Journal of Environmental Management , **72** : 117-131.

Exploring the links between natural resource use and biophysical status in the waterways of the North Rupununi, Guyana

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ABSTRACT

The North Rupununi District in south-west Guyana is comprised of a mosaic of ecosystems, including savannas, wetlands and forests, and is home to the Makushi Amerindians, who depend on the waterways for their subsistence needs. With logging and mining seen as increasing threats to the region, it is necessary to look at methods for engaging stakeholders in monitoring the status of their natural resources. This paper presents the results of a pilot study carried out to investigate water use by the Makushi Amerindians, and collect baseline data on the hydro-morphological aspects of the waterways. Methods included informal interviews, the use of the River Habitat Survey (RHS), and water quality measurements. The results indicate the heavy reliance of the Makushi on the waterways for their daily lives, particularly on fishing. Although ponds and creeks are important sources of fish, the rivers provide much larger catches of a greater diversity of fish species, both in the wet and dry seasons. The physical characteristics of the water sources used by the Makushi are mainly associated with the surrounding habitat types: the savanna areas containing the more nutrient rich white-water rivers, and the tropical forest areas containing the less nutrient rich black-water rivers. This study indicates that at present there is no direct evidence of adverse impacts on the waterways used by the Makushi in terms of fish catches, habitat conditions and water quality. A monitoring scheme was set up using this study's outputs as a baseline from which any future changes can be compared. Further work is to be carried out over the next three years to produce monitoring and sustainable management procedures for the North Rupununi ecosystems, by linking the physical attributes of the environment to biodiversity and subsequently local livelihoods, and by building capacity of local stakeholders through training.

KEY WORDS

Natural resources, monitoring, River Habitat Survey, water quality, Rupununi, Guyana, Amerindians

INTRODUCTION

The high productivity and diversity of tropical ecosystems provides a vast range of exploitable natural resources and thus do not always necessitate the conversion to large scale monoculture pastoral-agricultural systems for sustaining the livelihoods of communities. These natural resources also have a non-economic value, supporting local cultures in terms of belief systems and aesthetics (Robinson and Redford, 1991)

The use and management of natural resources in tropical developing countries is often not sustainable due to pressures for development benefiting the already wealthy. Local communities are generally inadequately resourced for implementing environmental monitoring and rarely have the power to redress the negative impacts of development on their environmental systems. One of the immediate and serious consequences of this is the potential loss of subsistence by those people on whose livelihoods the exploitation of natural resources depends (Agrawal and Gibson, 1999).).

In Guyana, up until the early 1990s, foreign investment was blocked, a situation which virtually self protected its diverse range of ecosystems and the local communities that depended on them. These environments are thought to support over 800 species of birds, over 200 species of mammals, over 500 species of fresh water fish and over 200 species of reptiles and amphibians, and still contain high numbers of Amazonian megafauna including the world's largest freshwater fish, the *Arapaima*, large cats, Black Caiman, large raptors such as Harpy Eagles, and Giant Otters. Wildlife plays a critical role in the lives of local people: wildlife and fish are the major sources of subsistence and often offer the only potential for sustainable commercial activity for Guyana's interior populations.

The environmental situation in Guyana changed in the early 1990s after democratic elections. The new government, hungry for foreign exchange, encouraged investors from abroad, and so began an intensification in exploitation of natural resources, namely logging and mining. State forests in Guyana can be given out for timber concessions, and presently cover approximately 8.8 million ha of the 14 million ha of exploitable forest (Parry and Eden, 1997). Of the existing State Forest, approximately 8.2 million ha was under concession in 1999 (Richardson and Funk, 1999), although only one third was actually logged. As a condition of foreign aid, a moratorium was placed on granting new concessions, but this was lifted and State Forest is now being extended by approximately 1 million ha towards the Rupununi District in southern Guyana.

Mining dates back to several hundred years in Guyana, but recently there has been a shift from bauxite to gold and diamonds. This has concentrated in the hilly sand and clay regions, primarily in the riverbeds. Some serious accidents have occurred in large mines e.g. the Omai mine (William, 1997), however the major mining pressure is from small-scale riverbed extraction that is extremely detrimental to the physical, chemical and ecological condition of local river systems.

The North Rupununi District in south-west Guyana is a mix of savanna, forest and wetland ecosystems (Eden, 1964, 1974), and the Makushi Amerindians, who inhabit this region, depend on this mosaic of vegetation forms for their subsistence needs. Their relationship with the environment is a complex one embedded in ritual practices and in beliefs where mythical creatures are directly linked to natural resource utilisation (Forte, 1996). Although shifting cultivation (mainly for cassava production), hunting and gathering take place, fishing is the mainstay of Makushi life comprising over 60% of their diet. The rivers, pools and creeks are therefore extremely important resources, and any damage to these systems threatens the survival of the Makushi way of life.

In the words of Kothari, cited in Forte (1996), "communities lack the resources to tackle threats or ecological issues at a regional scale". With logging and mining seen as an increasing threat to the ecosystems of the North Rupununi District as well as having a potential detrimental effect on Makushi culture, it is necessary to collect baseline data on the state of the environment as a benchmark for future changes. Although there are various sociological, biological and physical environment studies ongoing by local interest institutions, including the North Rupununi District Development Board (an Amerindian NGO), the Iwokrama International Centre for Rain Forest Conservation and Development and the University of Guyana, few studies have tried to link these three aspects into a single holistic approach to natural resource management.

A consortium of British and Guyanese institutions has now received significant funding to help build capacity for effective natural resource management in the North Rupununi District through training and the development of integrated management plans and associated monitoring systems. The Guyanese project partners include:

Environmental Protection Agency – representing the governmental sector;

University of Guyana – representing the educational sector;

Iwokrama International Centre for Conservation and Development – representing the research and commercial sector;

North Rupununi District Development Board – representing the Makushi Amerindians and their interests in local governance, education, research and commerce.

Our aim is to develop a methodological and technological framework for engaging stakeholders in a common, participatory decision-making process for monitoring and sustainable natural resource management.

This paper presents the first output of this project. In December 2001 a small pilot study was initiated in the region to:

1. investigate water use and management by the Makushi Amerindian communities;
2. collect baseline data on the hydro-morphology of riparian and in-stream areas ecologically and economically important to the Makushi Amerindian communities;
3. collect data on the social context of natural resource use by the Makushi communities.

STUDY SITE

The North Rupununi District is situated in south-west Guyana, and comprises savanna, tropical lowland forest and wetland vegetation types. Mean annual rainfall is between 1600mm and 1900mm, peaking during the rainy season months between May and September (Hawkes and Wall, 1993). The waterways respond to this seasonality with water levels rising in the rivers during the rainy season and flooding the savannas and forest, and then receding during the dry season, leaving isolated water bodies such as pools and creeks.

The Makushi territory in Guyana can be delineated by the Kanuku Mountains which run from east to west forming a rough division with the Wapishana territory to the south; the Essequibo River which forms a natural boundary on the east, and the Takutu and Ireng Rivers on the west which mark the international frontier with the Brazilian state of Roraima, which also contains a large Makushi population (Forte, 1996). There are 24 Makushi communities in the North Rupununi, although only twelve are represented by the North Rupununi District Development Board, a local community group, with who's consent the research was carried out. These twelve communities contain roughly 2700 people. The Makushi build their homes in the savanna, but plant their farms in nearby forest plots. However, in terms of fish, their principal food source, there is a duel reliance on savanna, wetland and forest water bodies.

The research was carried out during the dry season of 2000-2001 and was based within the Burro-Burro and Rupununi river catchments. Surveys focused on the main river channels and important water bodies to the communities of Surama, Annai, Crashwater, Rewa, Wowetta, Rupertee and Apoteri (see Figure 1). All survey sites were geo-referenced using a GPS system.

METHODS

Makushi water use and management

Three separate data collection exercises were undertaken: published data review; stakeholder workshop and Rapid Rural Appraisal (RRA). A range of pertinent data was reviewed from local, national and international sources. Important data sources included local non-governmental organisations, government departments and university libraries located within Guyana. Prior to the commencement of field work, a workshop was held with the community. This identified the main water sources used by the Makushi. Using this information, more in-depth interviews were carried out with the community members based on the RRA approach of using semi-structured interviews (McCracken *et al.*, 1988). RRA methods were favoured over the conventional use of questionnaires because information could be obtained quickly in a relaxed, informal manner. The questions asked of the community members about their water source use are listed in Table 1.

Hydro-morphological surveys

To collect information on habitat quality and to assess the impact of land use change on the hydro-morphology of riparian and in-stream areas important to the Makushi, two separate surveys were undertaken: a river habitat survey and a water quality survey. Both surveys were undertaken in the pools, creeks, lakes and rivers that the Makushi use for fishing. The water quality survey also included the rivers, water holes and wells that the Makushi use for drinking and washing.

River Habitat Survey

Impacts from land use change such as mining or logging can influence not only the chemical and biological quality of the river or water body but also the character and structural quality of the habitat. To assess any impacts of land use change and to provide a base-line monitoring tool for habitat quality a modified version of the River Habitat Survey (Environment Agency, 1997) was used. The River Habitat Survey (RHS) has been developed in the UK to provide a national survey tool that describes the character and quality of habitats, the modifications affecting them, and has allowed the creation of a database of river habitats so that regular monitoring of the state of river systems can take place (Raven *et al.,* 1998). It has provided a system for classifying rivers according to their habitat quality and allowed relationships to be determined between habitat, biological and chemical quality (Raven *et al.,* 1997). Modified versions of the RHS have been used in a number of countries to assess river systems and to assess the relationship of land use change amongst habitats, invertebrates and birds (e.g. Manel *et al.,* 2000).

For the purposes of this study the basic form of the RHS was maintained but land-use categories were altered to include land-use typical of interior Guyana (e.g. lowland tropical forest, slash and burn agriculture). The RHS records over 120 variables describing the channel, flow character, banks and catchment within three main sections (for full methods see Environment Agency, 1997). The first section involves 10 'spot-checks' of all features present at 50-m intervals. Recorded within this section are channel and bank material, features, vegetation types and land use as well as flow type within the channel. For this part of the survey, adjustments were made to some descriptors so that other water bodies such as lakes and ponds could be assessed. The second section contains a 500m 'sweep-up' assessment recording the predominant habitat features such as surrounding land use, bank profiles, extent of trees and extent of larger scale channel features. The third section records the morphological dimensions of the channel or water body.

RHSs were taken of all water bodies identified by the Makushi as being important for fisheries. These included ponds, creeks, lakes and rivers surrounding the Makushi communities. Two major river systems (Burro-Burro and Rupununi rivers) of great importance to the Makushi were surveyed every 10 miles along their length and above and below major confluences with other rivers or creeks within the Makushi territory.

All RHS data were entered into a database and analysed using a multivariate statistical software package CANOCO 4 (ter Braak and Smilauer, 1998). Principal Component Analysis was used to determine any associations between river habitat features and the type of water bodies surveyed.

Water Quality Survey

Nine water samples were taken at all the RHS points along the river systems, within the ponds and lakes and at important water holes and wells within the communities of Surama, Annai, Crashwater, Wowetta, Rupertee, Reewa and Apoteri. These samples were used as a one-off spot check of water quality to allow a comparison between water bodies at the time of study. Guidelines within Chapman (1996) were used to help in the selection of which parameters were to be measured.

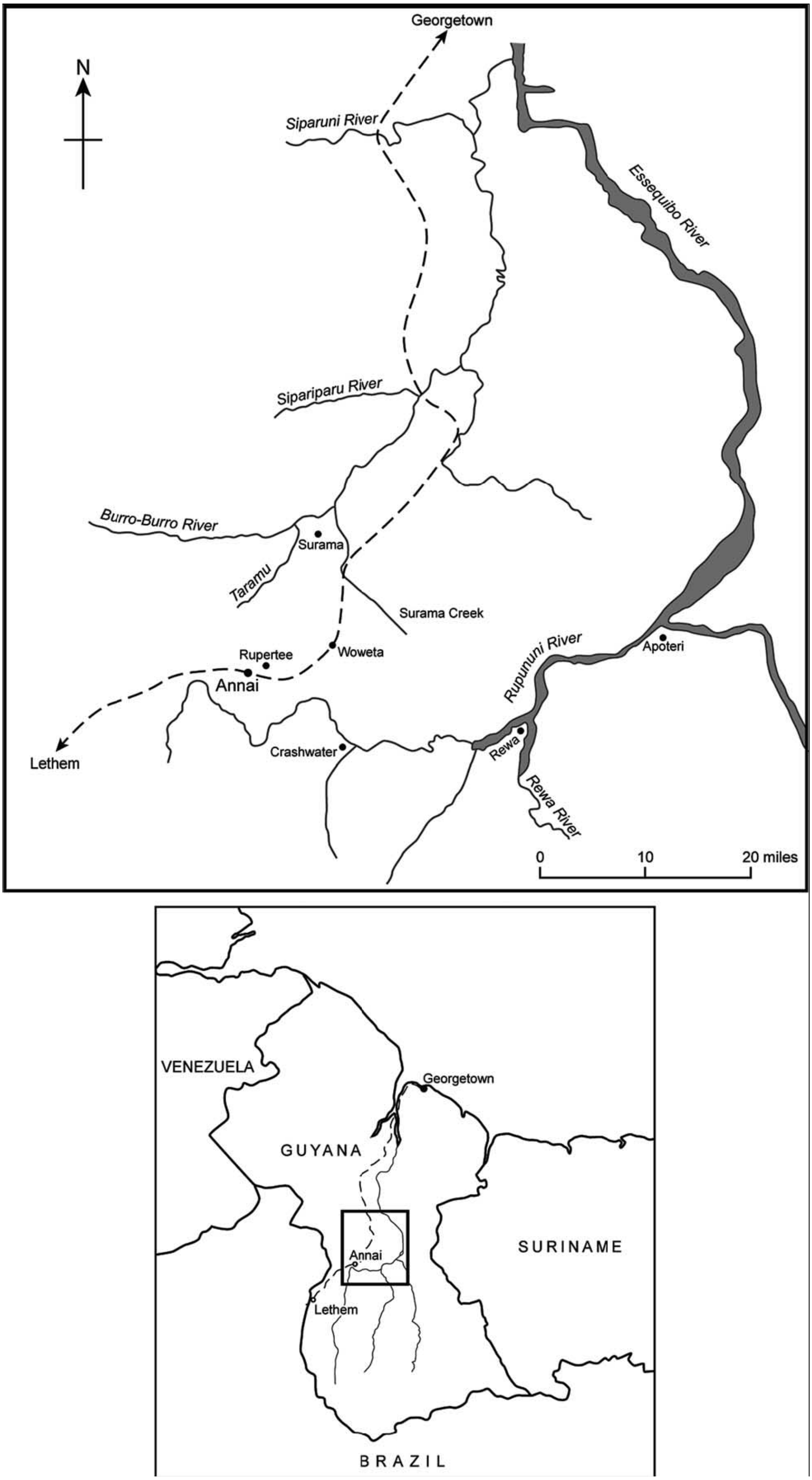

Figure 1. Map of North Rupununi District, and location of Makushi

Table 1
Questions asked of the community members about their water source use

Semi-structured questions posed for each water source
Do you use this water source? If not, why not? If yes, for what purpose/what service?
Over what spatial and temporal scale do you use this service?
If the service is extractive, what is the amount used?
What are the water source attributes that make you want to use it for these services?
Of these services, what's the most important?
For this service, how long would you travel?
Of these services, what are the present 'conditions'? (e.g. cleanliness of water, no./diversity of fish). Have you noticed any changes in these 'conditions', and if yes, what are they?
Are there any other areas/services that you could use instead?
Are there any management strategies for these services? e.g. regulation of fish quotas by community members, etc.
How is the land managed adjacent/upstream/downstream to where the water is used?

All samples were analysed for the following parameters: temperature; suspended solids (turbidity); conductivity; pH; dissolved oxygen; ammonia; chloride; nitrate; nitrite; phosphate; salinity; aluminium; magnesium; and iron. These water quality parameters were chosen as they may be able to indicate potential activities within the water catchment, such as mining and logging, and may be able to partially explain the relative abundance of certain species (for example, low levels of dissolved oxygen may explain the low diversity and abundance of certain fish species). Two specific activities were investigated for their impacts on water quality: mining and logging. The principal indicators for both these activities were relative increases in suspended solids, conductivity and dissolved nutrients, with a concurrent decrease in dissolved oxygen. Decreases in pH are usually associated with intensive mining (Chapman, 1996). Unfortunately it was not possible to measure mercury levels in the water as an indicator of gold mining due to constraints of equipment, preservation of samples and costs. Analysis of these activities on water quality impacts had to take into the natural variation, hence the need for the River Habitat Surveys and interviews with local communities.

All water quality data were entered into a database and analysed using a multivariate statistical software package CANOCO 4 (ter Braak and Smilauer, 1998). Principal Component Analysis was used to determine any associations between water bodies and water chemical quality.

RESULTS

Makushi water use and management

The Makushi utilise a number of different water bodies depending on whether it is the wet or the dry season for a number of varying uses. Results from the survey at Surama Village are analysed in detail to indicate the different types of use and the seasonal fluctuations in use (Table 2). Results indicate that fishing is the dominant service from the water sources (excluding the water holes). The pools and creeks become particularly important in the dry season as an easy source of fish, these being close to the community. However, they support only a limited range of fish species, and for greater diversity, the rivers are used. The main river channels are located at a greater distance from Surama than the pools and creeks so 'fishing trips' are undertaken, lasting from two days to a week. During these trips, fishing is almost continuous, and for short-term preservation, fish are salted and smoked along the journey.

Table 2
Water sources used by Surama Village

Water sources	Uses	Distance from community (time to walk)	Temporal use	Changes in condition
Water holes	Bathing, cooking, drinking	1–5 min	All year	Some have begun to dry out in dry season
Surama lake	Drinking, fishing	1 h	All year	Decrease in fish abundance, attributed to overfishing and fires in surrounding vegetation
Tiger pond	Fishing	1 h	Dry season	No
Hassa pool	Fishing	1 h	Dry season	No
Saba pool	Fishing	20 min	Dry season	No
Taramu creek	Fishing	1 h	Dry season	No
Surama creek pool	Drinking, fishing	1 h	Dry season	Decrease in fish abundance, attributed to overfishing and fires in surrounding vegetation
Burro–Burro river	Fishing	2 h, normally sleep overnight	All year	No
Sipariparu river	Fishing	1 day by boat with engine	1–2 trips per year lasting about a week	No
Cuipuru river	Fishing			
Siparuni river	Fishing	2 day by boat with engine	1–2 trips per year lasting about a week	Decrease in fish abundance and species, attributed to past mining along the river
Essequibo river	Fishing	3 days by boat with engine	1–2 trips per year lasting about a week	Decrease in fish abundance and species, attributed to past mining near confluence with Siparuni river

Table 3 Frequency of fishing visits and technique of Surama community members during dry season

Dry Season	Burro-Burro River	Hassa Pool	Surama Creek	Surama Lake	Saba Pool	Taramu Creek	Totals
Visits	52	42	38	133	18	40	323
Hook	8	0	0	6	0	2	16
Seine	3	1	5	11	1	2	23
Hands	1	2	1	1	0	1	6
Bow	1	1	0	3	0	1	6
Cast	1	3	6	6	0	3	19

A detailed analysis of fishing habits in the Surama community is presented in Table 3 and Table 4. This shows the frequency of visits to each site over the season and the technique the community member used during fishing (a person may have used more than one technique). The tables show that although a similar frequency of visits are undertaken for fishing during the dry and wet season, the sites chosen for fishing vary significantly between the seasons: the Burro-Burro River, Surama Lake, Saba Pool and Hassa Pool are the preferred sites during the dry season while Surama Creek and Taramu Creek are the overwhelmingly preferred sites during the wet season. A greater variety of fishing techniques is used during the dry season, while the hook is the dominant technique during the wet season.

Table 4. Frequency of fishing visits and technique of Surama community members during wet season.

Wet season	Burro-Burro River	Hassa Pool	Surama Creek	Surama Lake	Saba Pool	Taramu Creek	Totals
Visits	16	0	107	79	6	122	330
Hook	3	0	4	3	0	5	15
Seine	0	0	0	2	2	1	5
Hands	0	0	0	0	0	0	0
Bow	0	0	0	0	0	0	0
Cast	0	0	0	0	0	0	0

Table 5 Frequency of fish caught by Surama community members during the dry season, where 1 = rare, 2 = occasional, 3 = common, 4 = abundant.

Common name	Burro-Burro River	Hassa Pool	Surama Creek	Surama Lake	Saba Pool	Taramu Creek
Arapaima				1		
Arawana				1		
Baiara	4					
Banana fish	1					
Basha	4					
Butter fish	4					
Dare	1					
Dawala	4					
Dog fish (fox fish)				3		
Electric eel	1					
Fine fish	2				2	
Haimara	3					
Hassa		2	2	3		2
Houri			4	2	4	3
Imehri ("boots"/black)						
Imehri (brown)						
Kassi	1					
Kulet	1			1		
Kwan (type of dare)	4					
Lukanani				1		
Manji	1					
Perai	2				3	
Perai (red)				2		2
Perai (white)				2		
Policeman fish	1					
Satellite fish	4					
Sting ray	1					
Sun fish	1					
Tiger fish (rekiimi)	4					
Yakatu	4			3		
Yaki	1		1			
Yarrow		3	3	3		3

Interview data of fish catch abundance of the Surama community is summarised in Table 5 (dry season) and Table 6 (wet season). All fish nomenclature is derived from Forte (1996) and given in the Table 7. The tables illustrate that the Burro-Burro River and Surama Lake have the greatest diversity of species, and catches are more abundant compared to other sites during both the dry and wet season. Catches in the other sites are mostly restricted to Hassa, Houri, Perai and Yarrow, all medium to small sized fish.

Table 6 Frequency of fish caught by Surama community members during the wet season, where 1 = rare, 2 = occasional, 3 = common, 4 = abundant.

Common name	Burro-Burro River	Hassa Pool	Surama Creek	Surama Lake	Saba Pool	Taramu Creek
Arapaima				1		
Arawana				1		
Baiara	4					
Banana fish	4					
Basha	1					
Butter fish	4					
Dare	1					
Dawala	4					
Dog fish (fox fish)				4		
Electric eel	4					
Fine fish	2					
Haimara	1					
Hassa		1	1	1		1
Houri			1	1		1
Imehri ("boots"/black)	3					
Imehri (brown)	3		2			
Kassi	3					
Kulet	4			4		
Kwan (type of dare)				4		
Lukanani				1		
Manji	4					
Perai	2				.	
Perai (red)				2		2
Perai (white)				2		
Policeman fish	4					
Satellite fish	1					
Sting ray	3					
Sun fish	1					
Tiger fish (rekiimi)	4					
Yakatu	3		2	4		2
Yaki	3		2			
Yarrow		1	1	4		1

Similar results are reflected in Apoteri, Rewa, Wowetta and Rupertee communities (Table 8, Table 9, Table 10, and Table 11 respectively). The rivers, for example, the Rewa, Rupununi and Essequibo, have a greater abundance and variety of species, compared to the ponds and creeks. This is particularly apparent in Rupertee. Apoteri has access to two large rivers, and as can be seen from Table 9, probably has the greatest diversity and abundance of fish available to its community members.

River Habitat Survey analysis

A principle component analysis of the RHS data did not show strong differentiations in the sites (eigenvalues for ordination axis 1 = 0.133, axis 2 = 0.125, axis 3 = 0.09, axis 4 = 0.07), representing only 41.8% of the variation within the data set. Nevertheless, an attempt was made to illustrate the distributions along the first two axes for both the sample sites and the RHS variables. Table 12 shows the sample sites that produced scores greater than 0.5 or less than –0.5 for both axes, whilst Table 13 shows the RHS variables with scores greater than 0.5 or less than –0.5 for both axes. For the sample sites, distribution along axis 1 shows a grouping between the Rupununi river sample sites at the negative end of the axis and a grouping of the Burro-Burro river and Surama Creek sites at the positive end. A different relationship occurs on axis 2 where the Burro-Burro river sites are grouped at the negative end of the axis whilst the Surama Creek sites are grouped at the positive end of the axis.

For the RHS variables, distribution along axis 1 can be explained through variation in the bank material and channel substrate. Bank material of gravel sand and channel substrate of sand are the most negative variables whilst bank material of earth and channel substrate of silt/mud are the most positive variables. A different relationship occurs on axis 2 where the distribution along the axis is explained through the difference of flow within the water body. At the negative end of the axis the variable with the most negative score is that of “smooth flowing water” whilst at the positive end of the axis the variables with the most positive scores are “no perceptible flow” and “marginal deadwater”.

The scores for sample sites and RHS variables indicate a relationship between the Rupununi River sites and bank and channel material of sand variables. There is also a relationship between the Burro-Burro River and Surama Creek sites with bank and channel material of earth, mud and silt. The axis 2 scores suggest that the Burro-Burro River sites are associated with smooth flowing water whilst the Surama Creek sites are associated with no flow and marginal deadwater.

Table 7. Fish species found in this study (all nomenclature derived from Forte, 1996).

Common name	**Scientific name**
Arapaima	*Arapaima gigas*
Arawana	*Osteoglossum bicirrhosum*
Baiara	*Hydrolycus scomberoides*
Banana fish	*Pseudodoras sp.*
Basha	*Plagioscion sp.*
Butter fish	*Acestorhynchus sp.*
Cartabac	*Myleus rubripinnis*
Dare	*Leporinus sp.*
Dawala	*Ageneiosus ogilviei*
Dog fish (fox fish)	*Acestrorhynchus sp.*
Electric eel	*Electrophorus sp.*
Fine fish	*Astyanax sp.*
Haimara	*Hoplias macrophthalmus*
Hassa	*Hoplosternum sp.*
Houri	*Hoplias malabaricus*
Imehri ("boots"/black)	*Trachycorystes galeatus*
Imehri (brown)	*Trachycorystes sp.*
Kassi	*Rhomdia holomelas*
Kulet	*Pseudoplatystoma sp.*
Kwan (type of dare)	*Leporinus sp.*
Lau lau	*Brachyplatystoma sp.*
Lukanani	*Cichla sp.*
Manji	*Megalonema platycephalum*
Paku	*Colossoma sp.*
Patwa	*Cichlasoma sp.*
Peacocked-tailed bass	*Cichla ocellaris*
Perai	*Serrasalmus sp.*
Perai (red)	*Serrasalmus nattereri*
Perai (white)	*Serrasalmus sp.*
Policeman fish	*Trachycorystes sp. ?*
Satellite fish	Unknown
Sting ray	*Potamotrygon sp.*
Sun fish	*Crenicichla sp.*
Sword fish	*Boulengerella cuvieri*
Tiger fish (rekiimi)	*Pseudoplatyatoma sp.*
Yakatu	*Prochilodus rubrotaeniatus*
Yaki	*Rhomdia sp.*
Yarrow	*Hoplerythrinus unitaeniatus*

Water quality analysis

The quality of water sources used by Surama Village is given in Table 14. A principal component analysis was also carried out on the water quality measurements of 77 water bodies, including pools, creeks, the Burro-Burro and Rupununi Rivers and their tributaries, surrounding the communities of Surama, Annai, Crashwater, Wowetta, Rupertee, Rewa and Apoteri.

The result of the first analysis identified two outliers on axis 1, Hassa Pool (HP) and Surama Creek (SC), and two outliers on axis 2: Crashwater well 1 (Cr1) and Crashwater well 3 (Cr3). Hassa Pool had standing water and was used by Tapirs for defecation, thus had extremely high concentrations of dissolved ammonia (6.37 mg/l) and other dissolved chemicals (EC reading of 341 mg/l). Dissolved oxygen levels were also extremely low (4.3 %). Surama Creek also had standing water and was situated very closely to the slash-and-burn plots of some Surama community members. Crashwater 1, was a recently dug well whose walls had been fortified by bricks and mortar, possibly explaining the anomalously high pH value (9.5). Crashwater 3, on the opposite end of axis 2, was a freshly dug shallow well within podzolic soil, and had an extremely low pH value (3.77) and relatively high concentrations of dissolved aluminium (0.41 mg/l) and iron (0.2 mg/l) when compared to other well data.

Table 8. Frequency of fish caught by Rewa community members during the wet and dry seasons, where 1 = rare, 2 = occasional, 3 = common, 4 = abundant.

	Wet Season				**Dry Season**			
Common name	**Rewa River**	**Rupununi River**	**Ponds**	**Creeks**	**Rewa River**	**Rupununi River**	**Ponds**	**Creeks**
Peacock-tailed bass	4	4	3	3	3	3	2	1
Baiara	4	4			3	3		
Kulet	4	4	3	3	4	4	3	2
Tiger fish	3	3		2	4	4		
Perai	2	2	1	1	2	2	1	1
Kataback	4	4	3	3	4	4	4	3
Pacu	4	4			3	3		
Arawana	3	3			3	3		
Imehri ("boots"/black)	3	3	4	4	1	1	1	

A second analysis was carried out after the removal of these outliers. This showed that Tiger Pool, Taramu Creek, Annai 10, Annai 11, Annai 12, Burro-Burro 0, and Apoteri 1 were significant outliers on axis 1, once again characterised by higher concentrations of dissolved chemicals (high EC readings) especially ammonium and iron. These sites also had the lower dissolved oxygen readings and higher turbidity values.

The final analysis was carried out with the removal of all previous outliers and shows a distinction between the well data and river data (Figure 2). This is represented by the sites' distribution on axis 1 which accounts for 30% of data variance. The differentiation in sites is characterised by the lower pH values and higher concentrations of aluminium, ammonium and magnesium of wells, while open water sites showed higher electric conductivity readings and dissolved oxygen values. The turbidity and iron values were highly variable and did not show significant differences (axis 2 representing only 19% of data variance).

A principle component analysis was carried out with the water hole and well data excluded from the data set. This allowed a correlation to be undertaken between sample scores from the RHS principle component analysis with that of the water quality principle component analysis. This was undertaken to investigate whether there was a relationship between water quality and the RHS variables measured. The correlation results indicate that the water quality axis 1 has a significant correlation with axis 1 and axis 2 of the RHS H ($r = 0.49$, $r = 0.6$ respectively, $p< 0.001$). Distribution along the water quality axis 1 is explained by dissolved oxygen and turbidity at the negative end of the axis and electrical conductivity and ammonia at the positive end. Correlation between this relationship and the results of the RHS analysis suggests that the changes in bank and channel material and the presence of flowing water or standing water have an impact on the levels of turbidity, dissolved oxygen, electrical conductivity and ammonia found within the water bodies.

Table 9. Frequency of fish caught by Apoteri community members during the wet and dry seasons, where 1 = rare, 2 = occasional, 3 = common, 4 = abundant.

	Wet Season				**Dry Season**			
Common name	**Rupununi River**	**Esequibo River**	**Ponds**	**Creeks**	**Rupununi River**	**Esequibo River**	**Ponds**	**Creeks**
Peacock-tailed bass	4	4	3		3	3	2	
Baiara	4	4			3	3		
Kulet	4	4	3		4	4	3	
Tiger fish	3	3	2	2	4	4	4	4
Perai	2	2	2	2	2	2	2	2
Cartabac	4	4	3		4	4	3	
Paku	4	4			3	3		
Arawana	3	3			3	3		
Imehri ("boots"/black)	3	3	4	4	1	1	1	1
Dare	1	1	1		3	3	2	
Houri			1	1			1	1
Hassar			1	1			2	2
Patwa			1	1			4	4
Kassi	2	2	3	3	2	2	3	3
Yakatu	1	1	1	1	3	3	4	4
Manji	2	2			1	1		
Basha	4	4			3	3		
Arapaima			1				3	

Table 10. Frequency of fish caught by Wowetta community members during the wet and dry seasons, where 1 = rare, 2 = occasional, 3 = common, 4 = abundant.

	Wet Season			Dry Season		
Common name	Bash Pond	Mourai Pond	Rupununi River	Bash Pond	Mourai Pond	Rupununi River
Hassar	1	1		2	2	
Kassi	2			4		
Hourri	4	4		3	3	
Yarrow	4	4		4	4	
Peacock-tailed bass			4			3
Perai			2			2
Kulet			3			4
Arawana			4			4
Imehri ("boots"/black)			3			1
Patwa		1			4	
Yakatu		1			3	
Haimara		4			4	

Table 11. Frequency of fish caught by Rupertee community members during the wet and dry seasons, where 1 = rare, 2 = occasional, 3 = common, 4 = abundant.

	Wet Season		**Dry Season**	
Common name	**Bash Pond**	**Rupununi River**	**Bash Pond**	**Rupununi River**
Sword Fish		4		4
Peacock-tailed bass		1		3
Basha		4		3
Butter fish		4		4
Perai		4		2
Banana fish		4		4
Kulet		4		4
Baiara		1		3
Manji		3		1
Policeman fish		4		1
Pire fish		3		4
Imehri ("boots"/black)		4		1
Lau lau		4		1
Arawana		4		3
Paku		3		1
Hassar	1		2	
Kasso	2		4	
Hourri	1		3	
Yarrow	3		3	

DISCUSSION

Fishing patterns of the Makushi

Fishing is probably the most important service provided by the waterways for the Makushi Amerindians of the Rupununi District. Table 2 indicates the range of water bodies used by the Makushi for fishing, including creeks, pools, ponds and rivers, and although drinking takes place in some of these places, this is a secondary service due to the availability of wells and water holes. Fishing is an almost daily subsistence activity, and community members may typically spend half a day fishing, catching enough fish to last a day or two. Normally, one or two members of the family go fishing, but in cases when the whole day may be spent fishing, the entire family may go along to help. Water bodies within easy reach of the communities are fished all year round, although the amount of 'effort' i.e. the frequency of visits to each site, varies interestingly between the seasons. During the dry season, the pools, lake and river are most important to the Surama community (Table 3). This is due to the high concentration of fish in the confined water bodies (pools and lake) allowing easy and rapid fishing. In fact, Table 3 shows that the techniques of seine and cast net fishing are mainly employed during this period, reflecting the high abundance of fish, and the fact that the majority of fish found are small to medium sized. These are limited to species such as Hassa, Houri, Perai and Yarrow. For larger and a more diverse range of species, community members visit Surama Lake or the Burro-Burro River (Table 5) and have to use hooks to catch particular species. Although the amount of 'effort' is similar to the dry season, the creeks become much more important in the wet season (see Table 4). With the greater quantity of water in the creeks and flooding of nearby forest, they become the predominant source of fish. However, the concentration of fish is reduced, so fishing is mainly done using hooks, and the lake and river are still the sources of a variety of fish species (Table 6). The other communities surveyed rely more heavily on the rivers (Tables 8, 9, 10 and 11) in both the wet and dry season, although ponds do become more important during the dry season.

The physical characteristics of the water sources used by the Makushi

The RHS PCA results indicate weak relationships between sites and characteristics due to the complexity and heterogeneity in the later, but some relationships are discernible, principally between the Rupununi River sites and bank and channel material of sand variables, while the Burro-Burro River and Surama Creek sites had a significant association with banks and channel material of earth, mud and silt variables. This reflects the different surrounding habitat types; savanna vegetation on white sands (Eden, 1964; Sarmiento, 1983) dominates along the Rupununi River, whereas the Burro-Burro River is flanked by lowland tropical forest found on more silty soils (Hawkes and Wall, 1993). Correspondingly, the Rupununi River is a 'whitewater' river whereas the Burro-Burro River is 'blackwater' river. Whitewater rivers are typically more nutrient rich than blackwater rivers, and this is shown by the water quality results which indicate higher EC values along the Rupununi River.

Table 12. River Habitat Survey data PCA axis 1 and 2 scores for sites (only scores greater than 0.5 and less than –0.5 are shown).

Sample sites	Axis 1	Sample sites	Axis 2
Rupununi River (downstream 10 miles)	-1.85	Burro Burro River (70 miles downstream)	-1.24
Rupununi River (upstream of Essequibo confluence)	-1.84	Burro Burro River (60 miles downstream)	-1.20
Rupununi River (upstream of Rewa River)	-1.67	Burro Burro River (downstream of Siparuni confluence)	-1.15
Essequibo River (upstream of Rupununi River)	-1.44	Essequibo River (upstream of Burro Burro River)	-1.10
Essequibo River (downstream of Rupununi River)	-1.41	Burro Burro River (upstream of Essequibo confluence)	-1.07
Rupununi River (30 miles downstream)	-1.35	Burro Burro River (50 miles downstream)	-1.06
Rupununi River (20 miles downstream)	-1.30	Siparuni River (upstream of Burro Burro River)	-1.05
Rupununi River (downstream of Bat Creek)	-1.19	Burro Burro River (downstream of Cuipuru)	-1.03
Rupununi River (50 miles downstream)	-1.07	Cuipuru River (upstream of Burro Burro River)	-0.92
Rupununi River (Annai landing)	-1.04	Siparuni River (upstream of Burro Burro River)	-0.91
Rupununi River (upstream of Crashwater Creek)	-0.98	Burro Burro River (upstream of Siparuni confluence)	-0.89
Rupununi River (40 miles downstream)	-0.97	Essequibo River (downstream of Burro Burro River)	-0.87
Rewa River (upstream of Rupununi River)	-0.96	Burro Burro River (40 miles downstream)	-0.83
Rupununi River (downstream of Rewa River)	-0.86	Burro Burro River (downstream of Siparuni confluence)	-0.82
Saba Pool	-0.80	Burro Burro River (upstream of Siparuni confluence)	-0.71
Rupununi River (upstream of Bat Creek)	-0.77	Burro Burro River (20 miles downstream)	-0.62
Crashwater Creek (upstream of Rupununi River)	-0.51	Burro Burro River (upstream of Cuipuru)	-0.61
Burro Burro River (upstream of Essequibo confluence)	0.55	Bat Creek (upstream of Rupununi River)	-0.53
Burro Burro River (40 miles downstream)	0.57	Burro Burro River (10 miles downstream)	-0.52
Siparuni River (upstream of Burro Burro River)	0.58	Rupununi River (40 miles downstream)	0.52
Burro Burro River (downstream of Siparuni confluence)	0.58	Hassa Pool	0.77
Burro Burro River (downstream of Cuipuru)	0.60	Burro Burro River (Upstream of Surama Creek)	0.80
Burro Burro River (50 miles downstream)	0.61	Surama Lake	0.91
Bat Creek (upstream of Rupununi River)	0.64	Taramu Creek (Tiger Pond)	0.94
Burro Burro River (upstream of Siparuni confluence)	0.67	Saba Pool	1.17
Burro Burro River (downstream of Siparuni confluence)	0.68	Surama Creek (Pool 2)	1.27
Siparuni River (upstream of Burro Burro River)	0.71	Surama Creek (Pool 1)	1.34
Cuipuru river (upstream of Burro Burro River)	0.71	Rupununi River (Annai landing)	1.35
Burro Burro River (60 miles downstream)	0.73	Burro Burro River (downstream of Surama Creek)	1.47
Burro Burro River (20 miles downstream)	0.86	Crashwater Creek (upstream of Rupununi River)	1.53
Taramu Creek (Tiger Pond)	0.89	Surama Creek (Chris Pool)	1.61
Hassa Pool	1.06	Taramu Creek (last pond of creek)	1.78
Burro Burro River (10 miles downstream)	1.23	Surama Creek (upstream of Burro Burro River)	2.93
Taramu Creek (last pond of creek)	1.25		
Surama Creek (Pool 2)	1.50		
Surama Creek (Pool 1)	1.54		
Surama Creek (Chris Pool)	1.96		

Although the pilot study did not detect any harmful levels of chemicals in any of the sites, there were some interesting variations in water quality. Some stagnant pools had extremely high concentrations of natural chemicals, but several fish species were still abundantly fished from those sites. For example, Hassa Pool and Surama Creek Pool had ammonia levels of 6.73 mg/l and 4.03 mg/l respectively, and supported high numbers of Hassa, Houri and Yarrow species. Although the majority of wells had acidic water, some wells had particularly low pH values e.g. pH 3.77. Further investigation is needed to examine whether this has any potentially harmful effects on health.

Table 13. River Habitat Survey data PCA axis 1 and 2 scores for variables (only scores greater than 0.5 and less than –0.5 are shown).

River habitat survey variable	**Axis 1**	**River habitat survey variable**	**Axis 2**
Bank material - gravel sand	-0.90	Smooth water flow	-0.67
Channel substrate - sand	-0.77	Underwater tree roots	-0.66
Bare bankface	-0.57	Eroding earth cliff banks	-0.65
Right hand bank height	-0.53	Depth of water	-0.63
Presence of pools	0.51	Overhanging tree boughs	-0.61
Extent of trees	0.51	No channel vegetation	-0.60
Number of unvegetated point bars	0.52	Ponded reaches	0.54
Exposed bankside tree roots	0.65	Number of unvegetated point bars	0.54
Lowland Tropical Forest within 50m of banktop	0.66	Complex vegetation structure on bankface	0.56
Lowland Tropical Forest within 5m of banktop	0.74	Slash and Burn agriculture within 50m of banktop	0.57
Channel substrate - silt/mud	0.76	Unvegetated side bar	0.60
Bank material - earth	0.89	Emergent broad-leaved herbs in the channel	0.65
		Marginal deadwater	0.71
		No perceptible flow	0.74

Table 14. Quality of water sources used by Surama Village. *these are the average values from 18 wells sampled.

Water quality indicators	Water source										
	Water holes*	Surama Lake	Tiger Pond	Hassa Pool	Saba Pool	Taramu Creek	Surama Creek Pool	Burro-Burro River	Sipariparu River	Siparuni River	Cuipuru River	Essequibo River
pH	5.13	5.90	6.63	6.70	6.22	6.63	6.53	6.31	5.91	5.57	5.79	6.15
DO2 (%)	53.35	91.5	15.6	4.3	80.3	16.3	9.23	77	71.6	79.2	72	97
EC (mg/l)	14.33	24.7	131	341	26	130	103	24	23	18	27	18
Salinity	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°C)	27.74	28.3	27.2	24.7	30.9	26.7	23.7	24.9	23.8	25.1	23.8	28.6
Turbidity (NTU)	<10	10-20	<10	>40	<10	<10	>40	<10	<10	<10	<10	<10
Chloride (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0
Aluminium (mg/l)	0.03	0.01	0.04	0	0.01	0.03	0	0.03	0.01	0.01	0.01	0.07
Ammonia (mg/l)	0.14	0.19	0.97	6.73	0.03	1.23	4.03	0.06	0.02	0.18	0.18	0.05
Iron (mg/l)	0.01	0	0.38	1.33	0	0.44	0.27	0	0	0.25	0.25	0.15
Magnesium (mg/l)	8.58	8.5	5.67	4.5	0	4.25	0	7.5	0	0	0	8.0
Nitrite (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0
Nitrate (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0
Phosphate (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0

Table 15 Correlation coefficients for river habitat survey and water quality axis 1 and 2 PCA scores

	Water quality axis 1	Water quality axis 2
River habitat survey axis 1	0.49	0.23
River habitat survey axis 2	0.60	0.17

Impacts on Makushi water sources: present state and questions for the future

A rich diversity of fish species are harvested by the Makushi, particularly in the rivers. A feature of this biodiversity is the continued presence of healthy populations of many species that have been overharvested in many other Amazonian areas. These include the Arapaima (*Arapaima gigas*), Kulet (*Pseudoplatystoma* sp.), Lau Lau and Tiger fish

(*Brachyplatystoma* spp.), Lukunani (*Cichla* sp.), Paku (*Colossoma* sp.) and the Peacock Bass (*Cichla ocellaris*) (Watkins, 1999).This 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.

The RHS and water quality data corroborate the fish species information, in that no significant evidence indicated that logging, mining or other human activities were having an effect on the hydro-morphological parameters measured, probably as a result of the current limited extent of these operations. These measurements will now be used as a baseline from which any future changes can be compared.

The results of the study are somewhat in contrast to views aired by the Makushi community. Some Surama community members commented on the decrease of fish populations in the Siparuni River and at the confluence of the Burro-Burro with the Essequibo River and blamed past mining in the area (see Table 2). It may be that enough time had passed for the chemical traces of mining on the rivers to be negligible, or that the indicators used in this study were not appropriate for picking up the effects. Mercury pollution, for example, is one of the main environmental pollutants in riverbed mining, but it was not possible to test this in the present study due to costs and technical difficulties. Spawning grounds may have been damaged by the digging up of the river beds and subsequent changes in turbidity could explain the loss of fish. A survey of fish and spawn populations in these rivers and the post-disturbance recovery period would be an important study in the future.

Of the sites close to the communities, again there is no evidence of human impact on water quality. This is especially true of nitrates, nitrites and phosphates that would only come from detergents, agricultural pollution etc. This is an important result because at the moment these levels are negligible. The Makushi practice slash-and-burn cultivation, and it seems that at present this is not having a significant impact on the water courses. However, some community members in Surama commented on the increased incidence of forest fires, sometimes a result of agricultural burns becoming uncontrollable. This could potentially affect local waterways in terms of sediment load and nutrient status, as could agricultural intensification. Regular fires in the savanna vegetation around Annai, Rewa, Wowetta and Rupertee could also be affecting fish populations, as the savanna floods in the wet season thus becoming significant spawning grounds (personal communication, Dr Graham Watkins).

Although the data collected indicates that the environment where the Makushi live is unaffected by extractive economic activities at present reduced levels, the measurements taken were one off, and since seasonal variations may be significant, regular monitoring is needed. The study ended with a workshop in Surama Village during which the results of the project were presented to the community members. A monitoring scheme was also proposed and discussed, to be undertaken by one of the authors, Yung Sandy. This involves taking monthly measurements of pH, dissolved oxygen, EC, temperature, turbidity, nitrite, nitrate and phosphate at key sites identified by the community members. It is hoped that this regular monitoring will identify any changes that may take place.

The conservation and management of Makushi water resources: concluding remarks

The extraction of natural resources by local people is believed to be compatible with conservation as long as there is low environmental impact as well as incentives for users to conserve resources provided they hold secure rights (Lynch and Alcorn, 1994). This study indicates that at present there is little or no impact on the waterways used by the Makushi in terms of fish populations, habitat conditions and water quality. However, this could change in the near future. Only 8 of the 24 Makushi communities in the North Rupununi District have legal title to some of their traditional lands (Forte, 1996). With logging and mining concessions moving ever closer to the North Rupununi, and the construction of a major new road potentially running through the area (linking Georgetown with Lethem), adverse effects on the fish communities and their habitats is very probable. In fact, the most recent Guyana National Development Strategy (2001-2010) states that one of the most pressing issues in the freshwater fisheries sector is "the need to protect the waterways from environmentally destructive practices associated with the expansion of mining and forestry operations". The modification of substrates and river morphology through these activities can cause increased turbidity, loss of habitat and alterations in water chemistry, seriously affecting fish species, as well as other aquatic plant and animal life.

In the North Rupununi, the intricate network of rivers, creeks and streams, and the seasonal flooding of the area mean that management of the waterways must have a spatial and temporal dimension. Migration of fish, for example, is an important feature of the area, with some species, such as of the genus *Prochilodus*, travelling distances of over 100 km (Watkins, 1999). During the flooding of the rainy season, fish also travel to other habitats, for example, from riverine forests to wetlands and savannas, to spawn. This implies that even a localised disturbance within a river system has far reaching consequences even beyond the river channel. Therefore, habitats need to be managed within the catchment context to optimise survival at every life stage. The latter point is also pertinent to ecotourism as a form of sustainable management and economic activity in the area. Although tourists are few as yet, visitors come to the area to view the stunning wildlife, including the caiman and giant otters. These top predators in the food chain are also vulnerable to direct changes in their habitat, as well as indirectly through potential decreases in fish populations. The other area of urgent concern is the unmanaged commercial exploitation of fish in the area. Over-harvesting has already seen large decreases in fish populations in other parts of Amazonia. It would seem that economically important species such as the Lukanani and Arapaima, as well as traditional food sources, including the Paku, are being targeted in the North Rupununi District (Watkins, 1999).

It is now being recognised that local stakeholders are integral to the sustainable management of wildlife resources. The role of outside “experts” has shifted from solution provision to capacity-building so that the stakeholders themselves can arrive at a suitable compromise between development and conservation (Dakoh, 2003). The results of this study provided the impetus for a recently funded project by the Darwin Initiative (Department of Environment, Food and Rural Affairs, UK) to begin in late 2003. This will investigate sustainable management of the North Rupununi ecosystems, including the savannas, wetlands and forests, linking the physical attributes of the environment to biodiversity and subsequently local livelihoods. It will also help build capacity for effective biodiversity management through training of six community members and the development of ecosystem management plans and associated monitoring systems for the North Rupununi Region through the participation of local stakeholders.

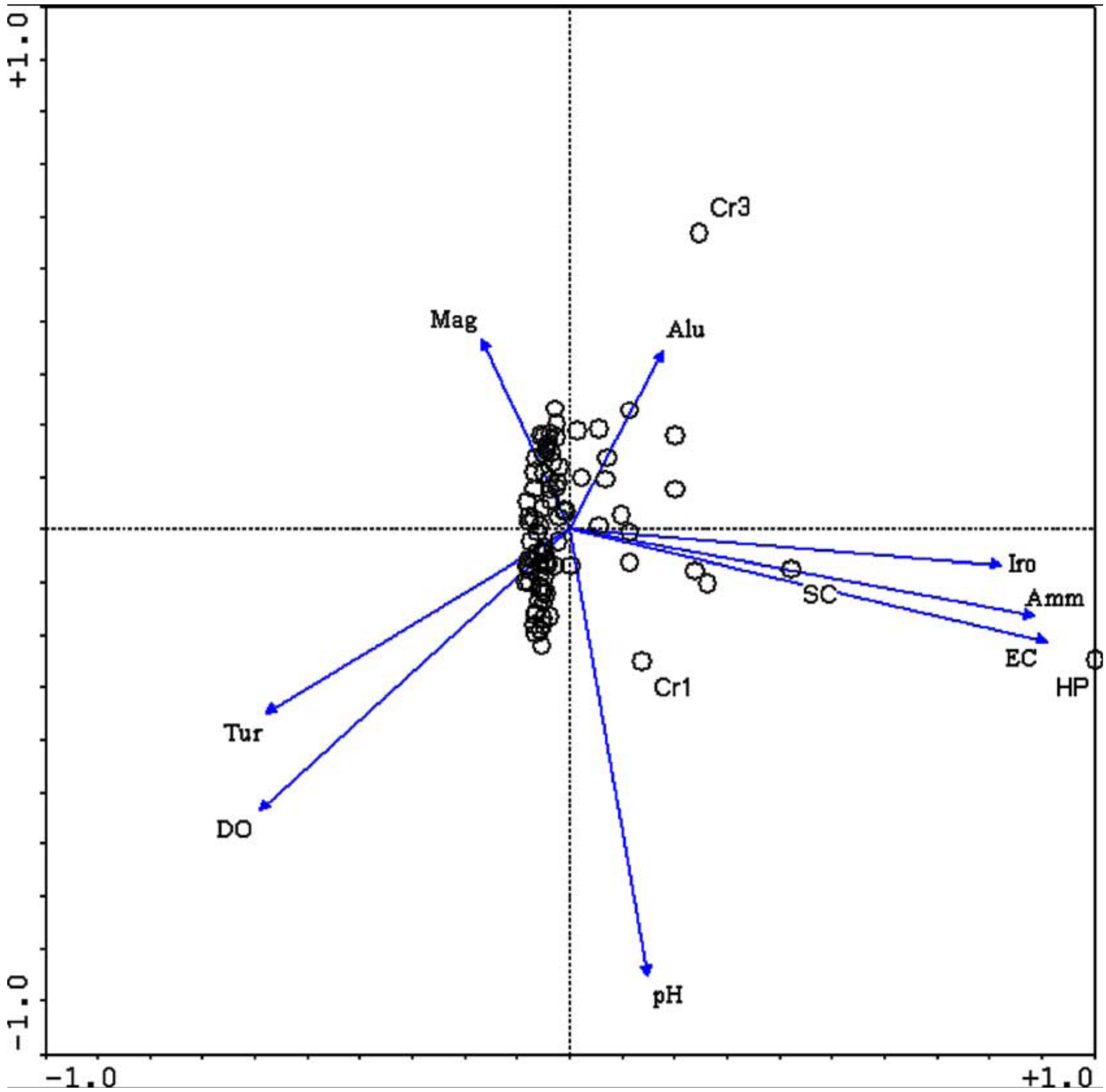

Fig. 2. Principal component analysis of water quality data

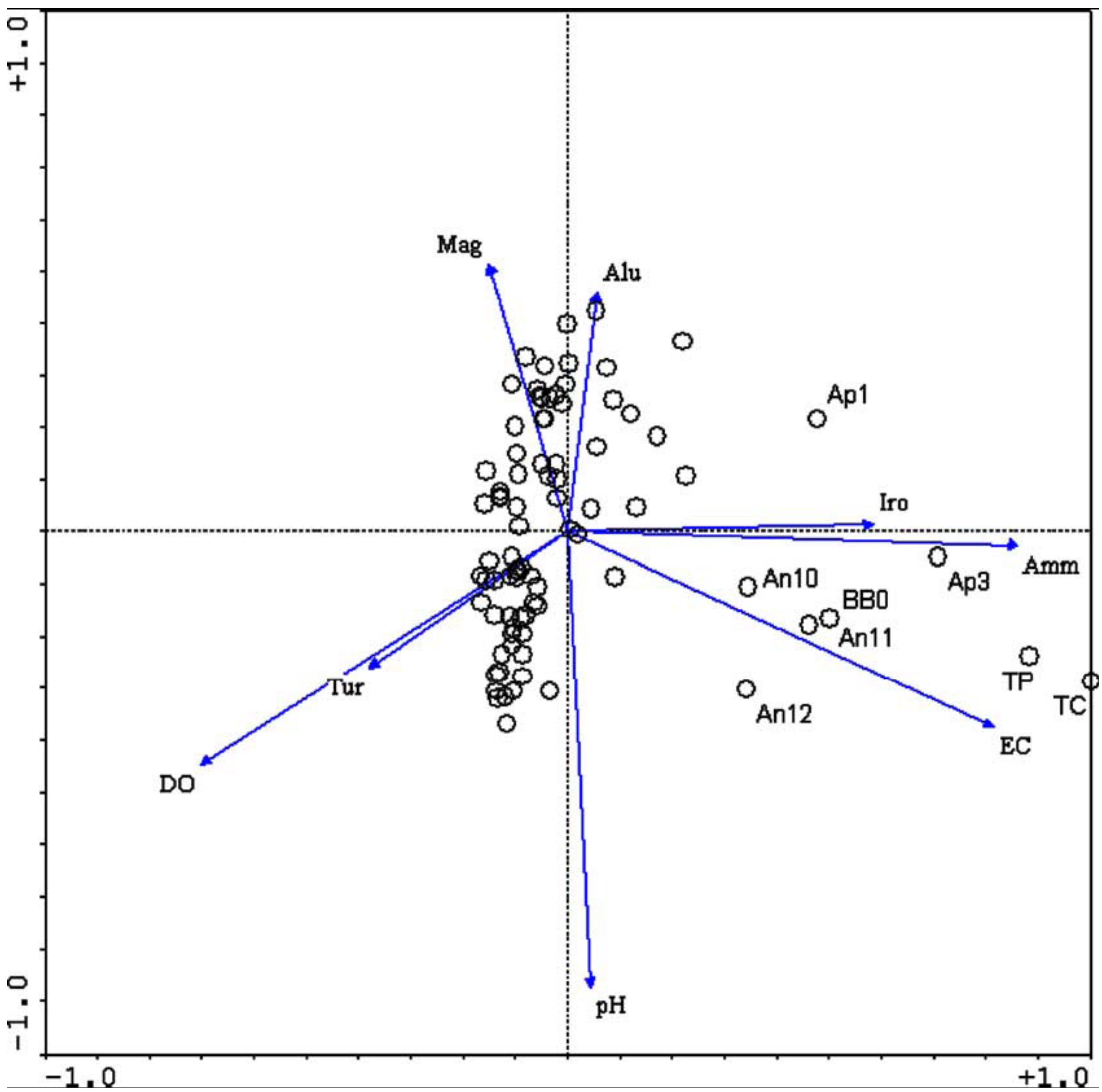

Fig. 3 Principal component analysis of water quality data with the outliers Hassa Pool and Crashwater 3 removed,

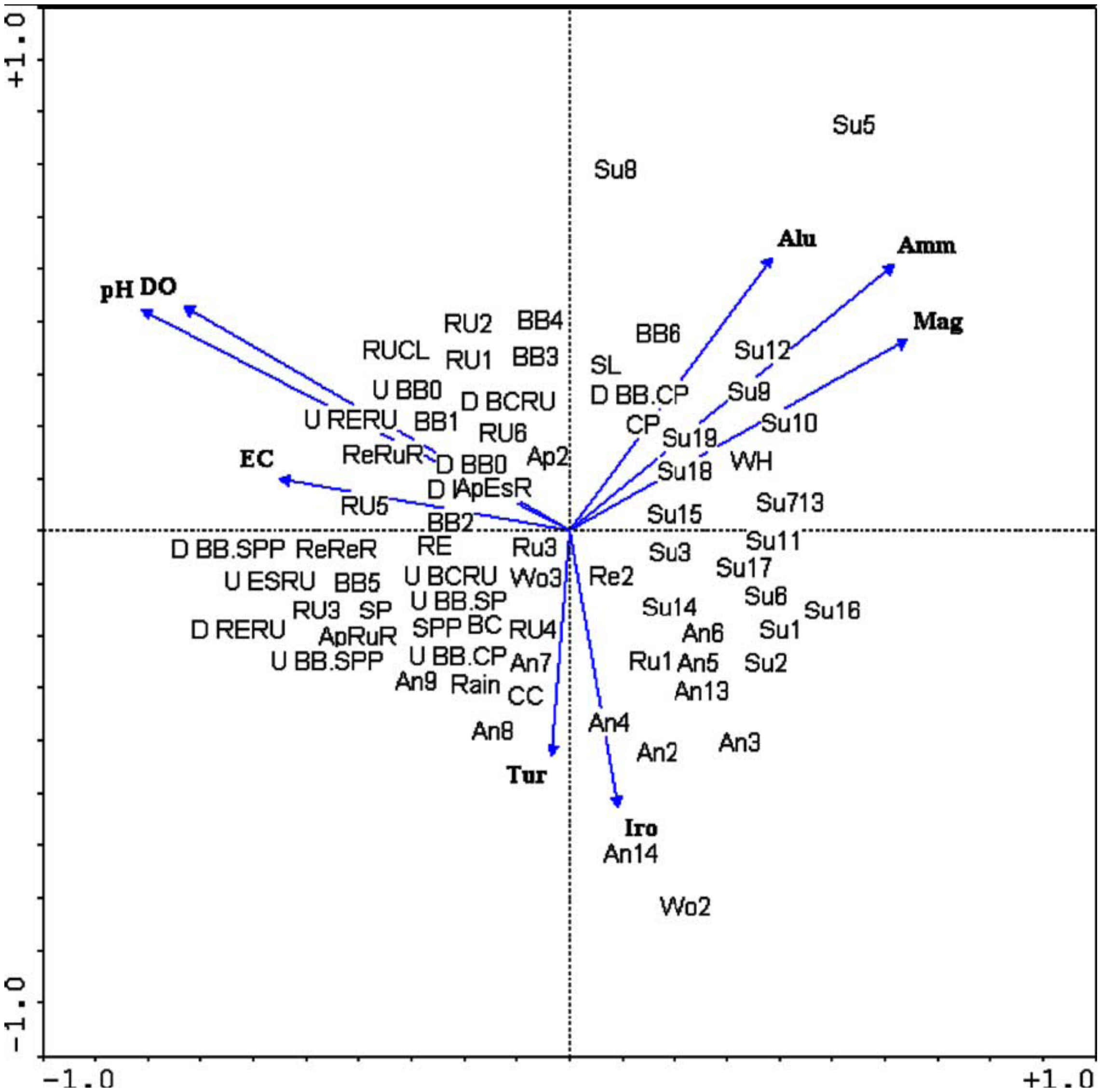

Fig.4. Principal component analysis of water quality data with all major outliers removed.

Abbreviations: DO = dissolved oxygen; Amm = ammonia; Alu = aluminium; Mag = magnesium; EC = electrical conductivity; Tur = turbidity; Iro = iron; Su = Surama well; An = Annai well; Ap = Apoteri well; Cr = Crashwater well; Re = Rewa well; Ru = Rupertee well; Wo = Wowetta well; U = upstream; D = downstream; SL = Surama Lake; SP = Saba Pool; BC = Bat Creek; BB = Burro-Burro River; RU = Rupununi River; RE = Rewa River; SP = Siparuni River; SPP = Sipariparu River; CP = Cuipuru River; EsR = Essequibo River

Recent attempts by the North Rupununi District Development Board and other regional stakeholders to have the North Rupununi officially demarcated and for the Makushi to be granted additional management rights over their landscape, have encountered significant difficulties. It is hoped that the Darwin Initiative's key outputs: management and monitoring plans for the North Rupununi; and a qualified and competent team of Makushi community members for implementing the plans, may provide the appropriate requirements for official acceptance of demarcation. How the North Rupununi will be managed on demarcation will be up to the willingness of the Makushi communities to support and fund the monitoring and management plans.

CONCLUSIONS

The results of our study have implications for the conservation of the Makushi way of life. Firstly, it advocates the current fishing practices and levels of extraction of fish by the Makushi. Secondly, it indicates a pristine environment within which the Makushi could develop sustainable commercial activities to improve their livelihoods. And thirdly, it highlights the need for Makushi-led monitoring and management of the waterways so as to protect both the Makushi communities and their natural resources against unsustainable commercial activities principally perpetrated by external bodies.

ACKNOWLEDGEMENTS

We would like to thank everyone that made this study possible including Dr Norma Bubier, all the residents of Surama Village, especially Sidney Allicock and Yung Sandy, and all the residents of Annai, Crashwater, Wowetta, Rupertee, Rewa and Apoteri. We would also like to thank the following funding bodies: Royal Geographical Society, Royal Holloway, University of London, Mercers Trust and the British Academy.

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