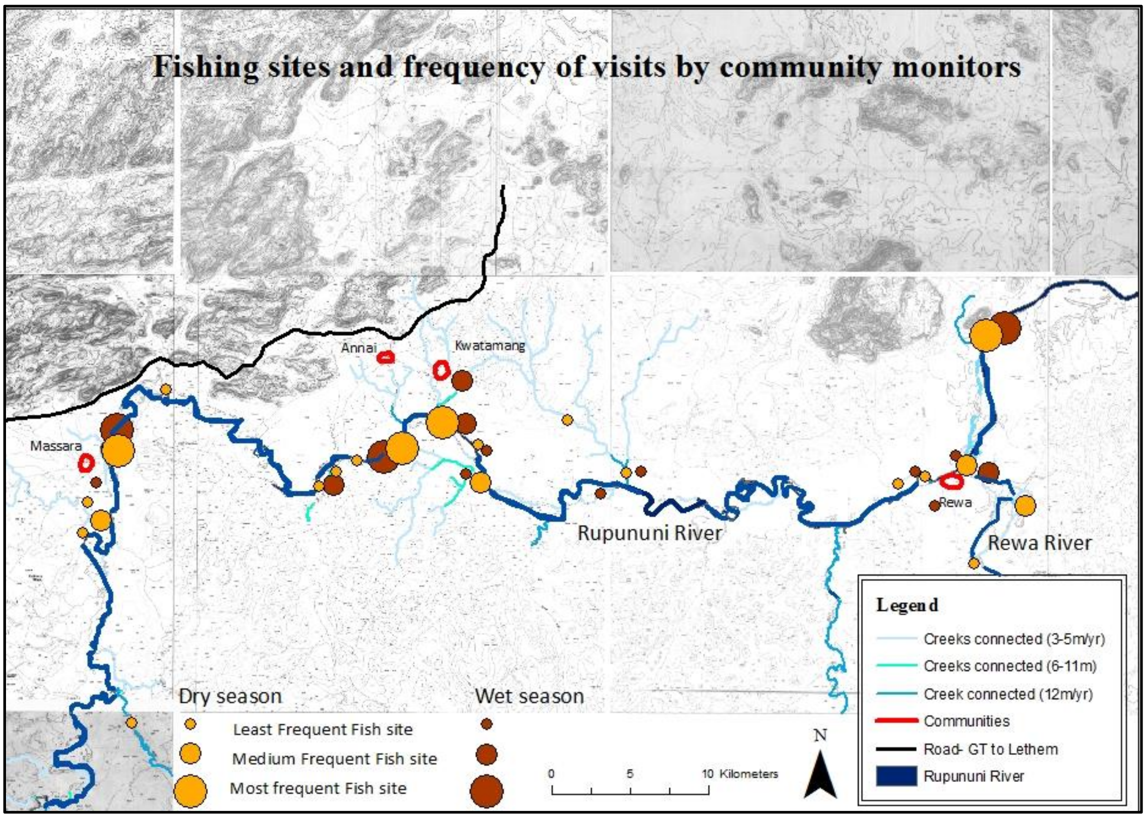
However, these fires took place rather long time ago – the respondents thought about 10-20 years ago, but were unsure when exactly they happened. Grass Pond was the only site out of these where the vegetation structure had fully recovered, although a difference in the type of vegetation compared to the more mature south side of the pond could still be seen. The other sites have only had some regeneration, around the banks. The local guides thought it was because the fires had burnt so hot that it caused the soil to become too hard for any large trees to grow. No further data was collected to verify or deny the reason for this absence of regeneration.

The second type of shading vegetation is the floating one, mainly made up of different types of water lilies, water hyacinth and floating grasses. To grow these requires light to reach down into the water column; the water thus needs to be rather clear and/ or shallow to allow for this to take place. However, at least two sites were reported to have lost all their lilies and floating vegetation from one year to the next (Pine Pond and Moby Pond). For Pine Pond this had resulted in a drastic decline of fish abundance and people did not use this fishing site as much as they had previously (Field notes 28 January 2011). For Moby Pond one small area had remained with floating vegetation, but about 95 percent of total pond area was now free from floating vegetation. These two examples show how ES supply areas can change over a rather short temporal scale.

The last important habitat feature to discuss is deep-water pools, which were found and mapped along the Rupununi River, Rewa River and some of the creeks. These deep-water pools function as dry season refuges for many fish species across the Rupununi. These sites, particularly all along the Rupununi River, also constitute the most popular fishing sites for many, as they are favoured habitats for many of the catfishes the local communities prefer to eat (Field diary 12 April 2011). Thus, these deep-water pools may be one of the most important environmental features in the landscape to sustain the fish ES. This result is in line with the findings of Baird and Flaherty (2005), who investigated the major environmental factors affecting the success of 'fishing free zones' in the Mekong River and found that deep-water pools were the most important feature in the landscape. They also highlighted the importance of microhabitat diversity as a key factor to maintain and enhance the Mekong fisheries, thus supporting the importance of the identified heterogeneity of the landscape, and suggesting that all habitat types are important to sustain a healthy supply of fish.

6.1.4 Seasonal effect on the fishing patterns and ecosystems of the North Rupununi

How the seasons affect fish as an ES has already been discussed to some extent in chapter 5. This section will focus on the spatial aspect of the fishing sites and how the season influences where the fishers go to fish. The community maps (Map Appendix 1-9) illustrate where the subsistence fishing sites and commercial fishing sites are located for each of the communities. Maps 6-9 show the location of fishing sites in the wet season. By comparing the two season maps (Maps 1-5 for dry season) for the five communities it becomes clear that some new fishing sites are created in the wet season compared to the dry, and that often these are located nearer to the communities. These are in many cases spawning migration routes up creeks or through the savanna and forest. Establishing these fish routes is of special importance for the conservation of this lateral migrating group of fish species (Barletta *et al*., 2010). However, the main pattern is that the fishing sites in the wet season only shift slightly from their location in the dry season. Rather than fishing in the pond or in the river in the wet season, the Makushi fish in the bush surrounding the same pond and along the same stretch of the Rupununi River but in the flooded forest or savanna. This pattern can be seen in Map 6.1, which shows the community monitors' fishing effort (who recorded their fishing activity for 6 months during 2011), indicating their fishing sites and frequency of visit.



Map 6:1: Map showing fishing frequency and location for the community monitors according to season (Source: Map maid by author using Guyan lands and Surveys Commision's base maps)

The wet season normally starts towards the end of April to the beginning of June, with May to July being the main wet season. These rains lead to the transformation of the Rupununi landscape, as discussed in chapter 2, from savanna to inland sea (see Plate 6.2) with an average wetland size of 3,480 km^2 as the Rupununi floodplain merges with the Roraima floodplain in Brazil (Hamilton *et al*., 2002) . The huge amount of rain that fell in May 2011 can be seen in Fig. 6.5. A peak of about 600mm is abnormally high, and compared to previous years (Fig. 6.6) a more average rainfall amount would appear to be around 400-500mm during these months. All the communities agreed that 2011 had the highest water level they had ever seen. This is indicated by the quotes below, first from a woman in Massara, and second from a women's focus group in Annai:

> "*Never seen river high like this, water normally only comes up to that bush, now the boys house is flooded"*.
>
> *"Everywhere flooded – even where it hasn't flooded before, we are sinking more and more, where our fathers and grandfathers used to farm it now floods"*.

Plate 6.2: Photos showing the transformation of the North Rupununi landscape from the savanna in the dry season to the flooded wetland in the wet season (Source: photograph taken by author)

With the rains comes the rise of the water levels in the Rupununi River, which quite rapidly rose in depth (Fig. 6.4). The increased force and volume of the river was observed to start pushing through water in the dried up creeks, and it began to flow over the riverbank in the low lying areas. This initial rise of the river depends to a high degree on rains that fall in the South Rupununi's savannas and Kanuku Mountains, residents explained. Shortly afterwards the surface water from the North Rupununi savanna and the Pakaraima Mountains starts to fill the dry creeks, tributaries to the Rupununi River, with clear rainwater. These two processes were observed and described by several field guides. They contribute first to the connection between the Rupununi River to the creeks and ponds, and second to the subsequent spectacular 'fish marching', where the spawn migration of the fish takes place, which allow them access to their breeding grounds and rich feeding areas. The importance of the connectivity for the health of the whole Rupununi ecosystem will be discussed in a later section.

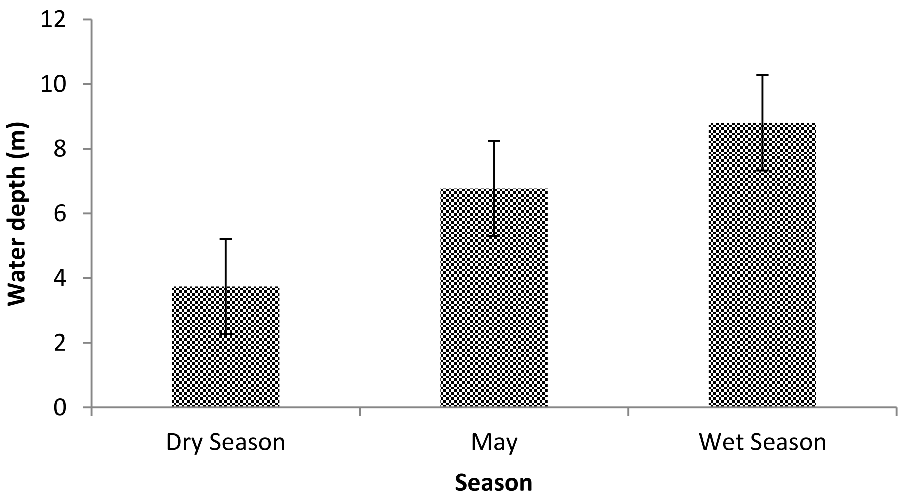


Figure 6.4: Average Rupununi River water depth measured in both the dry and wet season, and the month of May, which is the intermediate period when the water is rising

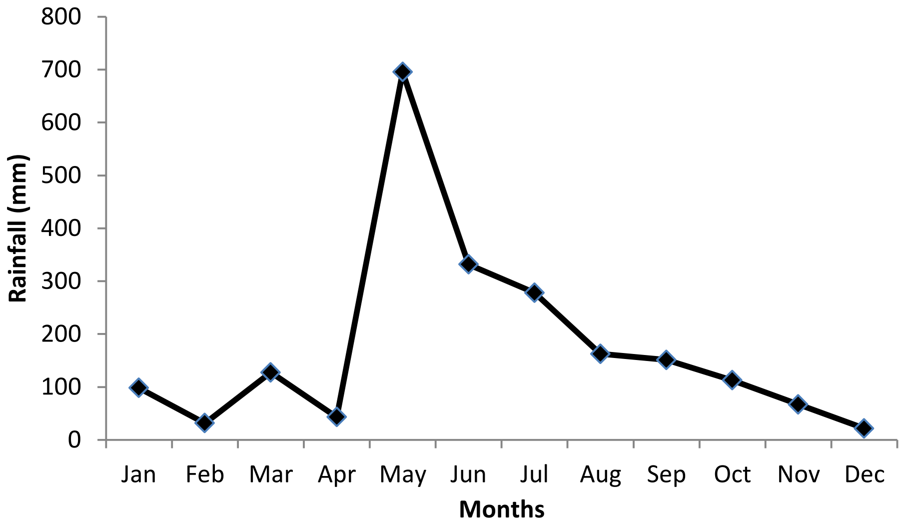


Figure 6.5: Monthly rainfall data for 2011 at Bina Hill, Annai, North Rupununi (Source: data provided by Iwokrama International)

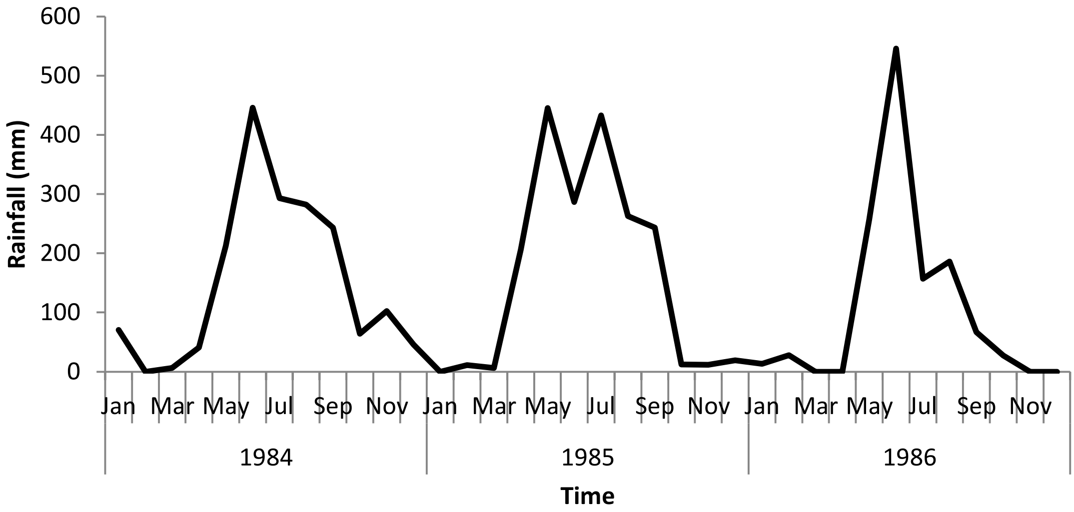


Figure 6.6: Rainfall data from Annai 1984-1986 before the monitoring stopped. (Source: data provided by Iwokrama International)

All of the communities become islands more or less in the wet season. The flood water surrounding the communities in 2011 (between June and July) had an average depth of 1.45m (Fig 6.7). As expected, due to its low elevation and proximity to the Essequibo River, Rewa was the community with the highest flooding depths. The flooding, although making fishing harder for the Makushi, makes traveling easier as shortcuts can be made through the forest and across the flooded savanna. These shortcuts create the opportunity for more people to fish at sites that are considered too far away in the dry season. For example, the shortcut from Kwatamang to Rewa can halve the travel time.

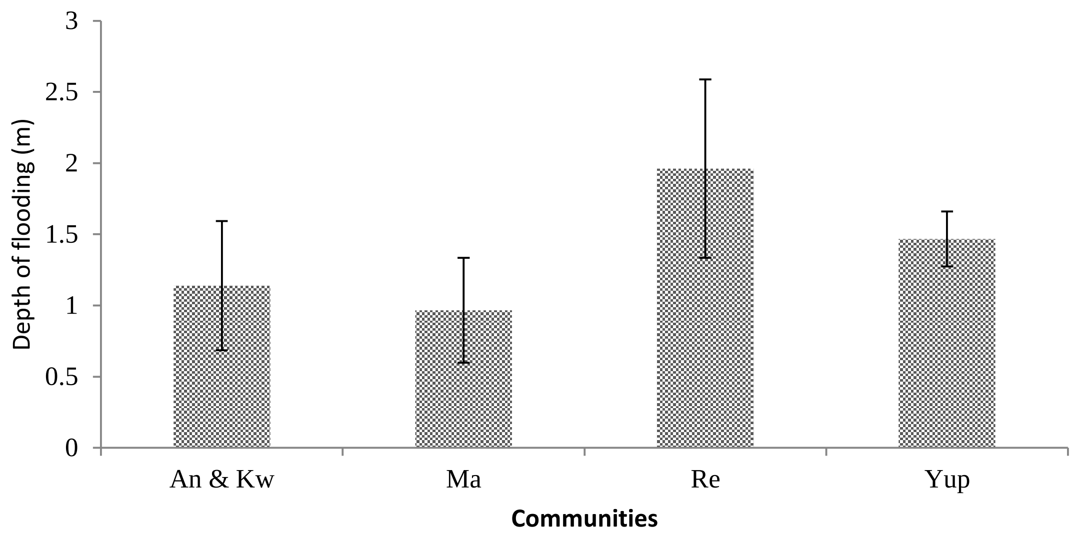


Figure 6.7: Mean depth of flooding measured around the different communities during June and July 2011

When the floodwater starts to recede, the respondents reported that fish very quickly move to new habitat patches, which means that some fish choose to stay and get trapped in the ponds, while others return to the river (Layman *et al*., 2009). This means that at the beginning of the dry season (September), the fish composition of these ponds is fairly well mixed. However, throughout the year the piscivoreous fish gradually become more dominant as they consume their prey (Field notes and McConnell, 1964). How prevalent this process is depends on several factors such as size and shape of the pond, water depth and vegetation covers (Field notes 28 April 2011). A pond that would show a very strong pattern of piscivorous fish dominance would be a fairly small shallow pond, which has no connection to the river or creeks, and has a smooth shape, either round or oval, and limited or no vegetation cover. An example of such a pond would be Big Bononi Pond on Massara land (Map 6.2). The fishermen reported that in April only Perais were left in the pond, indicating an extreme case of piscivorous dominance. This type of ecosystem process clearly affects where the fishers go to fish, as Perai is not a sought after species. The results also illustrate again how important the flood pulse and the connection with the Rupununi River are for the long-term survival of this pond and consequently the well-being of the Makushi.

The last of the pond types to consider are the ones that disappear during the dry season. These ponds are not valued as highly by the communities as they were not mentioned in the interviews and focus groups. However, through informal conversations and observation it became clear that these ponds can provide substantial amounts of fish, but they are only used for a few weeks of the year. Examples of these types of ponds are Donkey Pond in Rewa and Hassa Pond in Yupukari (Map Appendix 4 and 5). The communities wait until the pond contains the right water depth to maximise their yield. It also became clear that this type of event is in many instances a communal activity; as this type of habitat is only present for a short amount of time, people get together to fish and ‘roast’. It could thus be argued that these ponds have cultural value as they bring dates in the calendar when communities can come together and enjoy the surplus of fish.

I was told of one of these events in Rewa where a group of both men, women and children had gone out together for the day to the Donkey Pond (in March, 2011) to catch as many fish as possible to avoid ‘fish wasting’ as they expressed it, as the pond would soon dry out. Everyone in the group, apart from the youngest children, helped out to catch the fish using a wide range of techniques, such as cutlasses, knifes, cast nets, and bow and arrows. When they had fished for a while they stopped to eat, and used both the pot and sticks to roast the fish. The man who described the event expressed a great joy from this activity, as all people participating were telling jokes and laughing, he said (Field diary, 6/04/ 2011).

6.1.5 Cultural factors influencing fishing behaviour

When trying to understand the pattern of resource use, Read *et al.* (2010, p. 214), who studied hunting patterns in the North Rupununi, suggest that “it's important not only to consider influencing factors that relate to biophysical environment in space and time, such as abundances and logistical factors (i.e. the amount of effort required to bring home a kill), but also cultural factors such as meat preferences, taboos, and other prescriptions that affect how people interact with and relate to those spaces”. I would also like to consider this statement in relation to fishing patterns.

As with hunters, fishers make decisions on where to go fishing according to the current abundance of the sought after fish species (Dunn and Smith, 2011). Other logical and practical aspects are also considered, such as the time and effort needed to reach a particular fishing site. Decisions on where to fish can thus be linked to location of household and farming grounds. An unwritten rule, or pattern, was observed within the communities, whereby households located on one side of the community tended to fish in sites located closer to that side of the village, while households located on the other side of the village prioritised fishing sites on their side of the village. This most likely depends on ease of access to the fishing sites. For example in Rewa, households situated on the west side of the village tended to fish more in locations on the west side (e.g. Grandfather Pond, Henry Pond) whereas easterly located households tended to fish more in easterly located fishing sites (Grass Pond, Rewa mouth).

A similar pattern was also observed in Massara, where some of the households that lived further northeast from the centre of the village tended to fish in the ponds northeast of the village

(Riverburst Pond and Waterlilly Pond), whereas households on the other side of the village fished in ponds southwest of the village (Bononi Pond). This quite obvious divide of fishing sites clearly eases the fishing pressure on the area, as not the whole village population use the same fishing sites. However, similar divides in fishing sites were not observed in Kwatamang and Annai, most likely due to the reduced number of ponds in their surrounding area and their location further away from the river.

The importance of spiritual sites in relation to fishing patterns was found to have been more important in the past than today. Many people told stories of what their grandparents' generation used to believe, which was that numerous places in the landscape were considered dangerous and they therefore avoided visiting and using these sites. Some of these sites were ponds, and as a result the earlier generation never went fishing at these locations (Devil's Pond, Old lady Pond, Goat Pond, Blackwater Pond, and Oma Pond). However, today the ponds which were believed to be dangerous in the past are now being used by most people. So it seems that for the majority, traditional spiritual beliefs do not affect where the fishing takes place today. , as this quote illustrates from a younger man in Rewa;

> "*We had connection with spirits a long time ago but not so much now, it was helpful then. But when Christianity arrived many people lost this connection, so we don't use it much now".*

On the other hand, there seemed to be a great 'sense of place', which can be illustrated by the fact that all 89 fishing sites had been given their own names (Smith *et al*., 2012). The names represented either the person that found a pond, or how the pond, river, pool or creek was perceived. For example, Devil's Pond was perceived by previous generations to be dangerous, which is clear by its name. Another example is Goat's Pond in Rewa, where it is said that a goat lives, and if you hear or see the goat something bad will happen to you, as this older woman in Rewa describes:

> "*Goat pond supposed to be able to give a token, my cousin heard the goat and he died that same year*".

Even though most people now fish at sites that were previously regarded as taboo, other traditional beliefs are still very much alive and some influence the fishing behaviour. The beliefs mainly prohibit certain fish to be eaten by different groups of people. The group with the most prohibitions are pregnant and lactating women, who are warned against eating a number of fish on the grounds of them being fatty (Forte, 1996). It is believed that fatty fish cause diarrhoea in infants, and that the spirit of the fish is stronger than the new spirit of the baby, and can thus cause it harm (Forte, 1996). There are 16 species of 'fatty' fish identified by the Makushi. Another group with prohibitions is small children, who are warned against eating two types of bush Yarrow, as it is said they will become stupid from eating these fish (Forte, 1996). Other traditional beliefs related to fishing practices again concern pregnant women and their spouses. It is believed that fish know when a man's wife is pregnant and thus avoid being caught. The highly sought after fish Paku (*Colossoma*) is believed to "dive deep down and never more reappear if it is hunted by a man with a pregnant wife" (Forte, 1996, p. 120). Therefore, neither pregnant women nor their spouses are welcomed to join any fishing party.

The last factor to discuss is how stable the fishing sites have been for the communities in the North Rupununi. The long-term stability of fishing patterns is important to understand as it may reveal changes both within the community institutions and potentially the fish populations (Burger, 2001). The majority of the fishing sites identified in the Rupununi had remained constant for a long time, according to the respondents. However, one community, Yupukari, reported that many of their old fishing sites were no longer used. This was revealed in a focus group when an older resource map from 2002 was shown (Appendix 11); the respondents reported that many of these fishing sites were now no longer in use. The reason given for this change was that they had stopped farming so far up the river, and thus would not fish there unless they had another reason to be in the area. The reason for relocating the farms nearer to the village was the demand of attendance from schools, which meant that paddling 2-4 days to get to farming grounds and then returning home was not seen as feasible. This move of fishing sites, together with the change of now using taboo sites for fishing, gives an indication of the process that determines fishing locations, which is regarded as very important from a management point of view (Burger, 2001).

To end this section I would like to reiterate the words of Dunn and Smith (2011, p. 94), who studied the hunting pattern of the Miskitu in Honduras: "examining the spatial pattern of Miskitu hunting activity provides a window onto the complex interplay of ecology, geography and culture". I believe the same is true when exploring the fishing pattern of the Makushi, and that this study has given a rare insight into the complexity that determines a fisher's behaviour and how the landscape's spatial attributes affect the fishing pattern documented. Additionally, it has provided a deeper understanding of the fishing strategy and behaviour, which is essential for a management plan to be successful.

6.2 The importance of connectivity for the North Rupununi landscape

This study has for the first time identified, mapped and described key connectivity sites of the waterways in the Rupununi landscape. These sites represent migration routes for the fish to move between lakes and the river, but also the critical paths fish take to spawn and feed during the rainy season. Connectivity can be both an actual physical connection between two or more areas such as a creek or a stream, and it can be a migratory species that connects several ecosystems temporarily by transferring matter and energy ("mobile link species" Myers, 1993) at a regional scale (Granado-Lorencio *et al*., 2005). This study has focused on identifying physical links in the landscape, which allows the mobile link species in the aquatic environments to connect to new areas. Identifying important connectivity sites on a local scale is a necessity for understanding how these may affect provision of ES on a landscape scale. For example, an area like the Rupununi is known to be a very important area for biodiversity and spawning activity for many different organisms. However, it is not known what features and particular areas in the landscape are responsible for providing and sustaining these ES. This is why mapping and the identification of key sites are so important, because they allow for important habitat characteristics on the local scale to be mapped. In this section connectivity in relation to spawning sites will be discussed first, followed by an exploration of the Bononi Creek as a key area for connectivity. Lastly, lakes and creeks used by the Makushi will be classified according to their degree of connectivity, among other factors, in an attempt to better understand the Rupununi landscape and its characteristics.

6.2.1 Essential areas for fish spawning

Creeks become very important habitats in the wet season as they serve as corridors for fish to access spawning and feeding grounds on the flooded savanna and in the forests. The communities identified 30 creeks that are important for them and for the fish fauna. These creeks, and their connectivity degree (how many months per year they are connected to larger spatial scale), are all mapped on the community maps (Map Appendix 1-5) and the main spawning sites corridors are marked on Maps 10-11 (Map Appendix). The Makushi use these creeks mainly for fishing but also as transportation links, providing easier access to forest and savanna during the wet season. Out of the 30 creeks, eleven were identified as key connection sites during the focus groups (Table 6.3). The chosen creeks were monitored to establish when and at what water depth the fish start to swim up the creeks to spawn. The results show (Table 6.3) that the fish do not require great depth to initiate the spawn run, as the average water depth for all the creeks was only 0.86m (± 0.4).

The most striking result was that the spawn run took place almost at the same time (the nights of 8-9th May in 2011) for most of the creeks (73 percent), regardless of where they were located along the Rupununi River. The Makushi explained that the Rupununi River has to have reached a certain level before the fish will, or in many cases can spawn, as the increased water level of the River is the main factor allowing them access to the creeks. For other creeks (Annai and Kwatamang Creeks) it is a combination of rainwater flowing from the mountains and the river water rising. Nonetheless, the Makushi said it was the rainfall that fell during these nights that was the main cue for the fish to start spawning.

Although the majority of the spawning runs took place in May, there was one site, the Bononi Creek by Massara (Map. 6.2), which stood out because the fish spawned an incredible two weeks earlier there than in the other creeks. The importance of this creek will be further discussed in the next section (6.2.2).

Before leaving the subject of spawning, it is important to highlight that it is only ‘small’ fish (Yakatu, Patwa, Huri and others) that use the creeks to spawn, whereas the larger fish such as Baiara and Pacu migrate up river to the south savannas to spawn. These were seen to ‘march’ up on the 5th of May (Field notes, 5/05/2011). Waves in the Rupununi River were reported, which is a sign of this event taking place. However, the Baiara were ‘marching’ for an extended period during 2011 as they started with the unseasonal rains in March and continued to go up river throughout April and May (Field diary, 5/06/2011).

For the communities, the fish ‘marching nights’ are culturally important as an event that brings the community together to catch fish communally (Field diary, 15/05/2011). However, recently the communities have started recognising that targeting fish at this stage should be avoided, or at least restricted, as it could have negative consequences on the health of the fish population (Field diary, 27/11/2010).

Table 6.3: When and where the fish started to spawn and associated water depth in the creeks

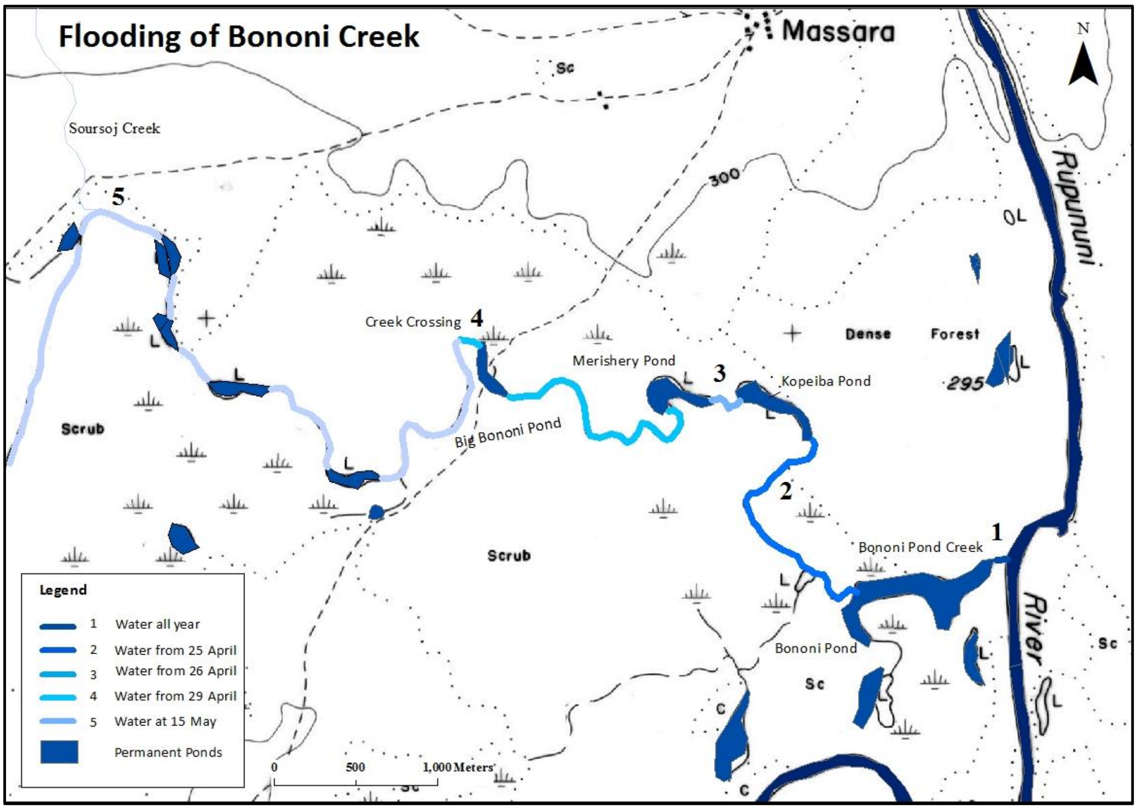
Location	**Date when fish swam up creeks to spawn (2011)**	**Water Depth (m)**
Annai Creek	8th May	0.55
Kwatamang Creek	8-9th May	0.47
Bononi Creek	26 April	0.4
Donkey Creek	8th May	0.9
Old Lady Pond Creek	8th May	1.05
Makarapan Pond Creek	9th May	1.15
Grass Pond Creek	9th May	1.1
Prantash Pond Creek	9th May	1.1
Surama Creek	16th May	1.55
Kwatata Creek	8-10th May	No data
Kumaka Pond Creek	14th May	0.3

6.2.2 Hotspots in the landscape – key sites that need to be protected

Identifying so called hotspots in the landscape is important because it allows integration of multiple spatial indices, which can then improve the understanding of landscape processes; it is also important for setting management priorities (Bryan *et al*., 2010; Crossman and Bryan, 2009). Bryan *et al*. (2010, p. 112) state that “hotspots of high priority for multiple spatial indices of social value can enable the identification of focal areas for the management of ecosystem services".

Bononi Creek was identified as a key hotspot in this study; it was found to stand out as an exceptionally important feature in the landscape for numerous reasons, which will be discussed in this section. As mentioned above (Table 6.3), fish spawned in this creek two weeks earlier than all other documented sites. This is important because it is not only the occurrence of the flooding that influences the health of the fish, but also the duration of the flooding, the respondents reported. Longer duration of the flooding means more time for the fish to spawn and feed in the newly accessible richer habitats. The more fat reserves the fish manage to build up, the higher chance they have of surviving and staying healthy during the nutrient poor dry season. In the light of this finding, the importance of the two extra weeks the Bononi Creek offers fish to reproduce and feed becomes apparent, and is most likely the reason why Massara is known for its high fish abundance, as the quote below from an older man in Annai illustrates:

"People in Massara, doesn't have any jungle or farm but they have lots of fish".



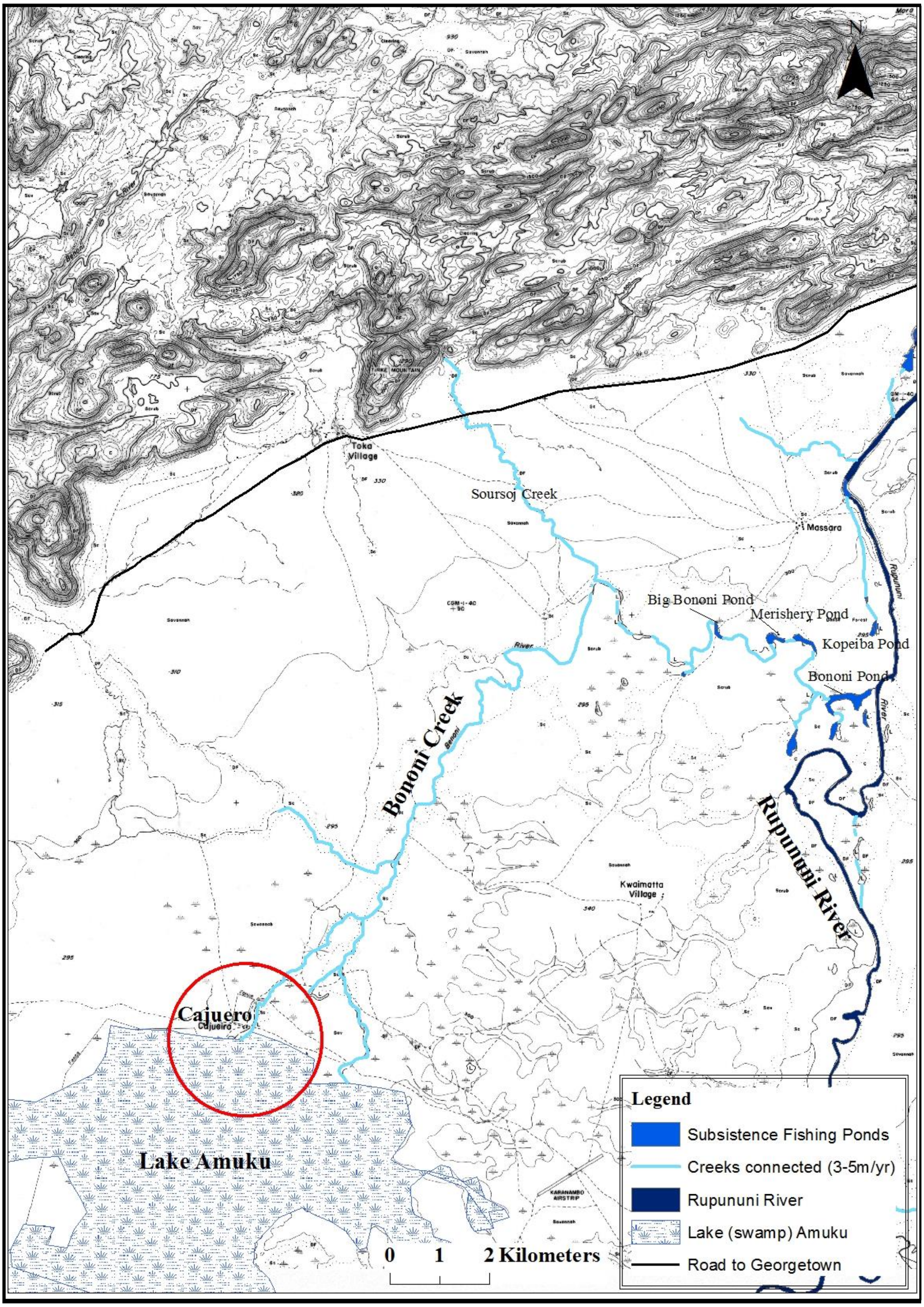
Map 6:2: Visualisation of how Bononi Creek is flooded and connected with the Rupununi River during April to May of 2011 (Source: produced by author, using basemaps from Guyana lands and Surveys Commision)

Another characteristic that makes Bononi Creek special is the high number of ponds that the creek connects during the wet season (Map 6.2). These ponds also stay wet during the dry season, producing a high number of subsistence fishing sites. How the Bononi Creek connects these ponds and how the fish subsequently follow this to spawn can be seen in Map 6.2. This map illustrates how fast the gradual connection of one pond to the next happens in this creek; as the map legend shows, it only took a day for the water to have connected site number 2 with site number 3. Then, only another three days were needed for the Bononi Creek to connect up to site number 4 on the map. Comparing the data from the Bononi Creek to the spawning table (6.3) discussed earlier, it can be concluded that the fish normally only waited one more night before they followed the water and swam up the Bononi Creek (Table 6.4). In some situations this could be a dangerous tactic as it might be too soon, resulting in fish getting cut off in a hostile environment if not enough water keeps flowing in or rain comes. However, it demonstrates the importance for fish survival to extend the time outside the normal dry season boundaries at all costs.

Table 6.4: Showing date and water depth when fish did their spawning run in Bononi Creek

Location	**Date when fish swam through creek (2011)**	**Water Depth (m)**
Bononi Cr to Kopeiba pond (2 on map)	26-Apr	0.4
Bononi Cr to Merisheri pond (3 on map)	27-Apr	0.67
Bononi Cr by big crossing (4 on map)	29-Apr	0.38

Bononi Creek is also an exceptionally important connectivity site in the Rupununi for another equally, if not more important reason. During this research it was possible to identify and confirm that the Bononi Creek represents the link between the Essequibo watershed and the Amazon watershed (Map 6.3). This link has been named the Rupununi Portal (de Souza *et al*., 2012) and is a unique biogeographical area that allows for the seasonal mixing of the two watersheds in Lake Amuku. The initial respondents reported two other sites of this alleged connection but these were later found to be dry in the wet season. Further investigation was undertaken and the Bononi Creek could be confirmed as a connection site. The Bononi Creek flows from the Rupununi into several different ponds until it enters into Lake Amuku by Cajuero (see red circle on Map. 6.3), which is the headwaters of Pirara River that flows into Takatu River, which eventually flows into the Amazon River. Some respondents also claimed that there is another connection site through Kaicumbe Creek, but due to restricted access and resources this link was not able to be confirmed nor mapped, as I could not access it.



Map 6:3: Map showing Bononi Creek and where it links (red circle) to Lake Amuku, which provides the Rupununi Portal between the Essequibo watershed and the Amazon watershed (Source: produced by author, using basemaps from Guyana lands and Surveys Commision)

6.2.3 Habitat connectivity of the creeks and ponds

Of the 30 creeks the Makushi identified, 80 percent dry out sometime during the year (see Appendix 1-5 for each category). The majority of the creeks (44 percent) are only flowing and connected with the Rupununi River during the wet season whereas some (20 percent) stay flowing, or at least contain water, all year round (Fig.6.8). There is also a group of creeks (18 percent) which dry out at some point during the year but contain deeper pools that still serve as habitats for fish and become a good fishing location when the water level has dropped.

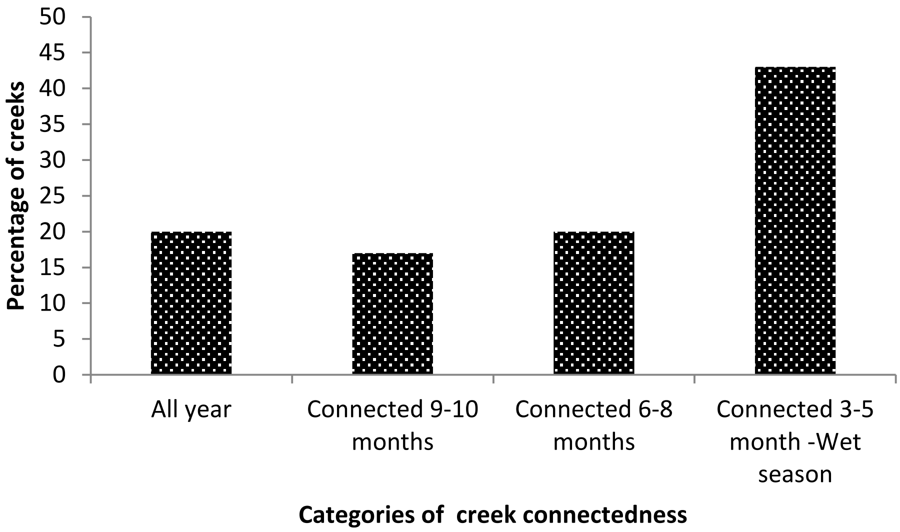


Figure 6.8: Creeks' connectedness with the Rupununi River

The creek's length is another interesting aspect of its spatial importance and impacts. The majority (80 percent) of creeks are of a small to medium length category (Table 6.5). The shortest creek is Tamparu Creek in Rewa, at 102m. The longest creek is Awarekru Creek in Yupukari with a length of 40.8km. The larger creeks were identified as good fishing areas whereas the small and medium ones were identified as good spawning creeks and good for transport, allowing access into ponds which are good fishing sites.

Table 6.5: Number and length of creeks divided into size categories

Categories of creeks	Length of creek (m)	No. of Creeks
Small	102-936	12
Medium	1514-8894	12
Large	10379-40800	6

Creeks identified of special importance were Bononi, Simonie and Bat Creek. Simonie Creek and Bat Creek are known for their abundant and rich habitats, which harbour some of the species that are very rare in other areas, such as the Haimara. Bat Creek is also special as its usefulness increases during the wet season, which contrasts with most of the other fishing sites that decline. Many communities reported that they go fishing in Bat Creek during the wet season, as the quote below from a younger man in Kwatamang shows:

> *"People go fishing in Bat Creek both low and high water, real good fishing area has endless of Lukunani".*

Lastly, comparing the creek data with the ponds' connectivity (Fig. 6.9), it becomes clear that the connectivity pattern is similar to the creeks', with 54 percent of the ponds only connected during the wet season and 17 percent connected throughout the year.

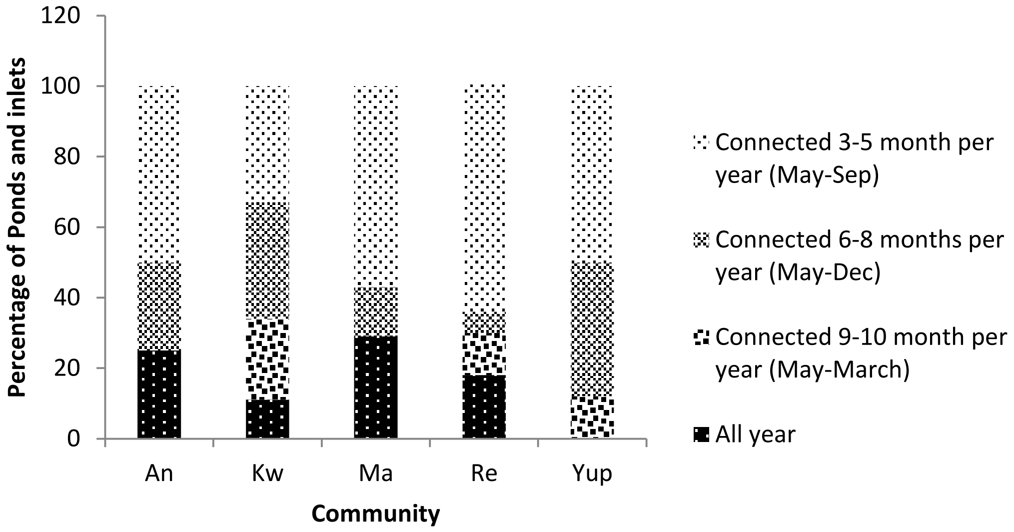


Figure 6.9: Percentage of pond connectivity for each of the communities

To illustrate the spatial scale connectivity of the ponds in the North Rupununi a diagram has been produced to illustrate how from the micro-scale, a pond in the dry season has no connection to other waterways in the landscape, and it is only surface run off and other terrestrial linkages taking place during this part of the year. However, when the water starts to rise the flow from one scale to the next becomes clear, as seen in Figure 6.10.

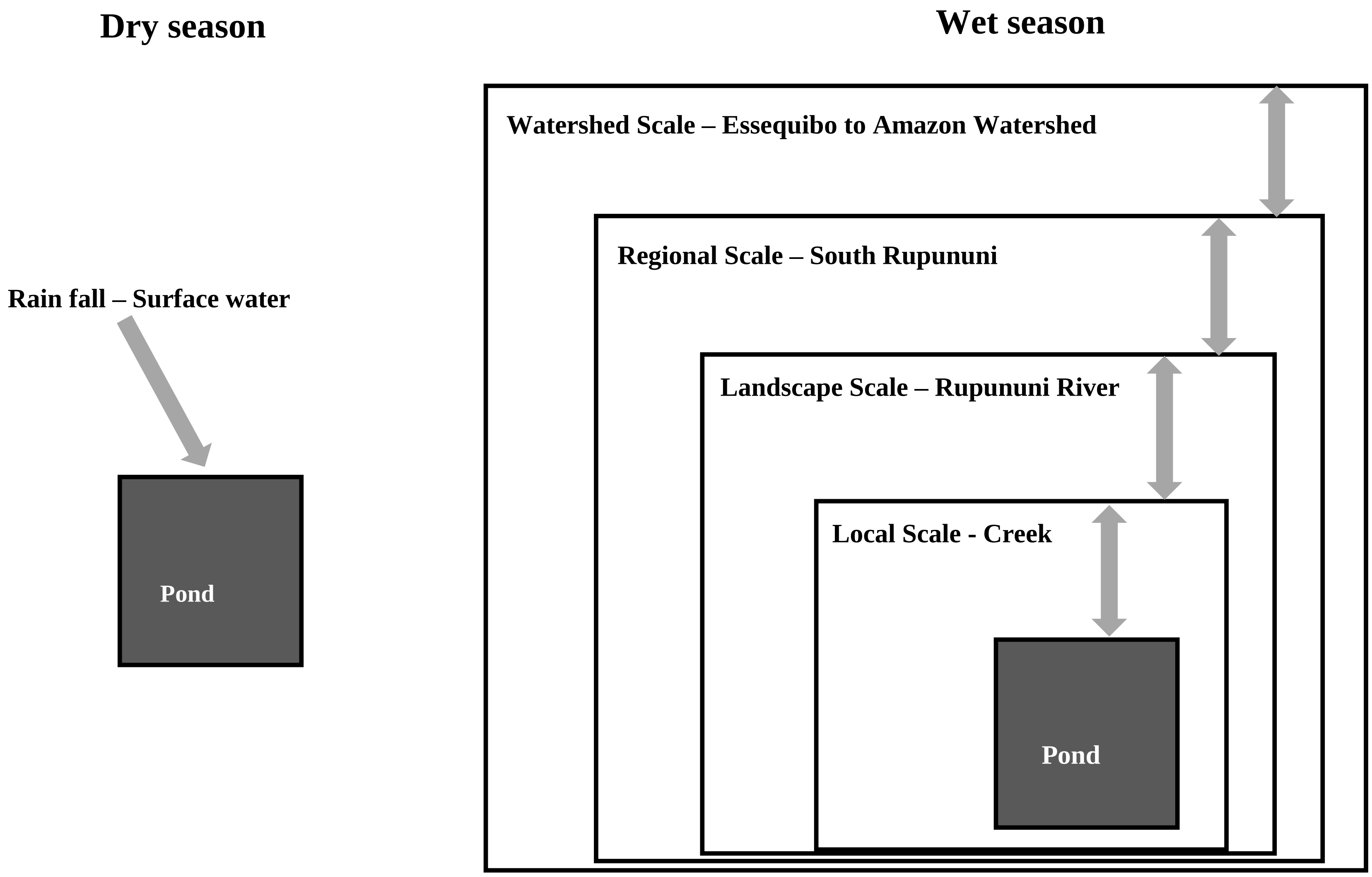


Figure 6.10: A) shows limited connectivity in dry season and B) shows multi-scalar connectivity in wet season

6.3 Key 'source' habitat sites

This study has been able to identify certain features in the landscape that are of key importance for the health and functioning of the ecosystem services. First are the 'source' habitats or at least habitats of higher importance in the landscape, because they feature something that is rare.

Pulliam's 'source' and 'sink' habitat concept (1988) is based on changes in population dynamics across heterogeneous landscapes and the persistence of populations in 'sink' habitats through reliance on inputs from 'source' habitats (Liu *et al*., 2011). The scope of this research project was not able to determine definitely if an area was a 'source' habitat, i.e. an area where births exceed deaths and emigration exceeds immigration at equilibrium, or a 'sink', an area where deaths exceeded births and immigration exceeded emigration at equilibrium. However, both physical and qualitative data in addition to observational field work has led to the conclusion that certain habitats can be identified as 'source' or at least key habitats in the landscape, which need to be maintained to secure the flow of ES. These include the blackwater creeks, such as Simonie Creek/Lakes, Bat Creek, Mouri Creek, Crashwater Creek and Tarraqua. Simonie may even be described as a hotspot because it not only provides ample amounts of fish to four communities, but is also a popular tourist spot for both the Caiman House in Yupukari and the Karanambo Ranch, located nearby. During the focus groups, both Massara and Yupukari highlighted and expressed the importance of Simonie as a very good fishing area and an area where many Black Caimans are found. They also recognised that the water is special because of its darker colour which not many other lakes and creeks have in the area. Tarraqua, Crashwater Creek, Mouri Creek and Bat Creek were all mentioned as especially rich in fish and host species that are rare in other habitats. The black water of these habitats thus seems to be a good indicator of exceptionally rich fishing waters in the Rupununi area and thus needs recognition for its importance in maintaining a healthy fish population, both for its biodiversity and for its food security.

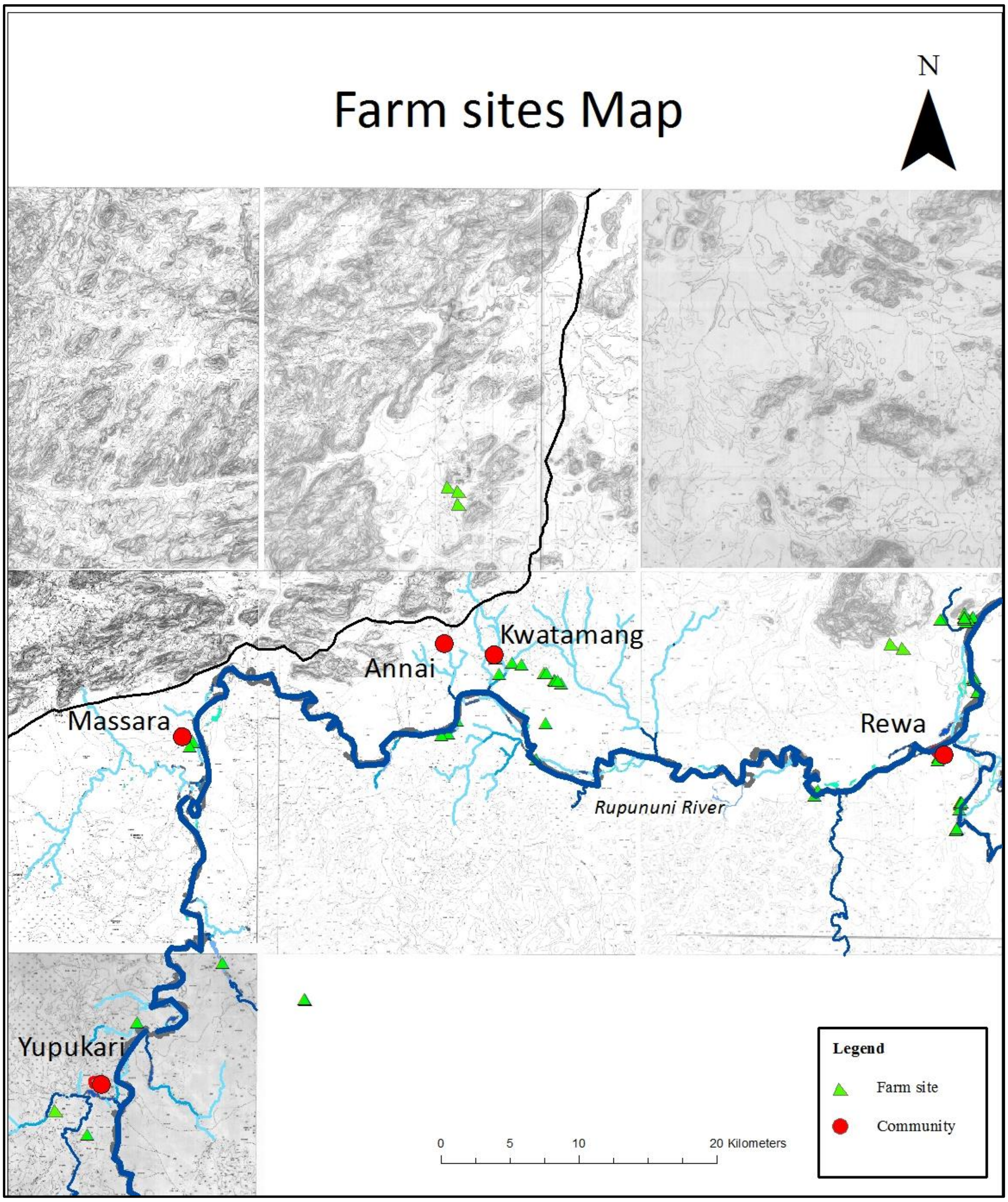
Key habitats from an ES perspective are the 'everyday' fishing sites which every community can identify. These key habitats can be defined on two grounds: first, it is a very good fishing site which the entire community knows about; and second, it is located only a short distance from the community, which makes it easy to access. A trend was identified in the responses to the question "which are the most important fishing grounds?" This was that all communities tended to answer the Rupununi River and one more site. That the Rupununi River was considered the most important fishing ground was expected due to its size and magnitude. However, that there would be such a clear second most important fishing site was not anticipated. The second most important fishing site varied between communities, but it was always a lentic waterbody (a pond or lake) that was located nearby (<5km). For Yupukari it was the Awarikru Lake, which is located about 800m from the centre of the village and at the bottom of the main hill (Map Appendix 5). Most people go there for their everyday fishing and catch a decent amount (20lb average) of fish. Moreover, this lake is not only used for fishing; it is also used for bathing and washing clothes, as well as taking tourists out in dugout canoes for wildlife spotting. The Awarekru Lake has a rich biodiversity, with many Black Caimans, birds, monkeys and Giant River Otters.

For Massara, it was the Bononi Pond which is very rich in fish and located about 3.5km from the main village. For Annai, it was Devil's Pond, which is just on the other side of Annai's Rupununi River main landing and contains a high number of fishes (Map Appendix 1). For Kwatamang, it was the Kwatamang pond, which is also located almost opposite their main landing on Rupununi River, with its high fish numbers (Map Appendix 2). Lastly, it was Grass Pond in Rewa, which has a rich abundance of fish, Black Caimans and bird life. It is also an important tourism area, as it is one of the main sites they bring guests to fish and to see Arapaimas, Giant water lilies, Black Caimans and other wildlife.

6.4 Farm lands – the distribution and limitation of dry land

The available area for farming for each community was found to be limited, as specific farming land needs to be at a higher elevation to avoid inundation from the annual flood pulse (Map 6.4). Two limiting factors were identified: first was the availability of terra firma, land that stays dry in the wet season, and second was the availability of good nutrient rich soil. For example, one man in Kwatamang stated:

> "*The farming area, Froggy and Crappo hill, has sandy soil that is not rich enough in nutrients, we can't grow bananas and other products that we can farm in area behind of Ruportee, where soil is red mud, good soil, where we can grow bananas, watermelon and corn. It is where our forefathers farmed*".



Map 6:4: Location of the five communities' farming areas (Source: produced by author, using basemaps from Guyana lands and Surveys Commision)

In the communities the farming areas are often divided into family areas, and in such an area several households can farm together, each using about 0.2-0.8 ha of land. This means Makushi households use a relatively small area for farming but they need to have enough land to allow for a fallow period after the 3-5 years they have used a site.

The communities have on average four areas that are used for farming (Table 6.6). The majority of these areas are located fairly far away from the centre of the community (Fig. 6.11

and Map 6.4) with an average distance of 9.3km (when measured straight from the centre of the village to the edge of the farm area). All the communities, except Yupukari, expressed their concern about losing crops due to flooding or waterlogged soils. It was reported that people had started to farm on lower grounds than previously because they had had a few dry years and because of the limited farming area available for most of the communities.

Table 6.6: The number of farm areas identified by the respondents per community

Community	**No. of farm areas**
An	3
Kw	3
Ma	5
Re	6
Yup	5

There appears to be a link between the distance to the farm lands from the community and the availability of terra firma. For example, the people of Massara (Fig. 6.11) have to travel the furthest, on average 18 km to reach their farmlands. This is because the community is located in the savanna, which has poor soil, and is on such a low elevation that they have to travel far to reach suitable arable land that remains dry in the wet season. Rewa is another community that had a lack of dry land. However, their scarcity of dry land is not only farm land but also village land. For example, part of the community was flooded in 2011, which caused nine houses to fall down and thus needed to be replaced, but people were not sure where to rebuild them as the availability of dry land was so limited. In contrast, Kwatamang is the community with the shortest mean distance (4.7 km) to their farming land and the lowest number of farming areas. This could potentially be linked to their large titled land which allows them to access enough high ground. The reason why Yupukari did not express any concern about available terra firma could potentially be linked to their higher elevation compared to the other communities, which means that their farmland has remained dry even with the abnormally high rainfall in 2010 and 2011.

The area of terra firma for each of the communities can be seen on the community maps (Map Appendix 6-9), supporting the previous argument that distance is a proxy for lack of dry land. When seeing the extent of the flooding it becomes apparent that a larger titled land area is needed to include more terra firma for all communities. Elias *et al.* (2000) studied the Makushi farming system in North Rupununi, and identified that the shortage of farmland most likely led to a sharp reduction of fallow periods, which might have a consequence on the longevity of the soil’s fertility. It is therefore this study suggested that the amount of terra firma is taken into account when titled land extensions are processed, as this issue will become even more serious in the future with growing populations and increased intensity of climate change.

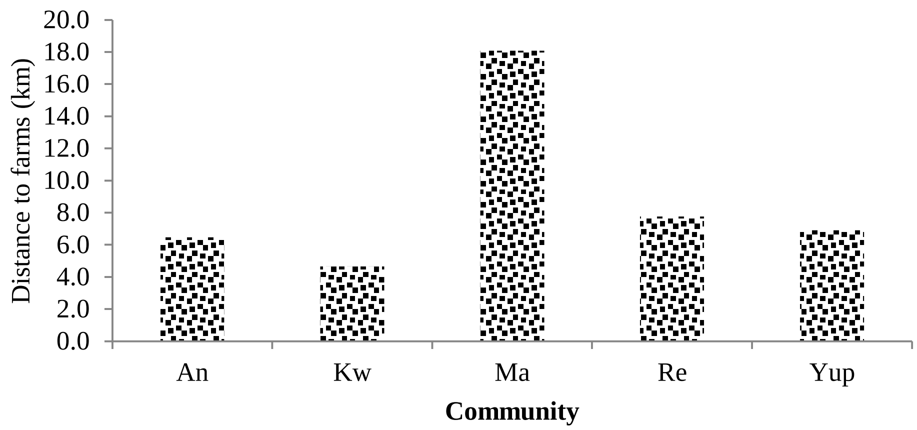


Figure 6.11: Mean distance to farming areas from each of the communities

6.5 Hunting sites – habitat, distance and customs

From the focus groups data, two main characteristics could be identified that indicate good hunting habitat: areas that are forested, and locations on a higher elevation. Forested hunting sites constituted 91 percent of the 22 areas identified by the Makushi. This can be explained by the higher number of species of game animals (such as paca, tapir, deer, and agouti) in the forest compared to the savanna (Read *et al.*, 2010). The result also corresponds well with Read *et al.*'s (2010) study of hunting patterns in the Rupununi, which found that 70 percent of kill sites were located in the forest. The second characteristic, the elevation of the hunting sites, can be linked to the seasonal pattern. At the beginning of the wet season (May-June), when the water level is rising, it creates islands of raised land on which animals become trapped; this creates a habitat that is easier for the Makushi to hunt in. All of the respondents hunted with bow and arrows, which they said was difficult. Many of the respondents expressed a desire to have a firearm to facilitate the hunting, and many referred back to when the Balata trade was still profitable and operational in the Rupununi (1960s), when many worked for these companies who supplied them with guns. Today though, hardly anyone can afford a weapon and thus the Makushi hunt in the traditional way, which makes these raised lands in the landscape key hunting sites.

The average distance from a community to a hunting site was 9.9km measured in a straight line (Fig. 6.12). This is a similar result to Read *et al.* (2010) who found that average distance from community centre to kill site was 9km. The distance to hunting sites varied between the communities. Rewa had the shortest average distance to a hunting site, whereas Yupukari had the longest followed very closely by Annai and Massara. This difference can be linked to their location, relative to forested areas; Rewa is a forest community, whereas the other four communities are located on the savanna. However, Kwatamang's average distance is not as high, but this can be explained by its location very near the forest edge. This hunting pattern was also found by Read *et al.* (2010), who showed that forest communities travel on average less (5.5km) than forest edge (9.5km) and savanna (12.5km) communities.

Most respondents (98 percent) did not see themselves as hunters, as the majority would only hunt a few times per year. When they hunted it was mainly during May and the wet season to complement the reduced fish catches with animal protein. These hunting trips would use the newly created islands to facilitate the activity. A number of these types of hunting occasions were observed in Rewa (11-12th May 2011), as several boats were seen anchored to these islands. Other types of hunting reported can be described as opportunistic – an unplanned hunting occasion when they just happen to see an animal. This type of hunting was often reported to occur in and around their farming areas as the farms attract animals (Map Appendix 1-5). Hunting at the farm also has the added bonus of eliminating some pest animals such as 'hogs' (peccaries), which were reported to be one of the worst pests after the achoushi ant (*Atta cephalotes*).

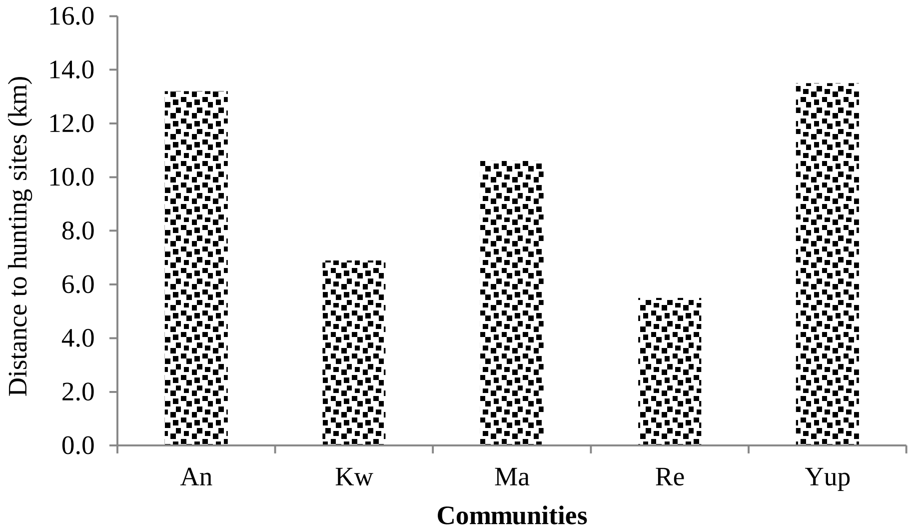


Figure 6.12: Distance to hunting sites from the different communities

6.6 Conclusions

This chapter has for the first time been able to identity and map out the fishing pattern of the Makushi; it has also for the first time described and mapped out the Rupununi Portal between the Essequibo and Amazon watersheds. Furthermore, key connectivity sites have been identified in the North Rupununi landscape and both farming and hunting grounds have been mapped out and discussed.

The first part of this chapter revealed that it was not only their TEK of biophysical factors that influence where the Makushi choose to fish, but also cultural aspects such as informal rules and reciprocity. Two different types of fishing, subsistence and commercial, were also discovered. Similar fishing patterns have been observed before among artisanal fishers in Brazil (Begossi, 2001). This behaviour indicates a benefit-sharing attitude and value system among the communities, which results in fishing for commercial purposes happening further away from a community to allow the fish supply for the community's subsistence to be sustained.

The second part discussed the importance of connectivity for the health of the Rupununi, both wildlife and humans. Key spawning areas and connectivity sites, such as Bononi Creek, were described and mapped. Furthermore, the Rupununi portal was also confirmed and monitored, showing its connection degree and subsequent fish spawning sites. That Bononi Creek connected to the Rupununi River and had fish spawning migration two weeks earlier than the other creeks monitored strongly indicate its high value for the health of the North Rupununi.

The last section described and discussed the spatial distribution of the farming grounds and the hunting locations. A clear shortage of terra firma for some communities was confirmed; it was also shown that hunting in many aspects follows similar patterns to the terra firma, as the wildlife depend on the dry land as much as the humans. Hunting grounds were established to be on higher altitudes and often near farms.

The next chapter (7) will follow on from this and focus on the implication of all the research findings from chapters 4, 5 and 6, in regards to management. Several potential management approaches for the North Rupununi will be outlined and discussed.

Chapter 7

Implications of the research findings to the management of the North Rupununi

The findings of this thesis indicate that even a biodiverse and rich ecosystem like the North Rupununi struggles to provide provisioning ES (such as fish) over subsistence levels, as the results indicate a decline in about a third of the fish species. The research findings also show evidence that traditional resource management strategies, such as taboo species and areas, seemed to have lost their influence on the majority of the communities. The traditional beliefs are still important for many people but they do not appear to affect the management of fish any longer. Therefore, something needs to change to guarantee the continued supply of vital ES that are produced in North Rupununi. Similar results are found worldwide, as most river fisheries are not used or managed sustainably (Welcomme and Petr, 2004).

In Guyana however the government with support from FAO is developing a National Policy on Inland Fisheries and Aquaculture (the final draft is being processed since Sep. 2012). The Policy has adopted an co-management approach, meaning the power is shared between the Government and the local stakeholders (Carlsson and Berkes, 2005). The majority of the management is done by the local stakeholders, but with the support of governmental bodies (Berkes, 2009). Guyana's Department of Fisheries, within the Ministry of Agriculture, is responsible for policy production. It released the following statement: *"Inland fish stocks are threatened by over fishing and other activities including logging, mining and road construction. These activities, if not properly regulated can result in serious effects on aquatic life and the rights of Amerindian populations in the interior of Guyana. Expanding harvesting of inland fish by non-Amerindians may adversely affect their food supplies and traditional lifestyle"* (Kaiteur News, 2010). This statement indicates and acknowledges many of the issues discussed in this study, and gives hope that the right type of management approach might be possible for Guyana in general and Rupununi in particular.

However, Guyana's current development plan, the Low Carbon Development Strategy, has identified the Rupununi as an area where more intensive agriculture and aquaculture might be developed (LCDS, 2009). The Rupununi is also an area where the government has allowed test drilling for oil; two sites have been explored so far, but more might be imminent as discussed previously in chapter 3. Furthermore, an expansion of the road running from Georgetown to Brazil, through the Rupununi, is another development project that is already in progress. These potential new development projects will most likely bring some positive effects for the communities, but also have detrimental effects on the status of many of the ES, and may pose threats to the Makushi way of life (Field notes from conversations). Thus, the decision on what type of development and management pathway is pivotal for the area.

The research findings have highlighted the importance of a sustained and healthy ES provision for the local communities but also for stakeholders at the national and international level. It is therefore crucial to ensure that any development in the North Rupununi is both socially and environmentally sound. Different approaches available for protection and management will be discussed in this chapter, where key requirements are identified and an assessment of the suitablility for each approach will be done using findings from this study. Lastly, a management approach will be proposed to conclude this chapter.

7.1 Potential management approaches for the North Rupununi

There are several management options available for a place like the North Rupununi; which is the most appropriate depends on a range of factors. This section will thus go through different management alternatives available and evaluate their appropriateness for the North Rupununi, based on this thesis's research findings.

7.1.1 Community-based management

The strengths and weaknesses of a CBM approach for conservation were discussed in chapter 2, where it was shown that a CBM's main benefit is its bottom up approach, where the communities get to be more in power over the management process, both the decisions and the needed management work.

Requirements needed for CBM to succeed include: (i) willingness of the community to participate and a positive attitude to conservation and management; (ii) inclusion of TEK and sufficient community capacity; (iii) an understanding and consideration of the scale related complexities and linkages that exist in the system; (iv) strong and stable institutions; (v) ability to limit access of outsiders and stable boundaries; lastly (vi) data to estimate sustainable harvesting quotas and to assess baseline of ES (Agrawal and Gibson, 1999; Berkes, 2004, 2007; Brookes *et al*., 2006; Garnett *et al*., 2007; Ostrom, 1990).

As outlined above, the first key requirement for a CBM to be successful is that the communities have an interest in conservation and want to take part in the management of the ecosystems.

Without their interest it is impossible to apply this approach. Fortunately, this research has demonstrated that all the communities in this study show an interest in conservation, and a proven understanding of the importance of it both for them and for coming generations. Still, some variations in the level of sacrifice for conservation could be detected between the communities, which could be important to consider in future initiatives. These differences might be linked to a higher population density in combination with a less rich supply of ES (for example around Annai and Kwatamang), or they might be linked to more tangible benefits of having an established eco-lodge in the community which generates monetary benefits already (e.g. Rewa and Yupukari). The other important area related to communities' attitudes is that of management. Attitudes to natural resource management was also investigated in this study and it was found that most (91 percent) of the local respondents are in favour of management as the quotes below demonstrate;

> *"Management of fishes is a good thing. Before we didn't think anything about it, instead we tried to kill them all [fish]. But then we used only arrows and hooks so caught less, now some people use nets, and these catch all fish from big to small".*

> *"Fish should be managed for everyday life, as if don't have fishes, you can't go fishing in the shop".*

> "*We want to manage our resources so that young people have resources too, to use for their house and food in the future*".

However, the respondents were clear about that they want to do the management themselves but potentially with the assistance from outside as 60 percent saw this as a necessity to improve capacity and to raise fund for the monitoring work, which the quote below demonstrate;

> "*Best management would be that the communities come together and make a body that check that the resources are being used in a sustainable way. This would mean that people would be more aware of the resources and problems with them. But has to use people that have a reputation to be responsible*".

Management of the area also seems to be supported from a national level as well, as the Inland Fisheries Policy is being developed in which local communities are highlighted as being key stakeholders of the management activities on the ground. In addition, management by local communities is also supported on a regional level by UNDP in their work on the Guiana Shield Facility which states; "The operating premise is that by preserving ecosystem functions make a significant contribution towards poverty alleviation and resource management by local communities, as well as help fulfil national obligations under the Multilateral Environment

Agreements" (UNDP, 2012, p. 5). Lastly, conservation organisations such as Iwokrama International have a long track record of working with the communities and supporting the management and the sustainable development of the area. These results indicate that stakeholders at local, national and even international scales are supportive of CBM, which allows for the conclusion, that the first requirement is set for a CBM approach to be successful in the North Rupununi.

The second key requirement is the inclusion of TEK, as this will allow the local people to feel more involved in the management process and it adds vital knowledge of the system from a local expert point of view. Extra effort to ensure that TEK is incorporated into any management plan is essential as they are both the local experts and main users; their knowledge is crucial for successful conservation (Berkes, 2006a). Another important aspect related to knowledge is the community's capacity to undertake the management, such as being able to set up mechanisms to enforce the management rules but also to have the capacity to do the monitoring. The research findings can certainly support the communities' capacity to undertake monitoring work, and their TEK has also been verified through the research findings, as discussed earlier.

The third requirement to consider is that of scale. First, regarding social scale, issues of the heterogeneity of a community and between communities at the local scale need to be considered, as people's interests may vary depending on a wide range of factors, such as gender, age, socio-economic group or ethnic group (Agrawal and Gibson, 1999). It is therefore essential to consider the diversity of opinion and wishes that might exist at the local scale (Berkes, 2006a). The research findings suggest that there are actually few disagreements among different local stakeholders on the value of ES. Similarly, the majority of the respondents wanted management to be decided and enforced on a local scale. However, the differences which were found in values between stakeholders at different scales also need to be considered in these approaches. This research has therefore been able to clarify some of the differences and similarities that exist within and between the communities and on larger spatial scales, which will be useful for future management initiatives and processes. It has been shown that a better cultural understanding by an outside agency, or individual, is important for the process of building trust, which is essential for long term success in the relationship between stakeholders at different scales (Garnett *et al*., 2007).

Another issue in regards to social scale is that of external drivers and how they influence communities. Major external drivers, which were identified in chapter 2, are the market and central government, which thus need to be taken into consideration. As the research findings indicate, the fish decline started when seine nets became available and when a market was created for outsiders; this allowed for more fish to be caught easier, and any extra could be sold.

Previously, there had been no incentives to fish more than could be consumed, but with access to a market, money could be made, which was reported to have incentivised more intensive fisheries.

Ecological scale also needs to be considered for this approach, because as discussed in chapter 2, it is very rare that the resource boundaries match the institutional boundaries, which might then lead to a scale mismatch problem (Barrett *et al*, 2001). Folke *et al*. (2007) propose that each CBM project must address the question: How does the scale (temporal, spatial, functional) of an institution relate to the ecosystem being managed, and does it affect the effectiveness and robustness of the institution?

In regards to the North Rupununi, the research findings have illustrated that the day to day fishing is mainly done on each of the communities' titled land; however, commercial fishing is quite frequently undertaken further away from the communities, which means the fishers use waters that belong to another community. As earlier discussed, this type of behaviour seemed to be accepted in the area as long as permission was sought first. Nevertheless some negative comments were noted, which might indicate that it is an issue the communities should bring up and clarify to avoid any future conflicts. Additionally, though the NRDDB exists and represents all 16 communities, the institution does not include the whole watershed, as the Rupununi River comes from the south and there are areas that are both private and state-owned along the river. In these areas the communities have very little power to influence what happens. For example, the two oil drilling sites are located on state land, which is in between community-owned land; a new logging licence has also been approved up the Rewa River. When reviewing the research findings in light of the CBM approach, taking these concerns of ecological and social scale into consideration highlights these areas as weaknesses and issues that clearly need to be addressed if a CBM approach is to be successful.

The fourth requirement for a successful CBM is the existence of strong and stable institutions, which is linked to what was discussed previously. It is known that the NRDDB is a stable institution which has had previous experiences of co-ordinating management, e.g. the Arapaima project, which means that this requirement is met for this approach.

The fifth requirement is that of stable land titlements and boundaries. As been discussed, all the communities in the North Rupununi have been approved titled land, which is positive, however as discussed earlier these areas do not always correspond to traditional use and would thus benefit from being extended. The extension of titled land is something the Government has promised but progress seems to be very slow (Donovan *et al*., 2012). Enforcing the communities land boundaries is another difficult issue. This requirement can thus only be assessed to be partially met and some strengthening of their land rights and enforcement or tougher regulation might be needed for the requirement to be fulfilled.

The sixth requirement, or at least preferred requirement, is the availability of appropriate data to estimate sustainable harvesting quotas and the existence of baseline data for ES. As described earlier (chapter 2) most countries have a lack of knowledge in relation to the biota of river systems, and tropical river systems suffer particularly (Welcomme and Petr, 2004). Findings from this study contribute here, as both current states and trends have been established for several ES in the North Rupununi. Welcomme and Petr (2004) also highlight that even though there is a gap in the understanding of systems, sufficient knowledge often exists to set at least interim conservation measures. Both Welcomme and Petr, (2004) and Berkes (2003) suggest that an adaptive management approach is used. This approach accommodates for the incomplete information which often exists about systems like the North Rupununi, as the adaptive management approach relies on iterative feedback learning in which policies develop and improve with time (Berkes, 2003; Gunderson, 1999; Lee, 1999).

It has been shown that large amounts of data and sophisticated models are not always needed in fisheries management (Johannes, 2000), particularly in small-scale fisheries, which dominate the inland fisheries both in Guyana and in many other similar places in the world. Here they can assess the condition and future trends of fish populations using lower input of data such as TEK and qualitative indicators (McConney and Mahon, 1998; Neis and Felt, 2000).

Johannes (1998) goes a step further in cases where there is very limited data: he suggests that precautionary management, or even data-less management, is needed to protect the ecosystems. Precautionary management’s main aim is not to control the production of living resources; instead it is to maintain their viability (Johannes, 1998). However, Johannes (1998) does not suggest not using any data at all – he supports the use of TEK and the use of information gathered in other similar locations.

When conducting research in ecosystems such as the North Rupununi, in which so much is unknown and in still largely pristine condition, it is therefore very productive to focus on gathering TEK data, which has been the aim of this study. Using TEK when data is insufficient is important, but even in systems that have more data available TEK can widen the range of information available to decision-makers and is in certain circumstances essential (Berkes and Folke, 1998).

Indicators are another type of data most likely required for the CBM approach. During this study considerable effort was made to try and identify indicators that could be used for management to assess the status of the wetland and in particular the fish populations. A good indicator, as described by Berardi *et al*. (2013, p. 29) "is that they should alert the monitors or system users before changes to the ecosystem become irreversible and preferably a good indicator should direct the management body to the area that needs attention". However, the concept of an indicator, or indicators, proved difficult to communicate with the local communities. Wilson *et al*. (2006) found similar difficulties with artisanal fishers in their study areas of Malawi, Zambia, Mozambique and the Mekong Delta, where the idea of an indicator was difficult to communicate with the fishers, and several expressed disbelief that any observations made in the present could give any meaningful information about future catches. This type of disbelief was not found in the Rupununi, but it did mean that not everyone understood what information was being sought. Despite this, some answers were given and most of them agreed (90 percent) that the water level of the Rupununi River was the most important indicator for predicting the health of the fish population. As discussed in chapter 5 and 6, the fish need high water to allow them to spawn and to feed on the savanna and in the forest. If the water did not go over the river banks or the flood did not last long enough, the fish would look meagre and may have worms inside, as two of these quotes indicate:

> "*Higher water level and longer time flooded make healthy fishes, lately been too dry*". (Older man, Annai)
>
> "*Sometime fish get diseases when water level is low, get maggots in stomachs*". (Older man, Kwatamang)

Wilson *et al*. (2006) also found similar results with the water level being the only indicator that was given. Although they were disappointed with this result, as on a small scale it would be difficult to monitor particular species of fish, from an ecosystem management perspective it could still be a useful indicator (Pitschkin *et al*., 2004). Because the water level in the Rupununi is influenced by ENSO and climate change as discussed in chapter 5, and from a long-term perspective, adaptation plans for climate change might be needed for the Rupununi, having a solid evidence base of the water level could be crucial. The limitation of this indicator for fish population is its short time scale, i.e. the impact of a low water level on the well-being of the fish and consequently the local communities is within a few months. Additionally, the recovery rate of the system is relatively short; Mol *et al.*'s (2000) study in Suriname indicated that most fish species had recovered one year after a severe drought event. The fish population's resilience to recover so quickly is positive, but from a human well-being point of view the consequences can still be severe in terms of food security. Moreover, how climate change will affect the precipitation levels in the region is still uncertain, as different studies suggest either a drying trend (Betts *et al*., 2008; Malhi *et al.*, 2008), or a wetting trend (Gloor *et al*., 2013). It is also uncertain if the fish population will be as quick to recover if the drought period is longer than a year (Mol *et al*., 2000). Therefore, data on the water level of the Rupununi River and on the flooding extent will be important for any development and management strategy to ensure resilience of the communities and the ecosystems.

7.1.2 Co-management

As discussed in the previous section, most local people in the North Rupununi want to manage their own resources. However, due to the state of the world today, with pressures of external drivers, cross-scalar issues and mismatch in resource and institution boundaries, communities might need assistance from outside. In the North Rupununi, at least 60 percent of the respondents wanted assistance from outside bodies, such as conservation and development NGOs and/or governmental bodies, for management needs. This result is in line with a UN report stating that indigenous people want to be supported, to be allowed to manage their own land (Lovera *et al*., 2013). Other evidence on local communities that had been left to manage their own land without support from top level legislation and regulation, has shown that outside resource users may threaten the balance of the system even though the local stakeholders use their resources sustainably (Cudney-Bueno and Basurto, 2009). For example, Cudney-Bueno and Basurto (2009) studied a CBM effort in the Gulf of California, Mexico, and found that locally crafted and enforced harvesting rules led to a rapid increase in fish abundance. Nevertheless, the news of the increase spread, and poaching by outsiders led to a rapid decline of the fish resource (Cudney-Bueno and Basurto, 2009). This example indicates that CBM can be effective but it might struggle if cross-scale linkages with higher levels of governance are not put in place. Thus, the co-management approach has been developed to allow the power to manage and use the natural resources to be shared between the State and local stakeholders (Carlsson and Berkes, 2005). Singleton (1998, p. 7) defines co-management as “the term given to governance systems that combine state control with local, decentralized decision making and accountability and which, ideally, combine the strengths and mitigate the weaknesses of each”.

For a co-management agreement to be successful, the requirements are rather similar to the CBM approach. The community needs to be interested in conservation and management, needs to have sufficient TEK about the resources in question, have the capacity to do the management job, and needs to have strong and stable institutions. Similar data need to be available as for the CBM approach, which means that the research findings that were outlined in the previous section can be used for this approach as well. However, the difference with this approach is that the cross-scale issues which were highlighted as not being sufficient in the CBM approach might be better addressed. There is normally also a difference in who initiates the management approach; with CBM, it can often be the community that initiates and steers the process bottom-up, whereas co-management is often initiated from the top but then strives to be both a top and bottom-up approach where the goal is to achieve shared power (Carsson and Berkes, 2005).

The main difference between these two approaches is the involvement of the State, and how they support the communities by creating the right regulation and legislation and potential funds available. Unfortunately, this thesis has not collected any direct data on whether the Guyanese Government is capable and how it would perform in a co-management situation. However, there is a previous example from the North Rupununi, when the Arapaima Management Project was set up and implemented (Fernandes, 2006). This project was initiated because the numbers of Arapaima had decreased steadily since the 1960s, when the trade of Arapaima to Brazil had started. Previous to this time there had been a strong taboo around catching Arapaima for the Makushi, as they were regarded as demons or the mother and father to all other fish (Fernandes, 2006). There was an influx of coast landers and Brazilian tradesmen and fishermen that started fishing Arapaima, and slowly the Makushi communities took it up as these were hard economic times, due to the civil unrest in the country (field notes 14 December 2010, one of the local guides told the story). The selling of Arapaima meat generated a considerable amount of money, particularly in comparison to other fish and jobs available in the region. The fishing of the Arapaima continued until the 1980s when the population had dwindled and they were close to extinction; by the 1990s management action was desperately needed to give this species a chance to recover.

Iwokrama together with NRDDB and the Government used the successful example of Arapaima management from Mamirauá Sustainable Development Reserve in Brazil as a template to develop a similar co-management programme for the North Rupununi (Castello *et al*., 2009; Fernandes, 2006). The programme trained and employed local people to do the monitoring and management, but also the educational side of the project. The programme particularly targeted the informal social mechanisms that had worked so well in the past to protect this species by attempting to make it taboo to fish Arapaima again, because the community as a whole would benefit more from the Arapaima returning than the individual fisher gaining money (Fernandes, 2006).

The programme was a success, and after only a year the number of Arapaimas started to rise, indicating that the local communities were respecting the management rules. However, the government had not delivered its part of the agreement at this point, which was to distribute sustainable harvesting quotas to the local communities; these were needed as it is illegal to harvest Arapaima in Guyana. The NGOs co-ordinating the agreement were never able to get anything in writing from the government and consequently the government delayed the allocation of harvesting quotes, which led to suspicion and disappointment among the local stakeholders (Fernandes, 2006). Eventually some harvesting was allowed, but the allocation was not seen as fair among many local people and it came a bit too late to instill the trust for the government that would have been desirable among the local communities (Field diary from discussions with local stakeholders).

The weakness of the government to act appropriately in this agreement needs to be considered and addressed in any future management initiative and actions taken to ensure compliance on their part. It also highlights the importance of having good governmental knowledge to understand how different governmental agencies work and what must be put in place to safeguard action on their part. Yet, despite the disappointing performance of the government, this project demonstrates how a management initiative that began as a top-down, externally driven project became a success due to the commitment and hard work of the local communities of the North Rupununi and the involved NGOs (Fernandes, 2006).

Similar results with regards to governmental bodies failing the co-management agreement to some extent have been found in South Africa, where again the local communities delivered their deal on management and conservation of the ecosystems, but the local and national governments were hesitant to give away any power or to share power with local people, which then delayed the benefits agreed in the co-management deal (Isaacs, 2012). Furthermore, similar results in co-management have been found in four case studies in Brazil (Seixas *et al*., 2004). In these cases, the government agencies in all four studies demonstrated little or no support for the local co-management institutions (Seixas *et al*., 2004). Reasons identified for this lack of recognition involved fragmentation of government agencies, which may also include power disputes between government agencies from different sectors. Moreover, the beliefs of individual staff members regarding CBM seem to have a higher importance than the government agenda (Barbosa and Hartmann, 1997). Subsequently, Seixas *et al*. (2004, p. 261) conclude that "conservative staff within government, who are used to top–down management, tend to hinder the participatory management process". I therefore suggest that these potential limiting tendencies of some Government agencies and staff need to be considered and addressed in the initial stages of a co-management agreement. I also agree with Fernandes (2006) that conservation organisations need to develop their capacities to deal with the governmental issues related to these types of agreements, as this process is difficult for local communities to influence and improve. Additionally, I would like to stress the need for government bodies to address this weakness and to ensure processes are put in place to improve the delivery of successful co-management agreements.

7.1.3 Payment for ecosystem services

As a management approach PES was developed to achieve more efficient natural resource management that fits the neoliberal polices of most developed countries, according to Engel *et al*. (2008). PES has quickly become the dominant management approach of the early twentyfirst century (Liverman, 2004). It has been regarded favourably by some as it translates external non-market values of the environment into real financial incentives for local actors to provide such services (Wunder *et al*., 2007).

However, the scope of application for PES is limited to only a narrow set of problems (Engel *et al*., 2008). Those suitable are where ecosystems are mismanaged because many of their benefits are externalities from the perspective of ecosystem managers, for example, carbon sequestration and watershed protection (Engel *et al*., 2008). This means that the main requirement for this approach to be feasible is that someone (normally a nation, company or NGO) is willing and has the resources to pay for the protection of particular ES. In Guyana, the REDD+ scheme is already being implemented, as Norway has paid Guyana's Government US$115 million so far, and has promised to pay a total of US$250 million until 2015. However, as of yet the Amerindians in the country have not had the opportunity to opt-in to REDD+. Furthermore, in the Verification of Progress report from the Rainforest Alliance (Donovan *et al*., 2012), the 'Verification Indicator 3: Protection of the rights of indigenous peoples', was judged as not met. This was partially due to the communities still not having had the opportunity to opt-in to the REDD+ agreement, but also because the Guyanese Government had failed to document and address land titling concerns for many Amerindian communities and that many Amerindians felt that their voices were not heard, particularly with respect to their views in the LCDS process (Donovan *et al.*, 2012). In addition to this, the review report highlights the painfully slow distribution of the funding mechanism, and the reduced efforts by the Government of Guyana to communicate and consult with stakeholders. This result corresponds well to what was found in this study, where half of the respondents had heard about the LCDS, but only 12 percent said that they understood it and had recieved some additional information.

Considering the lack of information to the communities together with the research findings of the difficulties most respondents had understanding the ES concept, a troublesome picture can arise; this is an issue the communities need time and assistance to understand. Moreover, signing the opt-in to REDD+ is an important decision for these communities, so much more needs to be done within this area to safeguard the Amerindians interests. As previously argued, maybe not everyone in a community needs to understand the concept, but it is essential that the leaders and other local decision-makers understand it fully and the implications that come with this approach. Other indigenous groups have been found to be very uncomfortable with PES and do not want to have anything to do with it (Lang, 2012), whereas other communities have managed to benefit (Espinoza Llanos and Feather, 2011). However, there are many pitfalls and many examples where communities have been tricked by private investors to sign contracts they did not understand (Lovera *et al.*, 2012; Espinoza Llanos and Feather, 2011).

Other reasons why many indigenous people do not agree with PES is that for them the forests are central to their traditions, culture and spiritual beliefs, and thus commodifying nature goes very much against their belief and worldview (Lovera *et al*., 2013). Many indigenous people see themselves as part of the natural world and not outside it, a worldview different to people who live a more disconnected lifestyle unaware and not directly dependent on nature for their survival. Another reason is that PES is based on a rather simplistic assumption that forests can only be conserved if the ES they supply are paid for, but there is hardly any evidence to support this assumption (Lovera *et al*., 2013). The third reason is PES schemes only seem to be successful when combined with regulations and bans that might have been successful on their own, and for a much cheaper price than the PES scheme (Lovera *et al*., 2013).

Other potentials pitfalls or risks with PES schemes concern how the money gained should be used and how it can be fairly distributed, both on a national and local scale. During the fieldwork, I witnessed the process of how one community dealt with the allocation of funds. The money had been given to the community for a particular project they had written they wanted to undertake. However, at this meeting it was decided that they could not undertake this project and instead it was better to divide the money up between the fishers so they could invest in fuel, or nets to get more fish. This one example cannot be used to generalise what would happen if the communities were given money, but it highlights the potential risk of giving money to communities inexperienced in managing projects and budgets. To minimise the risk and to ensure the best outcome, the right support mechanisms need to be set in place to ensure equitable benefit-sharing and capacity-building of the communities. In discussion about the LCDS, all people spoken to in the North Rupununi thought they would have the capacity to manage a REDD+ agreement, but they also stressed the importance of improving their financial and project management skills (Field notes).

In addition to the potential risk discussed above, other concerns have been expressed. One of the main concerns of this type of management approach has been that the services only persist as long as there is a market for them (Engel *et al.*, 2008). Any problem securing funding means that those resources are up for bid from other users and they could potentially be lost (Garnett *et al.*, 2007). Other criticisms of these programmes highlight the unequal power structure in negotiating prices of a service and participation on the market. PES programmes also lead to general ethical problems of assigning property rights and prices to environments of cultural and religious value or communal ownership (Liverman, 2004). It is also unclear to what degree poor households benefit from PES programs. The available evidence on participation of the poor in PES programs is mixed. From the PES programme in Costa Rica it was found that most of the PES participants are well off, but for some (44 percent) participants on the Osa Peninsula the

PES contribution constituted about 30 percent of the households' income (Miranda *et al*., 2003; Tattenbach *et al*., 2006).

Another example from Peru is a project called the Cool Earth/Ecotribal, which has been relatively successful and managed to avoid deforestation and secure a payment (US$30,000 for one of the communities and the other two must share the same amount) to three Ashaninka communities who own their land (Espinoza Llanos and Feather, 2011). Nevertheless, subsequent problems have occurred due to internal conflicts regarding the distribution of the funds, which has been deemed inequitable (Espinoza-Llanos and Feather, 2011). Furthermore, other case studies from Peru have not been this successful, and in most cases the local communities have been victims of fraud or manipulation by private financial companies who trick the communities to sign over their rights of carbon payments, or give them a very low price for the carbon dioxide stored (Espinoza-Llanos and Feather, 2011). However, more empirical data is needed before a conclusion can be made on how efficient PES schemes are at addressing both conservation and poverty alleviation (Engel *et al*., 2008). Still, there seems to be evidence indicating that private funded PES needs to be better regulated to ensure protection of the local communities.

Another potential danger with PES is that in the Global South, there are numerous un-broken traditions with long histories in religious beliefs that effectively conserve biodiversity without financial compensation. If starting to offer financial compensation in such locations it could lead to the breaking down of traditions, and both the local people and the environment can suffer losses. It is better in these locations to support those who advocate the maintenance of local traditions as that might be a more sustainable way of maintaining both cultural and natural values (Garnett *et al*., 2007).

There are other aspects that need to be taken into account when assessing PES programmes to understand where theoretically they come from and what they represent. Present day globalisation and the dominance of neoliberal thinking have fundamentally altered political, economic and social dynamics and processes. This has in turn influenced the processes and dynamics regarding protected area management and biodiversity conservation. It has also meant that more and more of society have become subject to the market logic or ‘commercialisation’, and PES is an example how this has been done in conservation. Büscher and Whande (2007) have termed the practice of commodification of conservation ‘neoliberal conservation’, where PES programs and carbon credits are two of the well-known examples. They argue that an acceptance of the influence of political economic issues on biodiversity conservation might lead to a better understanding of these wider dynamics, a better manoeuvrability of management and more successful conservation (Büscher and Whande, 2007). Despite their optimism, issues regarding the ethics of commodifying nature and the risks of relying on the markets for conservation of biodiversity need to be further considered and evaluated (Garnett *et al*., 2007).

7.1.4 The Ramsar Convention

The Convention on Wetlands of International Importance especially as Waterfowl Habitat is most often referred to as the 'Ramsar Convention' (Defra, 2006). It is an intergovernmental treaty which "provides the framework for the conservation and wise use of wetlands and their resources by national action and international co-operation as a contribution to achieving sustainable development throughout the world" (Defra, 2006, p. 2).

The main requirement for the the Ramsar Convention to be signed is that the government is willing to conserve and protect wetlands in the country. Thus it is a top down approach which will only survive if the value to the nation and to local communities can be seen (Beltran *et al.,* 2000). As discussed in earlier sections the success depends on how well the local communities rights and interests are taken into consideration and how well the participation process is set up with institutions and build on, or at least integrated, with TEK (Beltran *et al.,* 2000).

To assign a wetland Ramsar status is different from a protected area status as the Convention supports and encourages the 'wise use' of the wetlands. Wise use of wetlands has been defined as " their sustainable utilization for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem" and "Sustainable utilization" of a wetland is defined as "human use of a wetland so that it may yield the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations" (Davis, 1993, p. 4).

Considering introducing a Ramsar protected area for the North Rupununi would only concern the state-owned land of the area and not the Amerindian titled land. As outlined above, 'wise use' of resources is allowed under this protection, thus it should not encroach on the rights of the local communities to use these lands, which is essential to establish. However, the communities of the area need to be consulted on this issue first before any decision is taken; the author is thus in no position to argue for or against, as no data was gathered on this issue. Yet, as the research findings show, the communities' interests in conservation and their success in setting up local eco-tourism enterprises would most likely benefit from a Ramsar area designation. In addition to these positive points, making the state land of Rupununi a protected area would potentially safeguard the North Rupununi from unsustainable development in the future, which has been a concern for many as identified in the research. Most of the respondents quoted that they did not know if oil drilling was a positive or negative thing, but all showed concern for the health of the area and could see their vulnerability increased if the water and fish were contaminated.

From a Government point of view assigning the North Rupununi to a Ramsar protected area would aid to some extent in reaching the Convention of Biological Diversity (CBD) target for 2020. At present Guyana only has eight percent protected area nationwide, yet the government has signed the CBD targets which binds it to protect 17 percent of its land before 2020 (Donovan *et al*., 2012). In addition to this, a potential increase of tourism to the North Rupununi would most likely bring benefits nationwide and not just to the North Rupununi.

7.1.5 Indigenous protected area

Indigenous representative bodies, such as Global Forest Coalition and ICCA Consortium and Econexus, suggest the support and implementation of more Indigenous people and local communities' territories (ICCA), or just indigenous protected areas (IPA), as they have been proven to provide lower deforestation rates than established protected areas (Nepstad *et al*., 2006; Porter-Bolland *et al.*, 2012). This claim is supported by Nolte *et al*. (2011) who compared different categories of protected land in Brazil, which provided further evidence that indigenous lands are particularly effective at avoiding deforestation in comparison to other types of protected area. This evidence highlights the potential of ICCA and IPA as an alternative conservation approach to both the ES concept's market-based mechanisms and protected area approach (Lovera *et al*., 2013). However, information and research on how to best support ICCAs is remarkably scarce (Lovera *et al*., 2013). The ICCA consortium thus performed an analysis themselves of the best ways to support ICCA in 2010, and this concluded that legal and political recognition of ICCAs is the most effective way to support them. They also highlighted that indigenous and local people need to enhance their capacity to assess the resilience of their conservation and management approaches themselves (Lovera *et al*., 2013). Another important issue that needs to be considered in regards to ICCAs and which separates it from a CBM approach is the degree of 'traditionality', of a community, which will have implications on how much of their traditional way of life and management rules are still viable and used in the community. Potentially, communities that appear to have lost their traditional management behaviour might find it hard to manage the area sustainably without input from outsiders.

Considering the appropriateness of the North Rupununi to become an IPA in light of the requirements listed above and the research findings raises three issues. The first is, how does the track record of Guyana's Government look when it comes to the legal recognition of traditional land? Thanks to the Amerindian act, the indigenous people of Guyana have been quite fortunate in comparison to other countries, as they are allowed to have titled land. However, as reported in the thesis, the extension of the communities' titled lands has been a very slow process and most communities' titled land does not represent the land they have traditionally used. The poor performance of the government to assign titled land to the communities was also discussed earlier in relation to the nationwide REDD+ scheme, as the failed indicator of Amerindian human rights indicator was not met (Donovan *et al.,* 2012). A report from The Amerindian People Association (Colchester and La Rose, 2010, p. 35) calls for "urgent measures to establish effective, fair and transparent mechanisms to clarify Amerindian land and territorial rights in Guyana, including measures for a land rights settlement procedure that must involve indigenous representatives and experts freely chosen by our communities. Delineation, demarcation and titling must be based on customary occupation, land use and traditional tenure in full conformity with relevant international norms."

Considering this poor track record of the Government with the established need for both more titled land and terra firma, particularly as populations continue to grow, the need is high for good legislation to be implemented; however, the past actions of the Government do not instil much hope that it will happen any time soon. Still, it is part of the LCDS agreement and REDD+ that the Amerindian communities have the right to extend their titled land to traditionally used lands, so hopefully with the push from the international community and the Norwegian government, the Guyanese Government will improve the process and ensure the land belonging to Amerindians becomes rightfully theirs.

The second requirement is that communities are able to assess their own resilience. According to the research findings, this can be deemed quite hopeful; as the monitoring capacity of the communities is high they should be able to run similar monitoring programmes themselves – the issue might be the analyses of the results. However, given the close partnership the communities and institutions like NRDDB have with Iwokrama and CI organisation, it may be assumed that these assessments could be shared by them.

The third requirement is the degree of viable traditional management rules of the communities, which unfortunately is one that the North Rupununi might have lost quite a lot of during the many years of colonisation and missionaries. As the research has shown that taboo area and species seem to have lost their influence in most communities. Furthermore, only anecdotal evidence could be found for a few communities having their own management rules. This might, thus, indicate that the communities would struggle if they did not receive any assistance from outside which might indicate that this approach is not the most appropriate for the North Rupununi.

7.2 Suggested management approach

Considering the numerous management options that have been outlined and discussed in this chapter, it becomes clear that most of them are based on similar core requirements and that the most appropriate management option for the North Rupununi will most likely be a combination of some of these approaches. Therefore ideally, the author would suggest a co-management approach be agreed for both the fish and the wetland as a whole. However, I would like to stress the importance of designing the agreement with a heavy emphasis on CBM. This chapter has shown that the communities in the North Rupununi are capable and willing to manage their resources with some capacity and resource support from outside. Even though the strengths and most of the requirements were met for a CBM approach, some weaknesses were also identified such as boundary enforcement and land titling. This thesis has also strived to demonstrate the importance of considering the scale complexities in managing ecosystem services and thus, even though the Government has a rather weak track record in managing performance, excluding them from management would not be sustainable in the long term. In addition to these approaches, the author proposes that the government consider signing the Ramsar Convention but with the caveat that local communities which might be affected need to be consulted prior to any agreement. This would hopefully ensure that only environmentally sound development would be considered and that the North Rupununi can continue to provide healthy ES to the local communities and beyond. This approach would most likely be beneficial for the local people, but also for the national and international stakeholders concerned with conserving the unique biodiversity of this area without diminishing the potential of harnessing its riches for the future.

Chapter 8

Conclusions

This thesis has revealed findings and discussed their implications on a wide range of scientific areas. The ES concept has been used as a framework, which together with issues of scale tied this wide-ranging interdisciplinary thesis together. The aim of the study was to contribute to unravelling some of the scale complexities connected to freshwater ES and assessments in a social-ecological context. The thesis was also concerned with the potential application of the research findings in the conservation, management and development of an area like the North Rupununi. As discussed widely in the literature (chapter 2), conflicts or trade-offs often occur when 'development' projects want to increase the production of one ES at the cost of another. To abate this problem more information on how ES operate over spatial and temporal scales has been identified as a potential solution (Raudsepp-Hearn *et al.*, 2010). Understanding the source and the supply area of an ES and linking that to the institutional scale has been shown to be essential to achieve successful projects that address both conservation and development.

8.1 Contributions to perspectives and values of ecosystem services

The research findings from this thesis addressed the need for valuation of ES using a non-monetary approach, which was identified by both Folke (2006b) and Janssen and Anderies (2007) to be in great need of research. The thesis has also been able to support the few non-monetary valuation studies done in developing countries, and contributed to bringing new insights to how indigenous people like the Makushi value and perceive ES (Christie *et al.*, 2012). A number of factors such as scale, cultural values, basic needs, education and income were identified as explanatory factors for how people value and perceive ES. These findings support similar studies where valuation differs between scales (Hein *et al.*, 2006). However, a more homogenous valuation among the local stakeholders was found in this study. Only small differences were found between different income groups and none was found between genders; this was shown to be different in other studies (Harrter, 2010). The findings could both bring new insights to the standard valuation procedures and be used to resolve conflicts involving the implementation of policy and management programmes.

The thesis could confirm that the spatial scale of where and to whom the benefits were received influences how the stakeholders valued at least some of the ES – particularly the ES identified as most important. The difference found between the local stakeholders' conservation attitude and the attitude of stakeholders from conservation NGOs on a national scale was the motivation for why an ES was important. The local stakeholders tended to emphasise the utility value of an ES; it could also be seen that they valued predominantly provisioning ES. In contrast, representatives from the NGO highlighted the intrinsic values of ES more; they also showed this in how they ranked the ES, with a higher importance given to supporting and cultural ES. Similar results were found by Henfrey (2002) in regards to Wapishana communities in the South Rupununi. However, as discussed in chapter 4, this interpretation may be due to how the ES concept is structured and not down to how the Makushi see themselves and the natural world. Considering their positive attitudes to conservation, they highlighted both intrinsic and instrumental values. First they highlighted the need to make sure there are trees and fish left for their children and grandchildren to use in the future, indicating a more intrinsic view, whereas others highlighted the benefits a wild animal could continue to give if they brought tourists to see the animal instead of hunting it for food, implying a more instrumental value.

These findings will provide useful information for future conservation and development projects, as for example, in a conservation project both the utility side and the intrinsic side of conservation might need to be highlighted. However, it was also shown how important social mechanisms can be when it comes to implementing management rules (Fernandes, 2006), indicating the benefit social structures can have and the importance of trying to build on existing social values. Similarly for a development project, the local stakeholders' valuation indicates that their way of life is what they value highly. Potential conclusions that can be drawn from this result is that they value some development, but not at the cost of losing their culture and way of life. Thus, development projects that recognise this difference in values will have a higher likelihood of getting the approval of the local stakeholders.

When conducting research in a developing country with indigenous people the application of the ES concept should be treated with caution. As discussed in chapter 4, using the ES terminology proved rather difficult; conveying the concept of ES to the local communities was also challenging. Nevertheless, I think the non-monetary qualitative technique used in this study allowed the participants a better opportunity to explain and discuss how they value an ES, which might be difficult when using a monetary value. Monetary valuation of ES has proven to be rather challenging, particularly in developing countries, for a number of reasons (Christine *et al*., 2012). First, the use of hypothetical scenarios can be difficult to understand when the majority of the population has not had a high level of formal education. Secondly, the lack of exposure to a market economy will affect how people value ES. Thirdly, the valuation of many

ES will most likely need recalculation, as the actual market value for food products is not likely to be representative of the value they bring to subsistence rural indigenous communities.

Questions that need to be asked to improve the valuation process are: Which stakeholder group's value should count? If a more equitable valuation process is developed, which respects the difference in perspective depending on scale, what percentage divide would be a fair division? 50:50, or another? How often should the valuation process be done? Will the value remain 'true' for 2 years, 5 years or 10-20 years? Or is an inflation calculation rise sufficient to mirror the change in value? These systems and ES are dynamic – will the price reflect this? Does it have to?

These questions are for the most part relevant to both monetary and non-monetary valuation approaches. An issue that has emerged around the monetary valuation process is the lack of accuracy of the subjective value given in many instances (Garcí-Llorente *et al*., 2011), even though much information has been given prior to a monetary valuation exercise. For example, a species that is not considered cute or beautiful by the majority, e.g. bats, will be given a lower monetary value in comparison to a more publicly favoured animal like the Giant pandas. A valuation bias to 'cuteness' that does not accurately depict the functionality, importance or rarity of an animal or habitat could skew the result considerably, with potentially negative consequences. The question that arises is: what is more ethically correct? Allow the general public to value species and habitats of ES, even though they do not have the knowledge to understand the complex functionality and processes that take place in ecosystems to produce the ES? Or should trained experts in the area value these? What would be more democratic and what would be the most ethical approach – the approach that would produce the most accurate value, which hopefully would result in the greatest number or area conserved? This highlights one of the dangers or limitations of the monetary valuation approach and calls for the inclusion of other types of values to give a true picture of the ecosystem in question, as shown in these research findings.

The research findings have shown that using a non-monetary approach, such as ranking and scoring with discussions of how and why an ES is important for a person, bring more clarity and understanding of why an ES is important for a decision-maker on a national or regional level than the simple figure of a price. A monetary value might also be useful in decision-making processes as it allows for comparison with a currency that is familiar to the decision-maker. However, as this study has shown, a non-monetary valuation assessment can paint a better picture of the situation and describe all the values, even cultural ES such as groundedness and cultural values. The qualitative data will be able to better describe the situation for decision-makers far away, as this type of data provide the stories, faces and voices of the people concerned (Brennan and Valcic, 2012). By bringing a better understanding to the decision-makers, this will hopefully lead to a more pro-environment and ethical decision, as this type of data triggers emotions. The research findings indicate and support the calls of other scholars that an alternative valuation process is needed, at least for developing countries, as their livelihoods so often depend upon the land. The alternative approach could still include a monetary value but it would also include other valuation metrics, such as the one from this study, to ensure that all values are represented, that the process is more equitable and that the true picture is depicted and communicated to the decision-makers.

8.2 Contributions to understanding how temporal and spatial scale affects the freshwater ES of the North Rupununi

From a wider perspective this research has been able to identify the rich flows of ES the North Rupununi supply to stakeholders at local, national and international scales. How ES vary in quality and quantity over time is particularly important from a human well-being and poverty-alleviation point of view; this has been shown to be the case in North Rupununi, where the communities rely on the clean flow of the waterways and the fish they provide.

A better understanding of how the condition and supply of ES are affected by temporal scale was identified as an area that needed further research in chapter 1 (Syrbe and Walz, 2012; Fisher *et al*., 2009). The thesis has been able to contribute towards this gap with a range of results, such as how the dry and wet season affect the quantity and quality of the ES (water, fish and biodiversity). The reduced quantity of fish in the wet season was confirmed, as well as how the fish diversity as an ES remained similar in both seasons but with slightly different species composition. The temporal changes throughout the year, depending on the water level of the water bodies, were also described. This highlights the importance of the main fishing areas, but also how the diversity of fishing sites – the creeks, ponds and river in different sizes – are important for the continued supply of fish to the local communities and for sustaining the biodiversity. More long-term temporal scales were also analysed, where the Black Caiman abundance and water quality were found to be similar for the most part, but the fish abundance was found to have declined. However, these research findings exploring the long term temporal scale must be interpreted with some caution as only two data points were available. This is because the seasonal variability between years is so high and thus it is impossible to say with certainty that this variability is not just linked to annual fluctuation. Although, these findings combine both quantitative and qualitative data, which provides more certainty and as the majority of the participants described a decline during this time period it supports the research quantitative findings.

Current declining trends of fish abundance will most likely continue the downward trend if no action is taken by the local communities. The evaluated options for management from chapter 7 indicate that there are several approaches that would be appropriate for the North Rupununi if the right support is given on all scales in its complex social-ecological system.

The need for further research into spatial patterns of ES was identified by Burkhard *et al.* (2012) and Riitters (2000), as discussed in chapter 1. The thesis undertook an assessment of spatial patterns by mapping key ES supply and connectivity areas identified by the local communities which together indicate where important ES source areas are in a multi-scalar environment. This type of data and information, which the thesis has produced, should be consulted in any future development project for the area to ensure that its location will not negatively affect the vital freshwater ES studied in the thesis. To apply the type of on- the –ground mapping technique based on TEK to map out ES areas has to be seen as an important addition to capture more fine-scale information that the larger mapping tool such as Invest and Aries struggles to identify. However, the on-the-ground mapping technique may be both time and resource costly if performed by outsiders but if local people are used this might become a very productive technique to capture the important spatial information needed by decision-makers.

To the author's knowledge there is no other study which has worked both with the ES concept and performed on-the-ground mapping of key freshwater and fish ES. Furthermore, as highlighted in chapter 1 by Seppelt *et al.* (2011), many of these mapping assessments have had problems with freshwater habitats; as the scale is so large, their importance is not mirrored in many of the findings. Moreover, using remote sensing in a place like Guyana is very difficult due to the cloud cover, which means that fine-scale mapping on the ground is necessary and provides new data that would not be possible using any other methods.

By applying fine scale mapping, the research uncovered numerous unknown spatial patterns relating to the freshwater ES investigated. For the first time seasonal differences in the ES flow were mapped for the area. These maps reveal several spatial patterns. The first relates to the heterogeneity of the supply of ES in the landscape. When considering the supply of fish, this thesis has been able to identify particular areas that could be called hotspots; for example, Simonie Lakes and Bat Creek, because of their abundance of fish and because more than one community utilises them. These areas also supply many different ES and there is a potential risk of conflicts between resource users. The factor that seems to explain the greatest amount of difference between the waterbodies and fish abundance was turbidity, which links well with the examples of hotspots above, as both of these waters have much higher transparency compared to other waterbodies. Thus, blackwater with high transparency in the Rupununi was identified to be a good indicator for an ample supply of fish, or a potential source area of fish; this contradicts much of the literature on blackwaters, as they are known for their low nutrient levels and pH, resulting in low productivity albeit high fish diversity. I believe the explanation for this result can be found in the water quality findings, which indicated that although the Simonie Lakes/Creek are known for their blackwaters, they do not have as low pH or conductivity, which is expected from other blackwater rivers in South America as discussed in chapter 5. The potential consequences of these water conditions might be that the 'blackwaters' of Simonie allow more light through the water column, and as it contains some nutrition, these conditions allow for more primary production, which provides food and shelter for the herbivorous fish. In turn, a good supply of herbivorous fish attracts the predatory fish, which are in general the fish species the Makushi prefer. These results might explain why the fish, the Black Caiman and the Makushi all unexpectedly prefer these 'blackwater' habitats.

This thesis has for the first time produced seasonal distribution maps of ES over the North Rupununi, which is a research area that has not been much explored, to my knowledge. These maps visualise the seasonal changes in the spatial pattern of fishing and thus illustrate a more accurate distribution of the supply area for this important ES, as their complete spatial pattern is captured. This type of finding allows for better understanding of the ecosystem, which in turn may lead to better management of the area, and hopefully prevent any future development to be located on any of the identified key sites.

Continuing on the theme of connectivity, this thesis has been able to establish for the first time the link between the Amazon and Essequibo Watersheds. The link is Bononi Creek, which thus constitutes a critical connectivity habitat. The Bononi Creek is one of many key connectivity sites that has been identified through this research in the North Rupununi, and as discussed represents an area that connects different scales of the landscape; these are of particular importance for the status of ES and if lost would affect the supply of multiple ES (Amoros and Bornette, 2002). These types of links in the landscape allow the flow of ES from micro scale (pond) to the regional scale (watersheds). Bononi Creek's importance is thus apparent and therefore action must be taken to protect or at least ensure that its flow and health will not be threatened by any future development activities in the area. This result also enforces the importance of considering connectivity in landscapes. This refers not just to connectivity through waterways, but also the connectivity which takes place laterally between terrestrial and freshwater habitats, and the importance of protecting the forest and other riparian vegetation for the health of the fish population and to secure a continued supply of fish as an ES.

The novel research find of the connectivity site between the watersheds highlights the importance of this type of research in other remote tropical settings. It also supports Burkhard *et al.*'s (2012) call for more spatial data from the local scale to enable better decision-making. This research has also been able to identify key features in the landscape, like deep-pools, fruit trees, floating vegetation and rocky areas, which might need to be monitored and protected.

The third spatial pattern disclosed that the Makushi's fishing pattern is divided into two types: the subsistence fishing type, which takes place near the communities, within travelling distance of less than 5km, and the commercial fishing type, which requires further travel, if the fishing is for individual commercial gain. A social norm like this which ensures benefit sharing among the whole community is clearly important for food security and also assists in spreading the harvesting pressure wider in the landscape. Another documented spatial behaviour was that certain households used certain fishing sites located closer to their houses more often, and households on the other side of the village used other fishing sites. This again is a good example of a strategy some communities seemed to follow that reduces the pressure on the fishing sites. Understanding existing resource and fishing patterns are important for any management initiative as these should strive to build on already existing social mechanisms like the fishing patterns the North Rupununi communities' display.

This study has also provided another empirical example, by the work of the community monitors, which demonstrated the reliability and trustworthiness of employing local people to do ES monitoring. For the North Rupununi, this result is very promising and important, as much monitoring will need to take place both for community management processes, but also due to the REDD+ scheme in Guyana, which requires regular and reliable monitoring of a range of ES. Additionally, this study's triangulation of data has demonstrated that the qualitative information obtained through the focus groups and interviews is supported by field observations and quantitative data analyses, thus illustrating the reliability of the Amerindians' knowledge level and capacities.

8.3 Applicability of research findings

It is hoped that this thesis demonstrates an assessment method which greatly builds on the skills and knowledge of the local indigenous people to collect sufficient data to inform and advise governmental bodies in designing and implementing management strategies. It also serves to inform and guide development projects to ensure that they are located in the correct location, thus minimising the effect on the ES and particularly the source and key connectivity sites for the valuable ES, which both the local people depend upon and national and international stakeholders value.

The research has highlighted the difficulties areas like the North Rupununi and Guyana face, as they want to improve both the local and national populations' lives and well-being through development, but at the same time do not want to harm the environment. This position of care for the environment is not shared by all countries, and Guyana should be commended for deciding to try another development pathway, that of low carbon (LCDS, 2009). The major issues of depletion of the world's resources and extinction of species and habitats have been linked to the pressure of human population growth in combination with unsustainable development and harvesting (Rockström *et al*., 2009). Guyana is a rare exception where population density is remarkably low. The population density of the North Rupununi is also low, but population increases have been documented; together with the quite densely populated centres dotted across the North Rupununi, with vast areas of space between, might still cause some concern. Linking this to the research findings of the fish decline and the shortage of terra firma for farming, a potential issue for the future viability of the communities might be identified. This is a common issue that many locations and countries around the world face. How can a continuous supply of vital ES be secured when the demand for them is growing with the growing population? And at the same time, how can these types of areas improve human well-being and reduce poverty?

These two questions are what many scholars and organisations involved in these issues are trying to solve. As discussed earlier, the Guyanese government wants to increase food production in the North Rupununi; as it is made up of great savannas, turning these areas into agricultural land will be easier and less carbon will be emitted, as identified in the LCDS (2009). The issue is of course the location of these new agro-developments, and whether they will be conducted in a fashion that reduces the provision of other ES in the area. As the research findings on connectivity have shown, the North Rupununi is highly connected due to the seasonal flood pulse, and any contamination or surface run off would be difficult to contain and would most likely have a sever effect on key spawning sites

Another suggested development in the LCDS for the North Rupununi is aquaculture. Similar issues of pollution are of concern, as well as high investment costs. Instead the author suggest the less resource-intensive cultural based fisheries, or extensive aquaculture[15] as this would be cheaper to set up and run (De Silva, 2003). Furthermore, less technical expertise is needed and no artificial feed or pesticides are required, which reduces both running costs and the impact on the ES.

8.4 Future research needs

This thesis has contributed to unravelling some of the complexities of ES and spatial and temporal scale. However, much more is needed both within this wide concept but also for the

[15] Culture fisheries can be described as extensive aquaculture, where natural ponds are used to rear the fish and only minimal feed are used to rear the fish to minimise adverse effect on the environment and the cost to the communities managing these ponds (Lorenzen *et al., 1998)*.

Rupununi and Guyana as a whole. If the Government of Guyana wants to continue developing in a low-carbon way, a national ES assessment is needed, where the condition and trends of the nation's ES are established, together with main drivers of change. The mapping and valuation of ES are also needed on a national scale, to allow the government to fully assess their situation; to choose the most suitable development pathways, scenarios will need to be developed and explored. Furthermore, other countries similar to Guyana, which have not done any ES assessments, may also benefit from similar research to establish the critical source areas of both ecosystem stock and services. For larger scale assessments, such as on a national or watershed scale the use of some of the quite newly developed tools such as InVEST or Costing Nature (Tallis and Polasky, 2007; Silvestri and Kershaw, 2010) would be useful to explore.

A great gap in the knowledge has also been identified in the ecology of many of the fish species the Makushi rely on; further research to better understand their ecology and the evolutionary adaptations that are taking place in fish found in tropical freshwaters would be beneficial for the management of the North Rupununi and other similar areas in the tropics. Further research into tropical freshwater artisanal fisheries is much needed globally as much remains unknown about this important source of protein for many vulnerable and cash poor people.

In regards to the decline of the fish population and the increase in the population of the Rupununi, management might not be enough to sustain the fish population, and thus exploration into cultural aquaculture might be an avenue that needs exploring to ensure food security.

Research within the area of ES and scales is still very much needed to better understand the trade-offs that takes place when one ES is favoured. Questions to consider might be if it is better to design large spatial areas to provide one or a few provisioning services, such as agricultural crops and then set aside a separate area for conservation which has established high biodiversity. Or is the preferred development one that strives to produce a mix of all ES, i.e. one that does not override the others such as agroforestry, small-scale organic agriculture? The local scale cost to biodiversity when favouring a provisioning ES is well known, but if it can be shown that on a national scale the biodiversity stays the same, should this then be regarded as biodiversity protection or does biodiversity loss on the local scale matter?

A better understanding of landscapes' heterogenitiy and connectivity in terms of sustaining the supply of ES is essential and more research is needed within this field to prevent, or at least reduce, the impact of development projects and in the improvement of natural resource management.

Much more research is also needed within the field of ES valuation, where an improved valuation process needs to be agreed. More research into alternative methods to monetary valuation is needed to ensure that all types of values and stakeholders at all scales are taken into consideration. The gap of valuation studies in less developed countries also needs to be addressed if these countries are interested in using the ES concept in their development and conservation work.

8.5 Concluding remarks

The news that the government of Guyana has approved a logging licence for a large area up Rewa River – similar to where nature and discovery TV programmes explore the pristine forest that Guyana is famous for and tries to promote as a picture of itself – was greeted by many environmental officials with disbelief (in conversation with NGO staff). Rewa River is a known hotspot for its diversity and abundance of fish; on a larger scale it is one of the few pristine places left on this earth. On an international, national and local scale this decision risks losing the recognition of the pristine condition of the Rupununi, which might have considerable monetary consequences for tourism and its development in the area. It is therefore suggested that the government need to recognise that intensive industrial development projects such as large scale logging, oil drilling and intensive agriculture, do not complement the eco-tourism development they have invested in for the North Rupununi, which is in line with what Lauriola and Mistry (2009) advised. Thus, the recommendation would be to use the North Rupununi as a showcase area for how sustainable development really can be done – where more food can be produced in a sustainable way, and where small-scale local business like the North Rupununi peanut factory and cassava factory grow and increase the income and job creation in the area. I thus ask the government to be brave again – as you were when you took the decision to develop with low carbon as a strategy – stick to your commitments and you have a high likelihood to become world renowned for your bold choices, unique nature and fantastic multicultural country.

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Appendices

Appendix 1: Questionnaire for interviews and focus groups in North Rupununi

Community:

Gender	Age	Home village	Came to village	Main Income

Questions

Introduction

1. What do you like the most about living in North Rupununi?
2. What natural resources (ecosystem services) are important for you?
3. Can you identify any other natural resources (ecosystem services) that you benefit from or appreciate in the North Rupununi?

Perception of ecosystem services

4. Looking at the list of ecosystem services you mentioned earlier, could you rank the importance of these ecosystem services to you, starting with giving the most important service number one then 2 for the second most important service and so on.
5. Could you explain to me why you have given the ecosystem services their rank number? What is the reason behind their importance or their unimportance to you?
6. Would you say that there are other people outside this community that benefit and use these ecosystem services? If so, who are they and what services are they benefitting from?

7. Would you say that everyone in the community benefit in the same way from these ecosystem services?

Function and mapping of ecosystem services

8. a) Could you draw on the map where the natural resources you mentioned earlier are located? (e.g. Fishing sites, farms, hunting areas, etc.)
   b) How does the wet season affect the location and functioning of the ecosystem services?

9. Are there any critical areas that are needed to sustain the service? If so, could you draw on the map? (e.g. spawning sites)

10. What indicators would you say could be used to check if an ecosystem service is healthy? (fish, water, biodiversity etc.)

Threats and dynamics of ecosystem services

11. Does the availability or quality of these ecosystem services change during the year? If so, in what way?

12. Are there also changes in different locations? Which locations change?

13. a) Have the availability and/or quality of any of these ecosystem services changed over time?
    b) If, yes, in what way? Units? Time periods?
    c) What are the reasons for these changes?

14. Are there any other current threats to the ecosystem services that you know about?

15. Do you worry about any potential threats to these services in the future?

Management of ecosystem services

16. In what way would you like the North Rupununi to be managed? (Can bring in what they mentioned in threats)

17. (Have you heard of the Low Carbon Development Strategy?)

18. (What do you know about it?)

Appendix 2: Questionnaire for Georgetown organisations

INTRO

1. What does the North Rupununi mean to you?
2. a) Do you get any benefit from the North Rupununi?
   b) If yes, what type of benefits?

3. What type of ecosystem services would you say that the North Rupununi provides
   a) Locally?

   b) Nationally?

   c) Globally?

PERSPECTIVES

4. a) Could you please rank these Ecosystem services accordingly to their importance?

   b) Why have you given each of the ES the ranking that you have? Motivate, please describe how they are important for you?

THREATS TO THE ECOSYSTEM SERVICES

5. What factors would you say might affect the health of these ecosystem services?

6. a) Do you know if the quality or availability of these ES have changed at all over time?

   b) If so, what has caused these changes?

7. a) Do you know if there are any (other) threats to these ES?
   (e.g. oil drilling, over fishing, rise plantations, gold mining, road etc.)

   b) Do you see there being any other potential threats to the health of these ecosystem services in the future?

MANAGEMENT AND DEVELOPMENT OF THE NORTH RUPUNUNI

8. How would you like the North Rupununi to develop in the future?

9. What is your opinion about the LCDS?

10. How would you like the North Rupununi to be managed?

11. a) Do you think a payment for ecosystem services scheme would be a good way to manage the resources in the North Rupununi?
    b) What type of ES do you think a potential PES scheme should focus on?
    c) What do you think need to be put in place for it to be feasible?

12. a) Do you think the North Rupununi should be declared a RAMSAR site/protected in any way? Or if there are certain areas within North Rupununi that should be protected?

    b) If yes, what do you think is needed for it to be a reality?

    c) If no, please explain why?

Appendix 3: Brief fish abundance questionnaire

Fish Abundance table please tick (√) accordingly to your experience and knowledge. For each of the fish species listed below please tick whether you catch the type of fish in the dry season or high water time. Then tick the most appropriate category (rare, occasional, common or abundant) for each of the fish.

FISH SPECIES	Use in Dry season	Use in High Water time	RARE (Catch fish a few times a year)	OCCASIONAL (Catch the fish a few times a month)	COMMON (Catch fish on most fishing trips)	ABUNDANT (Catch fish on nearly all fishing trips)
Arawana						
Biara						
Banana fish						
Basha						
Butter fish						
Cartaback						
Dare						
Dawalo						
Haimara						
Hassa						
Houri						
Imehri						
Kassie						
Kullet						
Lau Lau						
Lukunani						
Manji						
Paku						
Patwa						
Perai						
Policeman fish						
Sun fish						
Sword fish						
Tiger fish						
Yakatu						
Yarrow						

Appendix 4: Tourism Questionnaire

Please circle or write your answers

Gender: Male / Female

Age: 0-18 19-30 31-40 41-55 56-65 +65

Nationality:

1. Where have you been in Guyana during your holiday?
2. What attracted you to the North Rupununi?
3. What type of wild life are you most hoping to see when visiting?

   Birds Mammals Fishes Insects Other

4. Please specify which species you would like to see the most
5. Of the ecosystem services listed in the table below, please indicate which of them that you think are the most important here in North Rupununi. Please rank by putting a number from 1 to 10, where 1 is the most important and 10 is the least important, in the table below.

Ecosystem Services	Importance (1-10)
Biodiversity	
Freshwater	
Climate regulation	
Fish	
Water regulation	
Beauty of landscape	
Fertile soil	
Timber	
Eco-tourism	
Food production	

6. How satisfied are you with your stay here?

   Very Satisfied Satisfied Fairly Satisfied Not at all

   Please give an explanation for your answer

7. What would you like to improve about your stay here in the North Rupununi?

Appendix 5: Table of when, where and how many people that took part in the interviews and focus groups

Community	Date	Interview/Focus Group (I/FG)	Number of people
Kwatamang	23 Nov 2010	I	3
Kwatamang	24 Nov 2010	I	2
Kwatamang	25 Nov 2010	I	2
Kwatamang	26 Nov 2010	I	2
Kwatamang	29 Nov 2010	FG	6
Kwatamang	30 Nov 2010	FG	4
Kwatamang	1 Dec 2010	FG	5
Annai	8 Dec 2010	I	3
Annai	9 Dec 2010	I	1
Annai	14 Dec 2010	FG	8
Annai	15 Dec 2010	FG	4
Annai	16 Dec 2010	FG	5
Annai	10 Jan 2011	I	2
Annai	11 Jan 2011	I	2
Rewa	19 Jan 2011	I	4
Rewa	20 Jan 2011	I	4
Rewa	21 Jan 2011	I	3
Rewa	24 Jan 2011	FG	4
Rewa	25 Jan 2011	FG	4
Rewa	26 Jan 2011	FG	5

Rewa	26 Jan 2011	FG	3
Yupukari	9 Feb 2011	I	2
Yupukari	10 Feb 2011	I	2
Yupukari	11 Feb 2011	I	3
Yupukari	14 Feb 2011	FG	3
Yupukari	15 Feb 2011	FG	3
Yupukari	15 Feb 2011	I	1
Yupukari	20 Feb 2011	FG	11
Massara	16 Mar 2011	I	3
Massara	17 Mar 2011	I	3
Massara	18 Mar 2011	FG	3
Massara	18 Mar 2011	I	1
Massara	19 Mar 2011	FG	4
Massara	19 Mar 2011	I	2
Massara	21 Mar 2011	FG	3

Appendix 6: List of organisations interviewed in Georgetown

Organisation	Date
Conservation International	24 May 2011
Department of Agriculture	25 May 2011
Forestry Commission	25 May 2011
Guyana Tourism Association	24 May 2011
Guyana Geology and Mines Commission	26 May 2011
Iwokrama International Centre	19 & 20 May 2011
United Nation Development Program	23 May 2011
WWF	26 May 2011

Appendix 7: Categories and codes for social analysis

Categories	Codes								
Basic needs	Subsistence living	Everyday living							
Cultural identity & custom	Traditional	Our land	Modernisation	Crafts					
Education	Training	Workshop	School	Naiveté					
Income	Tourism	Jobs	Money						
Scale	Local	Georgetown							
Worldview	Language	ES concept	Value	Important					
Natural Resource Management	Management	Conflict	Government	Wildlife					
Ecosystem service	Transportation	Shortcut	Beauty						
Environmental change	Climate change	Weather	Deforestation	Pollution	Indicators	Threat	Fish no.	Caiman no.	Pest
Important site in landscape	Fish site	Spawn site	Hotspot	Connectivity	Hunting site	Habitat features			
Seasonal	Water level	Dry season	Wet season						

Appendix 8: Fish species common and Latin names

Common name	***Latin name***
Arapaima	*Arapaima gigas*
Arawana	*Osteoglossum bicirhosum*
Armered catfish	*Amblydoras affinis*
Baiara	*Rhapiodon vulpinus*
Banana fish	*Pseudodoras sp.*
Basha	*Plagioscion sp.*
Bitter head	*Hemidoras notospilus*
Blinka	*Pseudoplatystoma sp.*
Bon bon	*Pseudocanthicus leopardus*
Butter fish	*Pimelodidae*
Button fish	*Metynnis sp.*
Cartaback	*Myleus rubripinnis*
Cascod	*Hypostomus karanambo*
Cat fish	*Pseudoplatystoma sp.*
Cotee	*Prochilodus sp.*
Curali (spp of Yakatu)	*Prochilodus sp.*
Cusin of Lau lau	*Brachyplatystoma sp.*
Dare	*Leporinus sp.*
Dawala	*Ageneiosus ogilviei*
Dimond fish	*Metynnis sp.*
Dog fish	*Acestrorhynchus falcatus*
False Biara	*Hydrolycus sp.*
False Lukunani	*Chichla sp.*
Flat-headed hassa	*Hoplosternum sp.*
Fox fish	*Acestrorhynchus microlepis*
Giri giri	*Platydoras sp.*
Haimara	*Hoplias aimara*
Hassa	*Hoplosternum littorale*
Houri	*Hoplias malabaricus*
Imehri (Boots/Black)	*Trachycorystes trachycorystes*
Imehri (Brown)	*Trachycorystes galeatus*
Johnny sp.	*Prochilodus sp.*
Kassi	*Rhomdia holomelas*
Kastimbo (hardarmed bigger then hassa	*Hypostomus squalinus*
Kullet	*Pseudoplatystoma fasciatum*
Kuni	*Tetragonopterus sp.*
Kuyu kuyu	*Oxydoras niger*
Kwan	*Leporinus sp.*
Larima (silvercat fish)	*Brycon falcatus*
Lau lau	*Brachyplatystoma sp.*
Logo logo	*Brachypopomus sp.*
Logo Logo type (Bait)	*Rhamphichthys marmoratus*

Common name	***Latin name***
Lukunani	*Cichla ocellaris*
Manji	*Megalonema platycephalum*
Moya (family to Imehri but brown)	*Parauchenipterusgaleatus*
Mud eel	*Synbranchus marmoratus*
Needle fish	*Farlowella sp.*
Paku	*Colossoma sp.*
Patwa	*Chichlasoma sp.*
Patwa II	*Satanoperca leucosticta*
Perai	*Serrasalmus sp.*
Perai (red-bellied)	*Pygocentrus natteri*
Peri (Black)	*Serrasalmus rhombeus*
Piab	*Moenkhausia sp.*
Podo	*Megalonema sp.*
Policeman fish	*Platydoras sp.*
Raphael cat fish	*Platydoras sp.*
Redtail fish (bait)	*Chalceus macrolepidotus*
Salta	*Pseudoplatystoma sp.*
Sardine	*Hemiodopsis sp.*
Sauta	*Hemigrammus sp.*
Serebe	*Astyanax sp.*
Shovel Head	*Pseudoplatystoma sp.*
Simha (type of Patwa)	*Geophagus sp.*
Sun fish	*Crenicichla sp.*
Sword fish	*Boulengerella cuvieri*
Tiger fish	*Pseudoplatystoma sp.*
Wabray	*Serrasalmus sp.*
White Paco	*Metynnis sp.*
Yakatu	*Prochilodus rubrotaeniatus*
Yaki	*Rhomdia sp.*
Yarrow	*Hoplerythrinus unitaeniatus*
Zip fish	*Megalodoras sp.*

Appendix 9: Community Monitoring Spread sheet

FISH MONITORING SHEET

Community:____

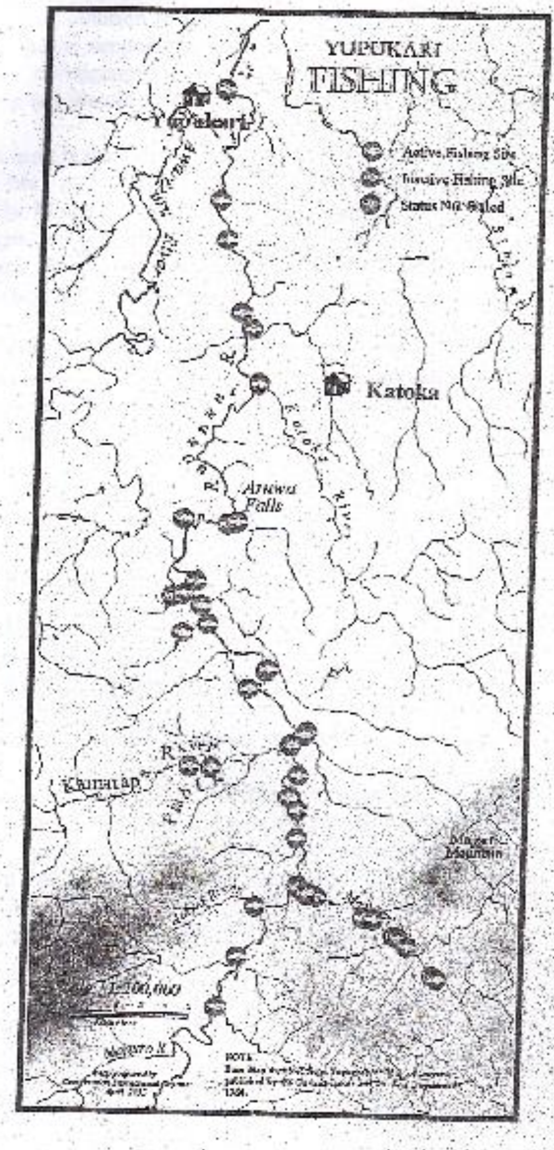
Data Collector:____

Date	Name of Fish species caught	Number of each fish species caught	Location	Estimated weight (lb)	Length of fishing trip (in hours)	Method

Appendix 10: All the identified fishing sites that the communities use.

Community	Fish site
An & Kw	Fish in Rup Riv down to Rewa. Upriver to Wagon, Manicole creek Tipitee, Crashwater creek, Devil's Pond, Monkey Pond, Tarraqua, Essequibo river, Rewa River, Savanna Pond, Mouri creek, Takatu Pond.
Re	Awarmie, Blackwater Pond, Bat Creek, Grass Pond, Taparo Pond, Henry Pond, Makarapan Pond, Turtle Pond, Banana soccle, Manahoe inlet, Rewa Mouth,Seawall
Yup	Mora pool in river on sharp bend south of the landing, Awarekru, Steamer, Kumaka Ponds, Boundary Pond, Moby Pond, Dare Pond, Mapari river, Aruwa creek, Rup Riv by Katoka for commercial, Jersey pool, Code pool, Simonie, Aruwa and Pagua pool, Drobai pool, Yup pool by landing,
Ma	Grave Pond, Paddle Pond, Massara pool, Bononi Pond, Merisheri Pond, Kopeiba Pond, Riverburst Pond, Parishara inlet, SImoni lakes and river, Iguana Pond, Oma Pond, Kwadra Pond, Small and big Krawa Pond, Big and Small Long Pond, Turtle Pond.

Appendix 11: Yupukari's old fishing sites maps from 2002.



Appendix 12: The adapted Wetlands Partnership monitoring form for hydro-ecological data

Sustainable Management of the Rupununi Site Monitoring Form				Page 1 of 9
A. Site details				
A1	Site Name			
A2	Site Code			
A3	Date of survey			
A4	Weather conditions			
A5	Name of surveyors			
A6	GPS location			
A7	Time survey started			
B. Geomorphic attributes				
B1	River type		Main River Channel	☐
B2			Creek	☐
B3	Pond or lake that floods directly from river		Cut-off channel (inlet with connection to river)	☐
B4			Former channel (separate from river)	☐
B5			Ox-bow lake (separate from river)	☐
B6	Pond or lake that floods back up small creek from river		Former channel (separate from river)	☐
B7			Ox-bow lake (separate from river)	☐
B8	Basin Ponds (these ponds have no direct input from the river flooding)		Permanent pond	☐
B9			Pond that dries out	☐
C. Hydrological attributes				
C1	Hydrological inputs	Groundwater discharge		☐
C2		Surface runoff		☐
C3		Surface overbank inundation from a river		☐
C4		Surface overbank inundation from a rise in water level of a waterbody		☐
C5		Precipitation		☐
C6		Other..		☐
C7	Flooding regime	Water present		☐
C8		Water not present		☐
C9	Water colour	Black		☐
C10		White		☐
C11		Clear		☐
C12		Brown		☐

Sustainable Management of the Rupununi Site Monitoring Form	Page 2 of 9

D. Waterbody dimensions and features

D1	Waterbody WATER width (metres)	
D2	Waterbody WATER depth (metres)	
D3	Waterbody WATER length (metres)	

			RIVER TYPE				BASIN TYPE	
Bank Orientation on river (i.e north)							All of the basin	
			Present	>33%	Present	>33%	Present	>33%
D4	Bank profiles	Not visible	☐	☐	☐	☐	☐	☐
D5		Vertical/undercut	☐	☐	☐	☐	☐	☐
D6		Vertical + toe	☐	☐	☐	☐	☐	☐
D7		Steep (>45°)	☐	☐	☐	☐	☐	☐
D8		Gentle (<45°)	☐	☐	☐	☐	☐	☐
D9		Composite	☐	☐	☐	☐	☐	☐
D10	Bank features	None	☐	☐	☐	☐	☐	☐
D11		Not visible	☐	☐	☐	☐	☐	☐
D12		Eroding earth bank	☐	☐	☐	☐	☐	☐
D13		Stable earth bank	☐	☐	☐	☐	☐	☐
D14	Bank vegetation features	Unvegetated bank base	☐	☐	☐	☐	☐	☐
D15		Vegetated bank base	☐	☐	☐	☐	☐	☐
D16	Bank material	Not visible	☐	☐	☐	☐	☐	☐
D17		Bedrock	☐	☐	☐	☐	☐	☐
D18		Boulder	☐	☐	☐	☐	☐	☐
D19		Cobble	☐	☐	☐	☐	☐	☐
D20		Gravel/sand	☐	☐	☐	☐	☐	☐
D21		Earth	☐	☐	☐	☐	☐	☐
D22		Sticky clay	☐	☐	☐	☐	☐	☐

			Present	>33%
D23	Bottom substrate	Not visible	☐	☐
D24		Bedrock	☐	☐
D25		Boulder	☐	☐
D26		Cobble	☐	☐
D27		Gravel/pebble	☐	☐
D28		Sand	☐	☐
D29		Silt/mud	☐	☐
D30		Clay	☐	☐
D31		Peat	☐	☐

Sustainable Management of the Rupununi Site Monitoring Form	Page 3 of 9

D. Waterbody dimensions and features continued

			Present	>33%
D32	Bottom features	Not visible	☐	☐
D33		None	☐	☐
D34		Exposed bedrock/boulders	☐	☐
D35		Unvegetated mid-channel sand bar	☐	☐
D36		Vegetated mid-channel bar	☐	☐
D37		Mature island	☐	☐
D38		Areas completely covered in vegetation	☐	☐
D39		Areas completely covered in debris (leaf litter)	☐	☐

E. Habitat characterisation

E1	Habitat types around waterbody	Forest - Flooded	☐
E2		Forest – Non-flooded	☐
E3		Savanna – Flooded	☐
E4		Savanna – Non-flooded	☐

			Present	>33%		Present	>33%
E5	Species present around waterbody	Wallaba	☐	☐	Water Cedar	☐	☐
E6		Palm	☐	☐	Inga Spp.	☐	☐
E7		Mora	☐	☐	Aripipi Pala	☐	☐
E8		Scrub	☐	☐	Gauvaballi	☐	☐
E9		Lana	☐	☐	Old Man Back	☐	☐
E10		Bamboo	☐	☐		☐	☐

			RIVER TYPE				BASIN TYPE	
Bank Orientation on river (i.e. north)							All of the basin	
			Present	>33%	Present	>33%	Present	>33%
E11	Extent of trees and associated features	Isolated/scattered	☐	☐	☐	☐	☐	☐
E12		Regularly spaced, single	☐	☐	☐	☐	☐	☐
E13		Occasional clumps	☐	☐	☐	☐	☐	☐
E14		Semi-continuous	☐	☐	☐	☐	☐	☐
E15		Continuous	☐	☐	☐	☐	☐	☐
E16		Shading of waterbody	☐	☐	☐	☐	☐	☐
E17		Overhanging trees	☐	☐	☐	☐	☐	☐
E18		Exposed bankside roots	☐	☐	☐	☐	☐	☐
E19		Underwater tree roots	☐	☐	☐	☐	☐	☐
E20		Fallen trees	☐	☐	☐	☐	☐	☐
E21		Coarse woody debris	☐	☐	☐	☐	☐	☐

Sustainable Management of the Rupununi Site Monitoring Form	

E. Habitat characterisation continued

			RIVER TYPE				BASIN TYPE	
Bank Orientation on river (i.e. north)							All of the basin	
			Present	>33%	Present	>33%	Present	>33%
E22	Bank vegetation types	Bryophytes (mosses)	☐	☐	☐	☐	☐	☐
E23		Short herbs/creeping grasses	☐	☐	☐	☐	☐	☐
E24		Tall herbs/grasses	☐	☐	☐	☐	☐	☐
E25		Shrubs	☐	☐	☐	☐	☐	☐
E26		Climbers	☐	☐	☐	☐	☐	☐
E27		Trees and saplings	☐	☐	☐	☐	☐	☐

			Present	>33%
E28	Waterbody vegetation types	Algae	☐	☐
E29		Floating	☐	☐
E30		Emergent	☐	☐
E31		Submerged	☐	☐
E32	Habitat niches	Otter dens and campsites	☐	☐
E33		Sheet rock	☐	☐
E34		Victoria amazonica (Big Lily)	☐	☐
E35		Floating grass	☐	☐
E36		Nymphaea (Small Lily)	☐	☐
E37		Guavaballi	☐	☐
E38		Maaho	☐	☐
E39		Moco moco	☐	☐
E40		Tapir entrances	☐	☐
E41		Arapipi Palm	☐	☐
E42		Water Hyacinth	☐	☐
E43		Busy Busy (Spiked rush)	☐	☐

F. Land use

	Land use (please note that there are more categories on the following page)		Waterbody	50m of bank top
F1		Fishing - Commercial	☐	☐
F2		Fishing - Subsistence	☐	☐
F3		Farming – Slash/burn without pesticide	☐	☐
F4		Farming – Slash/burn with pesticide	☐	☐
F5		Farming - Ranching	☐	☐
F6		Farming – Agro-forestry	☐	☐
F7		Hunting	☐	☐

Sustainable Management of the Rupununi Site Monitoring Form					Page 5 of 9
F. Land use continued					
F8	Land use continued	Trapping	☐	☐	
F9		Mining - Riverbed	☐	☐	
F10		Mining - Land	☐	☐	
F11		Tourism – Sport fishing	☐	☐	
F12		Tourism - Trekking	☐	☐	
F13		Tourism - Riding	☐	☐	
F14		Tourism – Boat trips	☐	☐	
F15		Tourism - accommodation	☐	☐	
F16		Tourism – Sight seeing	☐	☐	
F17		Settlement	☐	☐	
F18		Burning	☐	☐	
F19		Logging - commercial	☐	☐	
F20		Logging – local construction	☐	☐	
F21		Transportation - river	☐	☐	
F22		Transportation - land	☐	☐	
F23		Cultural significance / practice	☐	☐	
F24		Scientific research	☐	☐	
F25		Biodiversity conservation	☐	☐	
F26		Brick making	☐	☐	
F27		Gathering - Honey	☐	☐	
F28		Gathering - Seeds	☐	☐	
F29		Gathering - Plants	☐	☐	
F30		Gathering - Firewood	☐	☐	
F31		Gathering – other non-timber forest products	☐	☐	
F32		Recreation	☐	☐	
EXTRA NOTES					

Map Appendix

The map appendix can be accessed through request to the author.These maps are co-owned with the NRDDB whose permission also needs to be sought before maps are released for review.