WWF® BIODIVERSITY ASSESSMENT SURVEY OF THE UPPER BERBICE REGION, GUYANA

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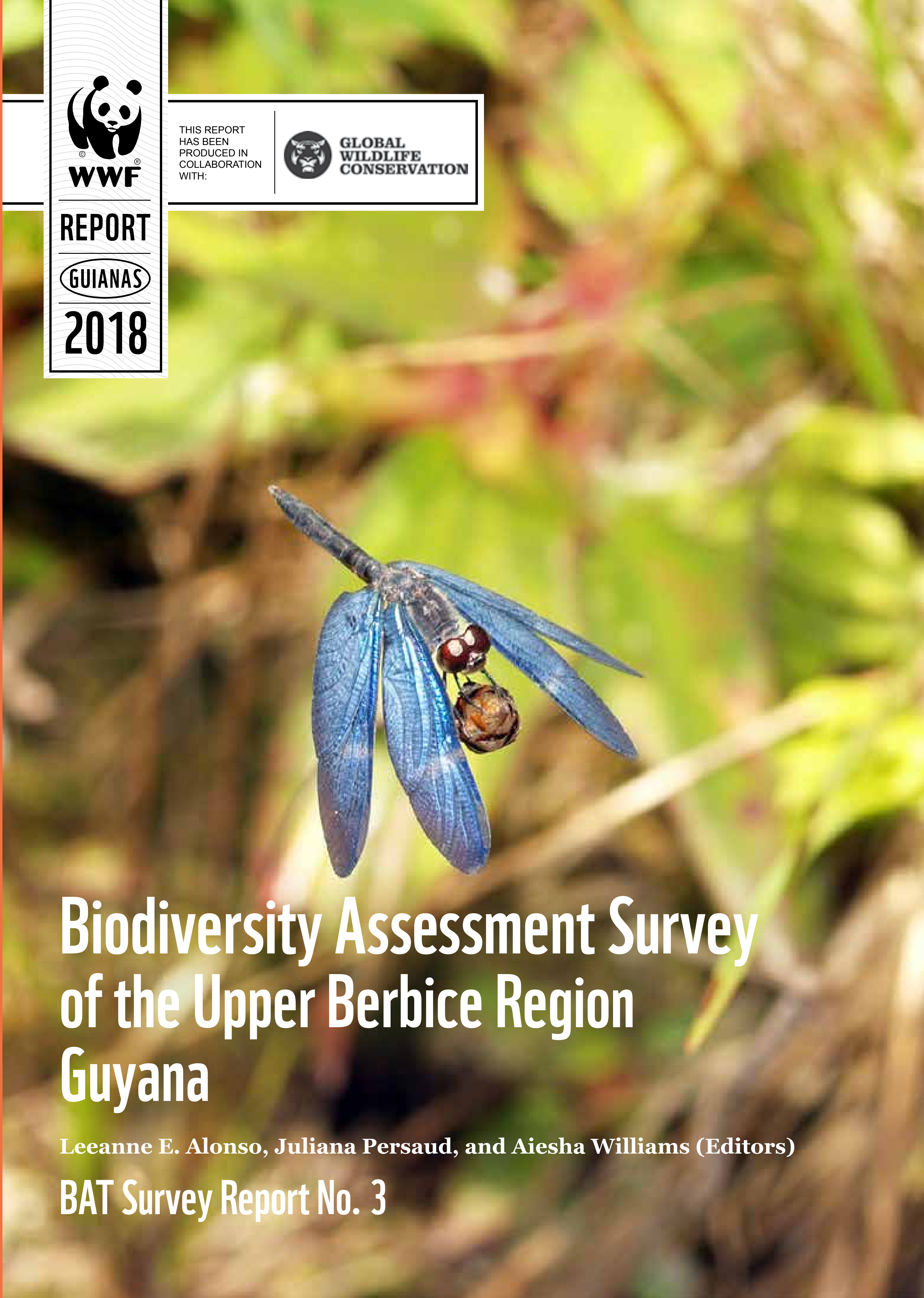

Biodiversity Assessment Survey of the Upper Berbice Region Guyana

Leeanne E. Alonso, Juliana Persaud, and Aiesha Williams (Editors)

BAT Survey Report No. 3

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The longhorn beetle (*Macrodontia cervicornis*) in its habitat. This species, which is listed as vulnerable, is one of the largest beetles, growing to a maximum length of 16.5 cm! It is easily recognisable, given its striking pattern and gigantic mandibles. Forests of the Upper Berbice region support an enormous wealth of biodiversity and generate critical ecosystem services.

This BAT survey and report were made possible through a collaboration of:

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Cover photo: Male of *Zenithoptera fasciata*; its iridescent wings provide a sparkle of colour in the lowland forests of Guyana. Odonates are good indicators of environmental health. © Natalia von Ellenrieder

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Biodiversity Assessment Team survey

Biodiversity Assessment Survey
of the
Upper Berbice Region
Guyana

Field surveys were carried out from 20 September to 2 October 2014

Leeanne E. Alonso, Juliana Persaud, and Aiesha Williams (Editors)

BAT Survey Report No. 3

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2018

Koninkrijk der Nederlanden

Contents

Preface **6**
Acknowledgements **7**
Participants and Authors **8**
The BAT Expedition **11**
  Objectives
  Team and collaborations
  Survey Sites
Context: Ecological Importance of the Upper Berbice Region **16**

The BAT Expedition - Findings in Brief **22**

BAT Recommendations for Conservation and Management of the Upper Berbice Region, Guyana **31**

Chapters

1. **Dragonflies and Damselflies of the Upper Berbice River Region** **34**
   Natalia von Ellenrieder and Rosser Garrison
2. **Amphibians and Reptiles of the Berbice River Camp and White Sands Camp, Guyana** **55**
   Andrew M. Snyder and Timothy J. Colston
3. **A Rapid Assessment of the Forest Avifauna of the Upper Berbice Region, Guyana** **72**
   Brian J. O'Shea
4. **Small Mammals of the Upper Berbice River Region in Guyana** **88**
   Burton K. Lim, Chetwynd Osborne, and Abraham Ignace
5. **Large and Medium Mammals of the Upper Berbice Region, Guyana** **100**
   Meshach Pierre, Leroy Ignacio, Dexter Torres, Edmund Torres, and Evi Paemelaere
6. **Fishes of the Upper Berbice Region, Guyana** **114**
   Donald Taphorn, Leanna Kalicharan, Elford Liverpool, Francesco Janzen and Jabaun Correia
7. **Aquatic Beetles of the Upper Berbice Region, Guyana** **128**
   Andrew Short, Shari Salisbury, and Nelanie La Cruz
8. **Ants of the Upper Berbice River, Guyana** **136**
   Michael G. Branstetter and Leeanne E. Alonso
9. **Decapod Crustaceans (Crabs and Shrimps) and Water Quality of the Upper Berbice Region, Guyana** **148**
   Cleverson R. M. dos Santos and Chetwynd Osborne
10. **Vegetation in the Berbice River Drainage , Guyana** **160**
   Santos Miguel Niño, Isaac Johnson and Zola Narine

APPENDICES

Appendix 1a **166**
Checklist of Odonates recorded during the Upper Berbice River Region Biodiversity Assessment Team (BAT) Expedition.

Appendix 1b **170**
Odonates found during the Upper Berbice Biodiversity Assessment Team Expedition: Habitat where found, data on known larvae, distribution (from Paulson 2015 and material examined), and conservation status according to IUCN Red List

Appendix 2 **173**
Amphibians and reptiles recorded during BAT Survey

Appendix 3 **176**
Final bird list for the upper Berbice biodiversity assessment survey, 21 September - 2 October 2014

Appendix 4 **186**
Small mammals species list

Appendix 5 **187**
Large to medium mammals- species list

Appendix 6 **188**
Fishes from sites in the Berbice and Corentyne River Basins

Appendix 7 **193**
List of aquatic beetles collected during the 2014 BAT survey of the Upper Berbice region of Guyana

Appendix 8 **197**
Preliminary list of identified ant species from BAT3 sampling (B3) near the Upper Berbice River and BAT2 sampling (B2) near Kaieteur Falls and the Upper Potaro River

Appendix 9 **203**
Decapod crustacean species of the Upper Berbice region

Appendix 10 **204**
List of plants collected from the Upper Berbice biodiversity assessment study - 20 September to 2 October 2014

Preface

Guyana's landscape is distinct in many ways, but most remarkable is that more than 85 per cent of it is still covered by rainforests, (the second highest proportion in the world, in terms of percentage of forest coverage relative to a country's total land mass), at a time when other countries are experiencing large-scale biodiversity loss and environmental degradation. At the same time, Guyana's biodiversity remains largely undocumented and poorly studied, leaving its national and regional governments and indigenous communities with a paucity of data on which to base land-use planning decisions.

This WWF (2018) publication represents a broad-based documentation of floral and faunal diversity in the Upper Berbice Region of Guyana, whose forests are among the least studied and most biologically diverse forest types in the Guianas. The Biodiversity Assessment Team (BAT) surveys, which were carried out in 2014, collected new data on terrestrial and freshwater taxonomic groups, and evaluated water quality to provide a comprehensive picture of biodiversity and habitats in the area. The BAT survey methods utilized internationally recognized sampling protocols, and undertook limited specimen collection for future identification and/or archival purposes, both local and foreign. This BAT survey was initiated by the Guyana office of WWF-Guianas, with the close collaboration of Global Wildlife Conservation. This survey included a knowledge exchange and local capacity development component, involving University of Guyana undergraduates, recent graduates, and local community residents along with the lead scientists.

The team of experienced field biologists, taxonomists and student and local community research counterparts worked through challenging field conditions to survey flora and fauna, and worked just as diligently to interpret and present the findings in a meaningful way to government agencies involved in conservation and land-use planning, academics, NGOs and wider civil society. We have by no means captured in full the rich diversity and unique species of this landscape. However, these results allowed us to put forward several recommendations for conservation and management for the wider region. These are elaborated in the BAT Recommendations section as well as in each chapter, and we hope that in Guyana and more broadly, these stimulate important discussions on the protection of tropical forests and freshwater ecosystems, foster collaboration and mobilize strong, meaningful conservation actions.

WWF-Guianas and Global Wildlife Conservation are committed to ensuring that conservation and development objectives are achieved in a way which allows ecosystems and species to persist, and people to enjoy the benefits afforded by functioning ecosystems well into the future.

WWF-Guianas, Guyana Office
Global Wildlife Conservation

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We thank the Centre for the Study of Biological Diversity (CSBD) at the University of Guyana for loaning equipment and ensuring timely verification of specimens, as well as assistance in the process of acquiring the specimen export permits. We also thank the Iwokrama International Centre for Rainforest Conservation and Development for the loan of camera traps.

Our sincere thanks go to the Guyana Ministry of Natural Resources and Environment (now the Department of the Environment) and the Environmental Protection Agency (EPA) for granting permission for the BAT Survey and for specimen export permits.

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Our daring Drivers:

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The BAT Expedition

Biodiversity Assessment Team (BAT) Survey Dates

20 September – 2 October 2014

OBJECTIVES

The principal goal of the Biodiversity Assessment Team (BAT) survey was to collect biodiversity baseline data for the Upper Berbice region that can be used by all stakeholders, including the Government of Guyana, the University of Guyana, local communities, NGOs, and the private sector, to make informed decisions about sustainable management and land use planning for this sub-region. The data will complement that of previous surveys undertaken, namely the South Rupununi BAT expedition, the Potaro/Kaieteur Plateau BAT expedition, as well as other research and monitoring conducted in Guyana, for broader planning and management interventions. The data are intended to contribute generally to the knowledge base for the wider southern Guyana region.

The results of the research will also help to facilitate comparison of various taxa found within the Upper Berbice River region, the Rupununi, and the Upper Essequibo River drainages. The BAT survey was designed to gather new biological data to help guide the relevant communities' resource use and management, and the country's land use planning, biodiversity conservation, and management priorities.

TEAM AND COLLABORATIONS

The Biodiversity Assessment Team (BAT) survey was organized and coordinated by WWF-Guianas in collaboration with Global Wildlife Conservation (GWC). The biodiversity assessment scientific team included Guyanese and international scientists with expertise in the detection and identification of birds, plants, dragonflies, ants, amphibians and reptiles, large mammals, small mammals, aquatic invertebrates (aquatic insects, molluscs, and decapod crustaceans), and fish. Water quality assessments were also part of the activities. The BAT survey methods utilized scientifically sound protocols and included specimen collection for future identification and archival purposes.

The BAT survey also included a knowledge exchange and local capacity development component, involving University of Guyana undergraduates, recent graduates, and local community residents along with lead scientists. For this survey, WWF-Guianas and GWC also collaborated with relevant national and international research institutions and organizations including the Centre for the Study of Biological Diversity (CSBD), University of Guyana, Panthera, and other national and international organizations.

SURVEY SITES

Camp I: Upper Berbice River Camp, 4° 09.241' N, 58° 10.627' W

20–25 September 2014

Camp 1 was located approximately 120 km south of the town of Kwakwani on the eastern half of the Upper Berbice River. The survey area covered approximately a 2 km radius around Camp 1 for most taxa and up to 10 km for birds and large mammals. Except for some recently constructed dirt roads, the area consisted of pristine tropical lowland rainforest on laterite soil. The area was approximately 110 metres above sea level. The dominant tree species here were *Mora excelsa* and *Astrocaryum* sp. palms. Between the campsite and the Berbice River, there were several wet and dry stream beds crossing the landscape. The forest had many very tall trees with large buttress roots, indicating that it is an old and unlogged forest.

Camp 2: Upper Berbice White Sands Camp, 4° 45.297' N, 58° 00.431 'W

26 September – 1 October 2014

Camp 2 was located approximately 75 km north of Camp 1 along the main access logging road. The site was located about 60 metres above sea level. The survey area covered approximately a 2 km radius around Camp 1 for most taxa and up to 10 km for birds and large mammals. The camp bordered a recently burned forest and a relatively pristine wallaba/dakama forest on white sand. Within the forest, the sand was covered with a thick mat of organic matter (leaves and roots), often up to 0.5 m deep. At this time of the year, the mat was very dry. A small black water creek ran through the forest near the camp toward the Corentyne River. The canopy trees of this forest were much shorter than at Camp 1, only up to 20 m tall. The wallaba forest around Camp 2 had three strata: canopy level dominated by dakama (*Dimorphandra conjugata*), mid-level dominated by soft wallaba (*Eperua falcata*), and lower level with many manoco or turu palms (*Oenocarpus bacaba).*

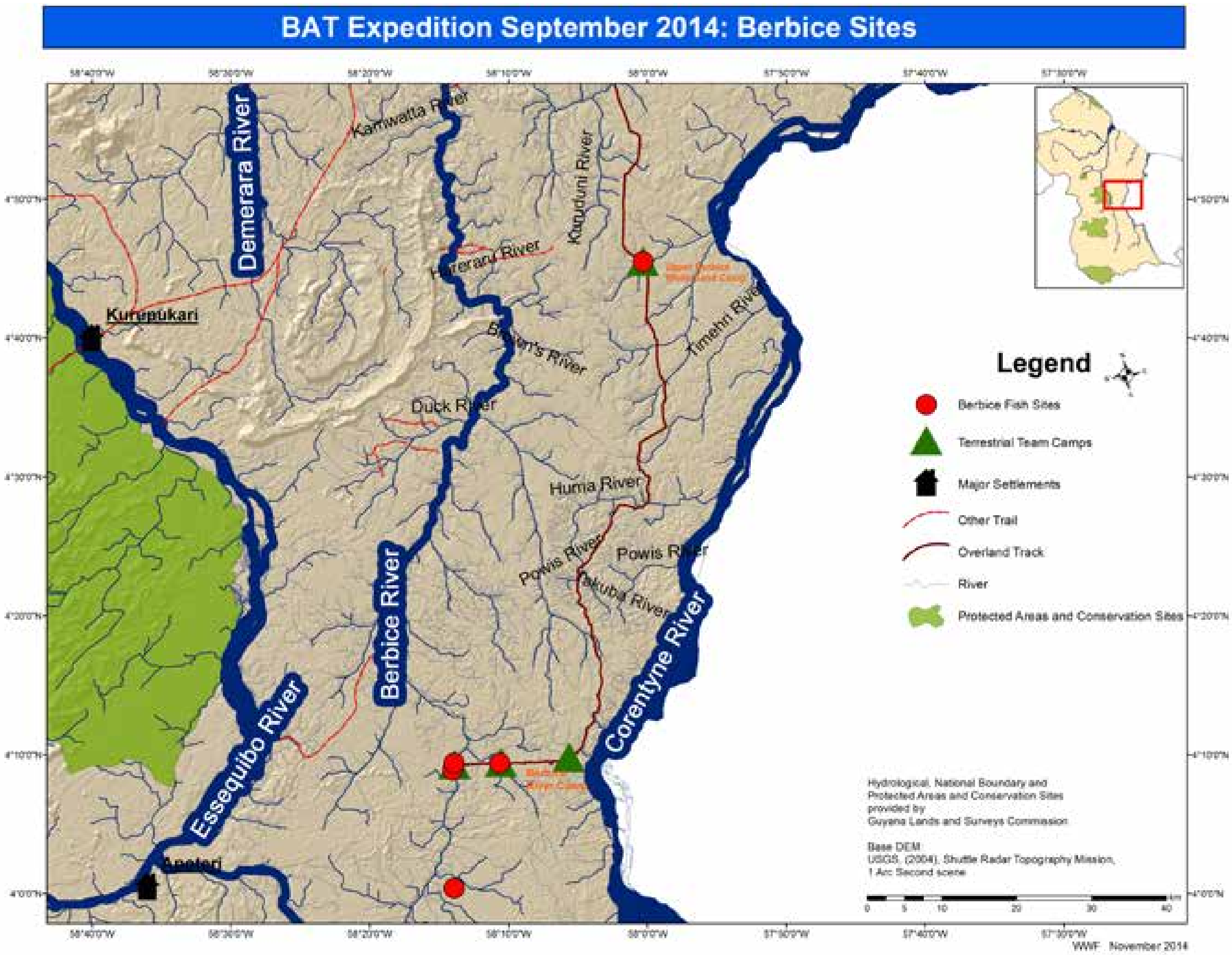

Figure A **Location of the survey sites in the Upper Berbice River and Upper Berbice white sands area.** © Oronde Drakes

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Biodiversity Assessment Team at the Upper Berbice River.

© Andrew Snyder

The access road through the Berbice rainforest.

© Andrew Snyder

Blackwater creek near white sands camp.

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Burnt portion of forest along access road in White Sands Camp.

Context: Ecological Importance of the Upper Berbice Region

Guyana, located on the ancient Guiana Shield of northern South Guyana, located on the ancient Guiana Shield of northern South America, is a land of immense natural resources with over 85% of the country still covered by pristine rainforests (the second highest proportion in the world, in terms of percentage of forest cover relative to total land mass). Extensive tropical grassland savannahs, and long free-flowing rivers also contribute to Guyana's natural wealth. The immense diversity of natural habitats, at both macro and micro levels, supports a high diversity of species, from small invertebrates to large mammals such as the jaguar, puma, giant anteater, giant armadillo, tapir, peccary and deer. While biodiversity remains relatively intact, emerging and growing threats such as mining, illegal logging and hunting, and infrastructure development pose challenges for the continued health of species and their habitats.

The Berbice region has an immense diversity of both natural habitats and species.

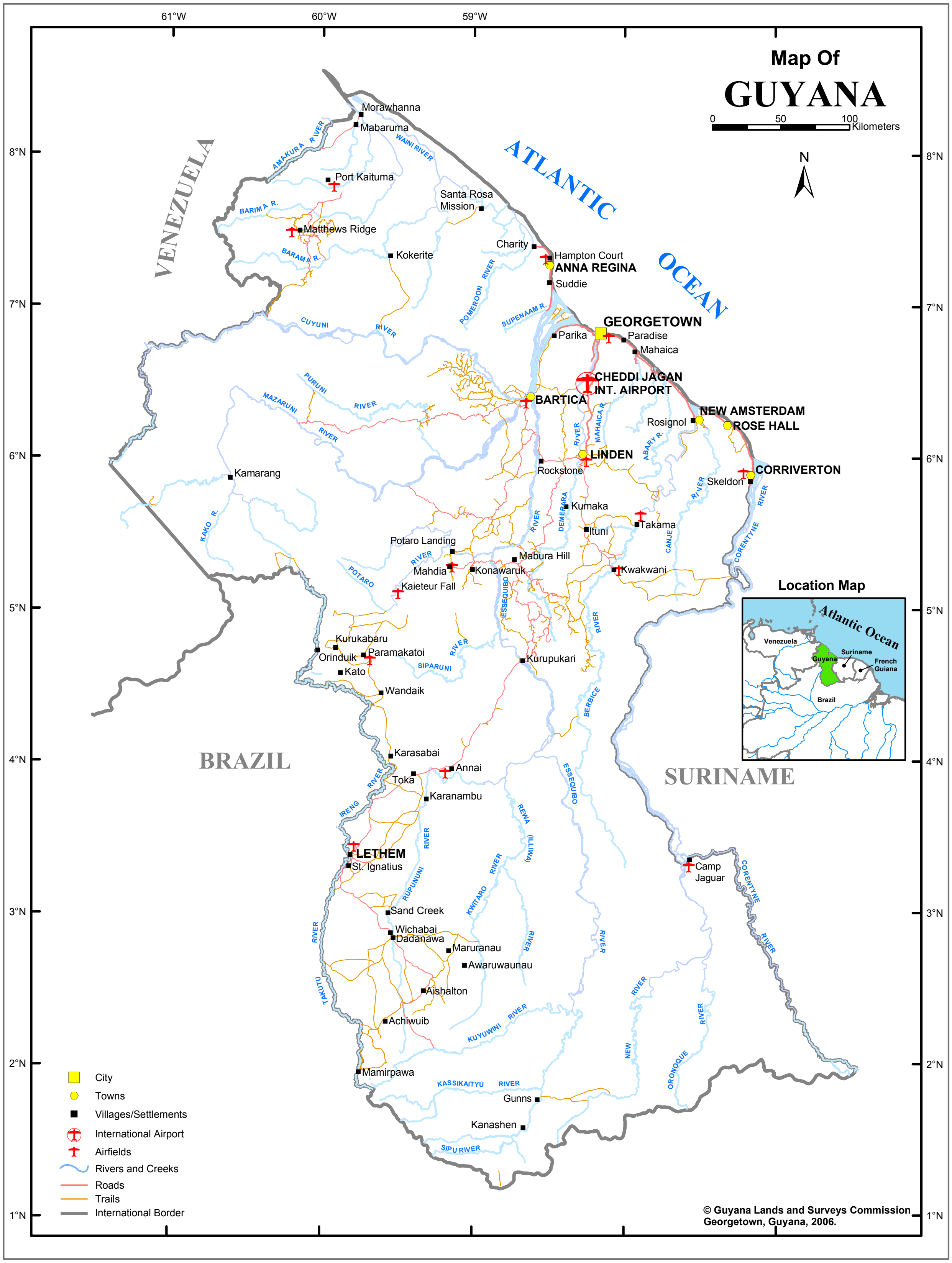

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Figure B **Map of Guyana showing the major rivers. © Guyana Lands and Surveys Commission, Georgetown, Guyana, 2006.**

Berbice River

Guyana has a large number of important rivers, including the Demerara, Essequibo, Mazaruni, Cuyuni, and Corentyne, all of which begin in the forests of Guyana's mountainous highlands and flow northward towards the ocean (see *Map of Guyana showing the major rivers*). Another important river, located in eastern Guyana between the Essequibo and Corentyne Rivers, is the Berbice River. The Berbice River originates in the highlands of south-eastern Guyana and flows north for 370 miles (595 km) through dense forests and the coastal plain to the Atlantic Ocean. The Berbice River gets its name from the Dutch colony of Berbice, which in 1831 became part of the then British Guiana (https://www.britannica.com/place/Berbice-River). The Berbice River is mostly navigable from the coast upstream for about 100 km, but further south there are rapids and the river becomes narrow and penetrates dense forest. Although the Berbice River today is a relatively small, independent coastal drainage tucked between the much larger Essequibo and Corentyne rivers, this was not the case for most of the over 100 million years of history of the South American continent. Several geologists have hypothesized that for most of the last 65 million years, a single river (the "Proto-Berbice") drained the Guiana Highlands' southern slopes and emptied into the Atlantic Ocean via a main channel that flowed through the Rupununi savannah and exited near the mouth of the modern Berbice River (Lujan 2008; see Chapter 6, Fishes, for more details).

Upper Berbice River region

The upper (southern) reaches of the Berbice River, referred to in this report as the Upper Berbice River, has long been inaccessible to people due to the lack of navigability and the dense forests surrounding it. The Upper Berbice River and the forests around it, east of Iwokrama, are among the least studied and most biologically diverse forest types in the Guianas. They are also among the most pristine forests in Guyana. This Upper Berbice River region, located between the upper reaches of the Berbice River and the Corentyne River along the border with Suriname, had never before been studied by biologists. The headwaters of the Berbice River are far upriver from the nearest permanent human settlements, and until recently, despite the existence of forestry concessions in the region, only minimal infrastructure existed to provide overland access to most of the area.

The Upper Berbice River region contains forests described by ter Steege and Zondervan (2005) as "forests on the southern peneplain" that are mainly covered with lowland mixed and evergreen seasonal forests. Preliminary evidence indicates that many elements of the vegetation and terrestrial vertebrate biodiversity are shared with the Essequibo River basin and wider Amazon, likely originating from the ancient Proto-Berbice River. Wallaba forest (dry evergreen forest) on white sands occurs within this region as well as dakama forest (forest dominated by *Dimorphandra conjugata*) that is common on the higher parts of water-divides from central Guyana to western Suriname (ter Steege and Zondervan 2005). Dakama forest contains very deep litter and is prone to fire. Other tree species typical of dakama forests include *Eperua falcata, Talisia squarrosa, Emmotum fagifolium* and *Swartzia bannia* (ter Steege and Zondervan 2005).

Early explorers of the Guianas likely visited this region, but few accounts of their expeditions or biological studies have been recorded. Birds, usually the best known taxonomic group in any region, were purportedly studied by John J. Quelch, curator of the British Guiana Museum from 1886-1900, who made trips up the Demerara and Berbice Rivers during that time, but his specimens are believed to have been destroyed in the 1945 fire that consumed the museum's natural history collections (Snyder 1966).

Threats to the Upper Berbice River region

In Guyana, wildlife has remained well protected mainly due to limited accessibility to the interior, where natural habitat still covers the majority of the area. The situation is gradually changing; an increase in the extractive industries is opening up new areas with a spreading road network that allows easy access equally to both prohibited and permitted activities. For many of these areas, little information exists on the biodiversity, therefore limiting the potential development of sound management plans to avoid or mitigate impacts or species loss.

Worldwide, one of the biggest threats to wildlife is habitat loss. However, the impacts of habitat loss cannot be separated from accessibility. While extractive industries have an impact on wildlife due to habitat loss or degradation, the construction of roads may be an even more detrimental factor. Direct impacts of roads include road kills and edge effects, which cause changes in the temperature and humidity of the forest. Indirect impacts once an area is made accessible include additional development (and habitat loss) and hunting of wildlife. This is especially true for species desired by people as food or for wildlife trade. Accessibility often drives population declines in medium-large mammals because they are typically the preferred prey item, and because of their slow reproduction rate and high resource demands.

Currently, the Upper Berbice River region is essentially uninhabited by people; there are no permanent settlements south of Kwakwani. In the Kwakwani area, small-scale logging has long been a mainstay of the economy. In 2013, Bai Shan Lin, a Chinese conglomerate which already had a presence in Guyana, further acquired large forestry concessions south of Kwakwani and began construction of a road to facilitate logging operations in the upper Berbice region. Today, despite Bai Shan Lin's concessions being repossessed in 2016 by the Guyana Forestry Commission, this road remains, extending for over 125 km, located south of Kwakwani, stretching between the Berbice and Corentyne Rivers. Logging concessions were granted in the region to Bai Shan Lin; others were granted state forest exploratory permits, including Grand Bright Forestry Inc., Rong-An Inc., and Variety Woods and Green Heart Limited. To the south of the Upper Berbice region, more than 0.56 million hectares were granted as logging concessions.[1] These companies operated, but licences were eventually revoked due to several reasons. This meant that all state forests below what is known as the 4th parallel were freed up and provides a broader range of options to be considered for allocation of the forests.

With increasing interest in the Upper Berbice River region from the extractive industry, especially for timber and mining, information on the vegetation types and biodiversity of the area was needed in order to inform conservation and development planning. **Concerns about access to this region by hunters and miners, as well as potential impacts of large-scale logging, prompted this third Biodiversity Assessment Team (BAT) survey** in September and October 2014.

[1] The law requires that selective logging be practiced in accordance with guidelines set by the Guyana Forestry Commission.

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The Bat Expedition – Findings In Brief

Summary of results

The Biodiversity Assessment Team (BAT) survey of the Upper Berbice River region revealed pristine lowland forests containing diverse and abundant wildlife. **These forests are among the most pristine forests the BAT scientists had ever encountered in Guyana, or in the Neotropics more generally.** Both sites contained rare species of birds that are heard but seldom seen in lowland Guyana forests. Several species of Odonata and aquatic beetles are likely new to science. Since this region had never before been surveyed, all BAT data constitute new range records and new information for Guyana.

THE UPPER BERBICE RIVER FORESTS ARE AMONG THE MOST PRISTINE FORESTS THE BIODIVERSITY SCIENTISTS HAD EVER ENCOUNTERED IN GUYANA, OR IN THE NEOTROPICS MORE GENERALLY

Habitat types

The forests at the two sites surveyed were very different in vegetation structure and composition and overall species composition. The range of habitats supports high species diversity within the region.

Upper Berbice River camp

The first site, the Upper Berbice River camp, was within an area of undisturbed, pristine forest with trees over 30 m tall on laterite soil. The dominant tree species, *Mora excelsa* and *Astrocaryum* sp., supported a high diversity of woody climbing plants. The forests around the Upper Berbice River camp harbour a high diversity and especially high abundance of wildlife. Signs of large mammals such as jaguar, puma, and brocket deer were common, being observed on several occasions. Birds and reptiles, uncommon in areas with hunting pressure, were abundant. A high diversity of all taxa was recorded despite the extremely dry conditions (no rain for the entire two-week period). Fish diversity was typically low for headwaters but contained large numbers of predatory fishes, indicating pristine and healthy river conditions.

Upper Berbice White Sands camp

The forest at the Upper Berbice White Sands camp was very different from the Upper Berbice River camp. The forest consisted of wallaba or dakama forest on white sand with three strata: canopy dominated by dakama (*Dimorphandra conjugata*), mid-level dominated by soft wallaba (*Eperua falcata*), and lower level with many manoco or turu palms (*Oenocarpus bacaba*). Habitats surveyed at the White Sands camp included both intact and disturbed forest along an active logging road.

Habitat condition

The two BAT survey sites represented different degrees of disturbance, with the Berbice River camp being remote and pristine. This camp was located at the end of a small road cleared for gold mining exploration with only light traffic from the miners. In contrast, the White Sands camp was next to a highly disturbed area due to a human-induced fire that burned a large extent of forest near to the camp, as well as with the presence of an active logging road with many large logging trucks traveling back and forth each day. Hunters were also seen to be driving along the road at night, leaving with tapirs and other wildlife. Some differences were observed in species composition between these two sites that are likely due to the degree of disturbance to the environment. For example, at the White Sands camp, the BAT team recorded an abundance of cane toads (*Rhinella marina*) as well as emerald-eyed frogs (*Hypsiboas crepitans*), which are "weedy species" commonly associated with anthropogenic disturbance. Similarly, the fish fauna of the Berbice River camp was found to be in pristine condition, while the stream in the Corentyne River drainage at the White Sands camp had been severely affected by deforestation and a nearby forest fire, but water quality was apparently still good there. The Upper Berbice River camp had higher species richness for bats typical of relatively undisturbed tall forest in the Guiana Shield, whereas the more disturbed forest of the Upper Berbice White Sands camp had higher relative abundance.

Species composition

In general, species composition of most taxa differed between the two survey sites, most likely due to the difference in forest types and soil types, and likely also due in part to the differences in habitat condition. Birds had a fairly low overlap of species between sites (66%), while for aquatic beetles, only 30% of the 137 species recorded were found at both camps, which is an extremely low level of overlap given the close proximity between the two camps. The two sites also differed in their reptile and amphibian composition, with many species recorded as exclusive to only one of the two sites. Small mammals had low overlap as well; the degree of overlap between the two sites was 22% based on the Jaccard Similarity Index. Another indication of faunal differences was the capture of four species of aerial insectivorous bats in the family Molossidae in open areas of the Upper Berbice White Sands camp, but not in the closed forest habitats of the Upper Berbice River camp. Dissimilarity between the two sites was also found for decapod crustaceans, with most species found only at one of the two sites.

The number of odonate species found at the Upper Berbice White Sands camp area was almost twice as high as that from the Upper Berbice River camp area, and the species composition of the two areas differed considerably with only 16 shared species (of 72). These differences can be explained by the different types of aquatic habitats sampled at each site and the higher diversity of microhabitats and larger area surveyed at the Upper Berbice White Sands camp.

Species diversity for some groups was higher at the Upper Berbice White Sands camp, likely due to the higher level of human disturbance at this site, which brought in additional species typical of more open areas, and species that typically to exclusively prefer more open marsh habitats, which were completely absent from the Upper Berbice River camp. This was particularly true for birds, aquatic beetles, and dragonflies/damselflies. Artificial pools had attracted typical marsh aquatic beetle species that normally would not be within the forest.

Species documented during the BAT survey of the Upper Berbice region

Key

For fish: *from Berbice River, **from Corentyne River basin tributary; ***% of species from Corentyne River.

[a] Likely new species to science

Taxon	# species Berbice Forest camp	# species White Sands camp	Total # species both camps	# species found at both camps (%)	# species new to science	# species new record for Guyana
Plants	-	-	89	-	-	-
Odonates (dragon-flies and damsel-flies)	31	57	72	16 (22%)	3	9
Aquatic Beetles	100	78	137	41 (30%)	16+	16+
Amphibians	16	7	20	3 (15%)	-	-
Reptiles	25	13	33	6 (18%)	-	-
Birds	205	196	271	130 (48%)	-	-
Large mammals	14	10	18	8 (44%)	-	-
Small mammals	1	1	2	0 (0%)	-	-
Bats	21	18	32	7	1	1
Fishes	87*	14**	92	9 (64%)***	3+	3+
Crustaceans (crabs)	4*	1**	4	1 (25%)	-	1
Crustaceans (shrimps)	4*	2**	5	1 (20%)	-	
Ants	65	15	77	3 (4%)	3[a]	9

Species of conservation concern documented during the BAT survey of the Upper Berbice region

Group	Species	Common name	IUCN Red List or CITES Category
Reptiles	*Melanosuchus niger*	Black caiman	Lower Risk/Conservation Dependent/I
	Paleosuchus palpebrosus	Cuvier's smooth-fronted caiman	Least Concern/II
	Chelonoidis carbonarius	Red-footed tortoise	II
	Chelonoidis denticulatus	Yellow-footed tortoise	Vulnerable/II
	Corallus hortulanus	Amazon tree boa	Least Concern/II
	Epicrates cenchria	Rainbow boa	Not Evaluated/II
Amphibians	*Ameerega trivittata*	Three-striped poison frog	Least Concern/II
	Allobates femoralis	Rocket frog/brilliant-thighed poison frog	Least Concern/II
Medium and large mammals	*Panthera onca*	Jaguar	Near Threatened/ I/II
	Puma concolor	Puma	Least Concern/ I/II
	Leopardus pardalis	Ocelot	Least Concern/ I
	Herpailurus yagouaroundi	Jaguarundi	Least Concern/ I/II
	Tapirus terrestris	Tapir	Vulnerable/II
	Pecari tajacu	Collared peccary	Least Concern/II
	Myrmecophaga tridactyla	Giant anteater	Vulnerable/II
	Priodontes maximus	Giant armadillo	Vulnerable/I
	Alouatta macconnelli	Red howler monkey	Least Concern/II
	Ateles paniscus	Red-faced spider monkey	Vulnerable/ II
	Pithecia pithecia	White-faced saki	Least Concern/II
Birds	*Tinamus major*	Great Tinamou	Near Threatened
	Crax alector	Black Curassow	Vulnerable
	Odontophorus gujanensis	Marbled Wood-Quail	Near Threatened
	Patagioenas subvinacea	Ruddy Pigeon	Vulnerable
	Psophia crepitans	Grey-winged Trumpeter	Near Threatened
	Agamia agami	Agami Heron	Vulnerable
	Spizaetus ornatus	Ornate Hawk-Eagle	Near Threatened
	Ramphastos tucanus	White-throated Toucan	Vulnerable
	Ramphastos vitellinus	Channel-billed Toucan	Vulnerable
	Celeus torquatus	Ringed Woodpecker	Near Threatened
	Pyrilia caica	Caica Parrot	Near Threatened
	Amazona dufresniana	Blue-cheeked Parrot	Near Threatened
	Amazona farinosa	Mealy Parrot	Near Threatened
	Epinecrophylla gutturalis	Brown-bellied Antwren	Near Threatened
	Hypocnemis cantator	Guianan Warbling-Antbird	Near Threatened

RESULTS BY TAXON

Dragonflies and damselflies

Odonata species from the Upper Berbice watershed in south-central Guyana were surveyed along various forested blackwater creeks, associated flooded forest, side pools, and the Berbice River for three days at the Berbice River camp and surroundings, and four days at the Berbice White Sands camp and surroundings. A total of 72 odonate species were recorded, including 31 species of damselflies and 41 species of dragonflies, and the estimated species richness for the total area surveyed was 87.29. This represents the first inventory list completed for this region. None of the 72 species found is endemic to the study area or to Guyana, but six species constituted new records for the country at the time the survey took place: *Neoneura bilinearis*, *Protoneura paucinervis*, *Phyllogomphoides atlanticus*, *Phyllogomphoides undulatus*, *Perithemis cornelia*, and *Perithemis mooma*. The number of odonate species found at the Berbice White Sands camp area was almost twice as high as that from the Berbice River camp area, and the species composition of the two areas differed considerably with only 16 shared species and a resulting complementarity of 77.77 %, which can be explained by the different types of aquatic habitats sampled at each site and the higher diversity of microhabitats and larger area surveyed at the Berbice White Sands Camp. Odonate diversity and abundance at the Berbice River camp area creeks, especially of damselflies, was lower than expected for a primary forest system, which could be explained at least in part by the lower diversity and abundance characteristic of tropical rainforests during the dry season. The Odonate assemblage of the Upper Berbice indicated a healthy environment, including several species (26%) characteristic of the Guiana Shield. The main threat to the diversity of odonates is habitat degradation.

Reptiles and amphibians

A total of 53 species including 20 species of amphibians and 33 species of reptiles were recorded for the entire study area during the BAT survey. When compared to other better-sampled areas of the Guiana Shield, these numbers are low, but are similar to numbers recorded in previous surveys of this region. Based on our data however, sampling completeness estimates predict that the total number of amphibian and reptile species for that area should be closer to 110. Furthermore, we provide the first records for a number of species in the Berbice forest. All of the amphibians encountered belong to the order Anura. Almost half of the anurans were tree frogs (Hylidae) with eight species, followed by the "southern frogs" (Leptodactylidae) with five species, toads (Bufonidae, three species), and single representatives of the families Aromobatidae, Dendrobatidae, Pipidae, and Strabomantidae. Within the reptiles, we recorded two species of crocodilian, three species of turtles and tortoises, 11 species of lizards, and 17 species of snakes. The two focal areas surveyed during this expedition differed in their herpetofaunal composition, with many species encountered being exclusive to a particular site.

Birds

Birds were surveyed over 11 field days, using 10-species lists to derive richness estimators for each site and to allow comparison of their bird communities with other sites in central Guyana. Sound recording was used to document the avifauna. During the expedition, 271 bird species were observed, including 38 Guiana Shield endemics, 15 species listed as either Near-Threatened or Vulnerable by the IUCN, and two species (the Rufous Potoo, *Nyctibius bracteatus*, and Pelzeln's Tody-Tyrant, *Hemitriccus inornatus*) with poorly known distributions in northeastern South America. The bird communities of the two sites were generally more similar to other sites in central Guyana than they were to each other, indicating high diversity in the Upper Berbice region. **Lower-stature forests on white sands were of particular interest, and represent a habitat type not currently included in Guyana's Protected Areas system. Aggressive monitoring of the new road through this region should mitigate threats from illegal mining and overharvesting of timber and wildlife.**

Small mammals

The small mammal faunal community in the Upper Berbice River region of south-central Guyana has never been comprehensively sampled. As part of the Biodiversity Assessment Team (BAT) Expedition to this area from 21 September to 1 October 2014, bats and rats were surveyed with standardized methodology to estimate species diversity and relative abundance at two sites: the Berbice River camp in pristine tall forest, and the White Sands camp in partially disturbed low forest. A total of 34 species were documented by 180 captures in mist nets and live traps. Most were bats comprised of 32 species and 176 individuals, whereas rats were represented by only 2 species and 4 individuals. The two sites were quite different with only 22% overlap in species. Although species richness estimators were higher for the Berbice River camp, species diversity indices were lower because the most abundant species of bat was only caught at this site. **The most interesting result was the discovery of a potential new species of round-eared bat.**

Medium and large mammals

A baseline assessment of the large and medium mammal populations was conducted in the Upper Berbice region using camera traps and opportunistic sightings at one site, and track surveys along 2 km transects at a second site. At the first site we detected 14 species; at the second site we detected 10 species, resulting in a total of 18 mammal species. Photographs, tracks and live sightings revealed several species that are threatened and sensitive to disturbance, including the giant anteater and giant armadillo. Differences in species recorded between the two sites were largely due to differences in survey methodology. Based on capture-recapture analysis of photographs, we estimated a preliminary population density of jaguars in the area to be 3.17 individuals/100km^2 (SE ± 1.18); and for ocelots to be 16.00 individuals/100km^2 (SE ± 3.79). Predator density and relative abundance of other mammals suggested a healthy mammal population. **Because of the recent influx of hunters, for sport and commercial purposes, we recommend management of hunting and access to prevent overharvesting of wildlife resources in this area where, until recently, wildlife has remained protected due to inaccessibility.**

Ants

During the survey in the Upper Berbice River, deep in the interior of Guyana, 164 separate collections were made from three sites, and these consisted of hand collections, baiting samples, leaf-litter samples, a Malaise trap, and light-trap samples. From the hand collections and bait samples only, a total of 78 ant species from 37 genera and 8 subfamilies are reported. One additional subfamily and 10 additional genera are also reported from leaf-litter samples, which still need to be processed to the species level. Among identified species, at least nine are new records for Guyana. One non-native species, *Paratrechina longicornis*, was collected from disturbed habitat in the small river town of Kwakwani. Although more work is needed to document the ants from the Upper Berbice River, our preliminary assessment suggests that the area has a very diverse and healthy ant fauna that likely includes new species. **Thus, new logging and mining efforts in the area should be monitored with care to help reduce negative impacts to an otherwise pristine insect fauna.**

Fishes

A rapid assessment of the fish diversity in the Upper Berbice River was conducted in an area of virgin rain forest. Fishes were sampled from eight localities in the blackwater Berbice River basin (from both the main channel and blackwater forest creek tributaries), and one clear-water site in a tributary of the Corentyne River. Fish were abundant in the Berbice River main channel, concentrated by low water levels of the dry season. Nine collections made during five days yielded a total of 92 species, 87 from the Berbice River and tributaries (about 65% of the 134 species so far reported), and 14 from the Corentyne tributary stream. Nine species were found in both basins. Large aimara (*Hoplias aimara*) were abundant in the main channel near rock outcrops. **Fifteen specimens were checked for mercury in their flesh, ten were found to be contaminated, and three had levels of mercury above those considered safe for human consumption.** The site in the Corentyne River drainage could include new species records for Guyana. Gold mining and deforestation for lumber are the immediate threats to fish biodiversity. Overfishing of aimara is more likely now that road access has been established by the logging company. Thus, **enforcing fishing regulations and educating fishermen on sustainable practices are needed to preserve the large fish species. Protection of riparian vegetation and enforcement of mining and logging regulations are important for maintaining the aquatic ecosystems.**

Crustaceans and other aquatic invertebrates

This BAT study presents a first look at the decapod crustacean community of the Upper Berbice region of Guyana. Nine species of decapod crustaceans, including four species of crabs and five species of shrimps were documented. A total of 168 individuals of crabs were collected, consisting of three species from the Trichodactylidae family and one species from Pseudothelphusidae. In addition, 156 specimens of shrimps included four species from the family Palaemonidae and one species from Euryrhynchidae. The crab *Valdivia serrata* (120 individuals) was the most abundant species collected. The shrimps, *Macrobrachium brasilense* (68 individuals) and *Palaemon carteri* (43 individuals) were next highest in abundance. The species of crab *Microthelphusa* sp. is considered a new species record for Guyana. More extensive sampling during different seasons is needed to fully document the species richness and ecology of decapod crustaceans, which will contribute to a sustainable management plan for aquatic resources of the area.

Water quality (in Decapod Crustaceans, Chapter 9)

Water quality at the Upper Berbice Base Camp 1 surveyed sites were (means, n=8): 28.9°C temperature, 44.4 µS/cm conductivity, and 4.31 mg/l dissolved oxygen (DO). Water quality at the single Upper Berbice River White Sand Base Camp 2 survey site was: 26.40°C temperature, 28.50 µS/cm conductivity, and 7.02 mg/l dissolved oxygen. Site 8 in the Upper Berbice River Base Camp 1 area had the lowest DO value.

Aquatic beetles

Aquatic beetles were surveyed in the Upper Berbice region of Guyana, sampling extensively around two sites. Most habitats consisted of primary tropical forest. More than 3,500 specimens were collected from 41 collecting events. A total of 137 species of aquatic beetles in 55 genera were identified. Two genera and at least 16 species are new to science, though additional new species are almost certainly to be identified from the material. The total observed species richness was comparable with other lowland tropical forest regions in the Guiana Shield. Species composition between the two camps was strongly dissimilar, given the relatively close proximity of the two sites. While some of these differences may be due to sampling artefacts or modest differences in microhabitat, **a number of species found in the White Sands camp suggest environmental disturbances have altered the water beetle community.**

Plants

Plants were studied at two sites within the Upper Berbice River region in September 2014. From a collection of 218 plant specimens, a total of 89 species representing 77 genera and 45 families were identified. At Berbice Camp 1, the forest is multi-layered, with trees up to 40 m in height; lianas are common, while epiphytes, lichens and mosses are scarce. The upper layer forms a compact canopy that protects the soil; dominant trees include *Mora excelsa*, *Eschweilera* sp., *Aspidosperma excelsum* (yaruru), *Goupia glabra* (kabukalli) and *Swartzia leiocalycina* (wamara). The forest at the Berbice White Sands Camp 2 was very different from Camp 1. This forest grows on white sand soil and has three strata: canopy level (up to 20 m tall) dominated by dakama (*Dimorphandra conjugata*), a middle level dominated by soft wallaba (*Eperua falcata*), and a lower level with many turu palms or manoco (*Oenocarpus bacaba*). Three plant species are new records for the Berbice region. **The forested areas of the Berbice River basin should be studied in much more detail, since several rare species were found in this preliminary study.**

BAT Recommendations for Conservation and Management of the Upper Berbice Region, Guyana

With increasing access and interest in the Upper Berbice Region and generally in the southern region of Guyana, a holistic approach is needed for maintaining biodiversity and promoting sustainable resource use. Thus, it is imperative that all parties involved in the region, including government, logging companies, investors, NGOs, and local communities, take measures to sustainably plan and manage any development projects in the region, including roads, to avoid negative environmental impacts and protect Guyana's unique wildlife natural environment.

Forest access has been linked to decreases in wildlife populations. An observation of hunters with multiple tapir carcasses during this BAT survey indicates that hunting was present within this recently opened area. The presence of threatened and disturbance sensitive species indicated that the forest is of high conservation value.

The key conservation recommendations from the BAT survey are:

Enforce and monitor environmental regulations: Ensure stringent monitoring by the relevant regulatory agencies, including the Guyana Forestry Commission (GFC), Environmental Protection Agency (EPA), and Guyana Geology and Mines Commission (GGMC), along with residents and relevant communities to ensure compliance with Guyana's regulations and laws, and to prevent overharvesting and the removal of protected species. Monitor the use of the logging roads, particularly the main access road, and take measures to prohibit unauthorized activities and regulate wildlife harvesting according to the Wildlife Management and Conservation Regulations (2013) and the Wildlife Management and Conservation Act (2016) Incorporate these BAT data into monitoring and enforcement activities of regulatory institutions. Specifically, we recommend good management of the following:

Logging: This should be monitored and regulated in order to preserve the integrity of this pristine forest and its freshwater habitats. It is essential that approved practices for reduced impact logging and mining are enforced in this area. Strict protection of riparian vegetation is essential for maintaining the aquatic ecosystems. **The BAT team recommends at least 200 m be protected along streams to maintain aquatic ecosystem health and diversity**.

Mining: Tailings and other sediments from mining operations should be contained in sediment catchment ponds rather than discharged into the river or tributary streams in order to avoid the excessive sedimentation downstream that destroys benthic aquatic communities. Fuel, oil and other lubricants for machinery should not be allowed to enter the river. No mining should be permitted along the shores/banks of the river. Shoreline vegetation must be maintained as required by law.

Hunting: In order to safeguard the populations of wildlife in the Upper Berbice region, especially threatened species such as tapir and tortoises, measures must be taken to ensure that hunting is regulated. Mining and logging enables increased access to areas for hunting, and these must be factored in when considering strategies to manage hunting.

Fishing: Enforcing fishing regulations, monitoring fishing activities, and educating fishermen on sustainable practices are needed to preserve the large fish species still present in this region.

Pristine forest: Forests in these areas represent Guyana's last true remote pristine frontiers, and should be protected. **Ideally, this region should not experience logging or mining, as there is a 1997 intention to have conservation be the dominant purpose of state forest south of the 4th parallel north, and this should be maintained.**

Species: Long-term monitoring of selected indicator species will provide information on the status of biodiversity within the region. Monitoring of the more sensitive species, including the tapir, jaguar, spider monkey, and red acouchi will provide an early warning of changes in the environment and impacts on key species.

Involve local stakeholders: Incorporate local stakeholders into decision-making, management, and monitoring of the area since they have the best local knowledge.

Conduct robust ESIAs: Incorporate the findings of this BAT survey into the Environmental and Social Impact Assessments (ESIAs) for the logging concessions, mining concessions and any other development projects in the region.

Create biodiversity reserves: Ensure that forestry concessions follow the Guyana Forestry Commission's guidelines for biodiversity protection within forestry concessions, which require that 5% of each concession be set aside as a biodiversity reserve. These areas should be selected to protect diverse, biodiversity-rich forested areas identified within each concession, such as the two sites studied during this BAT survey (4° 09.241' N, 58° 10.627' W; 4° 45.297' N, 58° 00.431 'W). We recommend that these sites be connected to form a contiguous corridor among the various concessions to maintain the species and habitat richness observed during the BAT survey.

Conduct additional surveys during the wet season: Surveys during the wet season are recommended in order to gain knowledge about the possible seasonality of the fauna of south-central Guyana, and in order to gather a more representative baseline of species diversity. In particular, additional sampling should be done for damselflies/dragonflies and amphibians/reptiles. During the brief periods spent surveying at each site, additional species were continuously recorded, indicating that many more species would have been recorded had survey time allowed.

Promote sustainable activities: Birdwatching could be promoted in this region, which features distinct forest types containing unique bird species, and therefore offers visiting birdwatchers the chance to see many of the endemic species of the Guiana Shield, all along a single road. Indeed, this may be one of the few benefits of road access to this region, which is otherwise a threat to the region's ecological integrity. Land-use planning which takes into consideration water sources and access to wildlife is recommended for long-term sustainability.

CHAPTER 1

DRAGONFLIES AND DAMSELFLIES OF THE UPPER BERBICE RIVER REGION

Natalia von Ellenrieder and Rosser Garrison

Summary

Odonata species from the Upper Berbice watershed in south-central Guyana were surveyed along various forested blackwater creeks, associated flooded forest, side pools, and the Berbice River, for three days at the Berbice River camp and surroundings and for four days at the Berbice White Sands camp and surroundings. A total of 72 odonate species were recorded, including 31 species of damselflies and 41 species of dragonflies, and the estimated species richness for the total area surveyed was 87.29. **This represents the first inventory list completed for this region.** None of the 72 species found is endemic to the study area or to Guyana, but **six species constituted new records for the country at the time the survey took place:** *Neoneura bilinearis*, *Protoneura paucinervis*, *Phyllogomphoides atlanticus*, *Phyllogomphoides undulatus*, *Perithemis cornelia*, and *Perithemis mooma*. The number of odonate species found at the Berbice White Sands camp area was almost twice as high as that from the Berbice River camp area, and the species composition of the two areas differed considerably with only 16 shared species and a resulting complementarity of 77.77%, which can be explained by the different types of aquatic habitats sampled at each site and the higher diversity of microhabitats and larger area surveyed at the Berbice White Sands camp. Odonate diversity and abundance at the Berbice River camp area creeks, especially of damselflies, was lower than expected for a primary forest system, which could be explained at least in part by the lower diversity and abundance characteristic of tropical rainforests during the dry season. The Odonate assemblage of the Upper Berbice indicated a healthy environment, including several species (26%) characteristic of the Guiana Shield. The main threat to the diversity of odonates is habitat degradation. To preserve the integrity of this pristine forest and its freshwater habitats necessary to maintain the current

odonate diversity, **it is essential that approved practices for reduced impact of logging and mining are enforced in this area.** In particular, **we recommend creating and preserving 200 m buffer zones along margins of the Berbice River and streams in the Upper Berbice region, and building catchment ponds to contain tailings of mining operations.**

Introduction

Dragonflies and damselflies (order Odonata) are found worldwide and present their highest species richness pantropically in forests. Compared to other insect groups they constitute a relatively small order, with about 6,000 described species worldwide (Dijkstra et al. 2013) and 1,800 in the New World (Garrison and von Ellenrieder 2017), and their adult taxonomy is relatively well known allowing for fast and accurate identification. Therefore, a fairly complete representation of their assemblage can be obtained for a particular place in a relatively short period of time, making them excellent candidates for rapid biodiversity assessments. Larvae are aquatic, and sensitive to water quality, bottom substrate, aquatic vegetation structure, and other structural characteristics of their habitat. Adults are terrestrial, selecting their habitat according to vegetation structure and degree of shading. **Alteration of habitats caused by logging, increased erosion, and water pollution elicit strong responses in the diversity and richness of the natural odonate community present in a forest**. Widespread generalist species prevail in temporary waters and disturbed habitats, whereas more vulnerable, often localized species occur only in undisturbed and well preserved freshwater habitats (Kalkman et al. 2008). Thus, odonates are useful for monitoring the overall biodiversity of aquatic habitats and have been identified as good indicators of environmental health (Corbet 1999; Simaika and Samways 2012).

The knowledge of the odonate fauna from Guyana has lagged behind compared to other countries in northern South America, and the ecology and distribution of many tropical species that occur in the country are still poorly known. A recent short survey in the Potaro-Siparuni Region increased the number of known species from 192 to 214 (von Ellenrieder 2017). Considering the extensive forests and varied biomes and topography of Guyana this is still a low number, and further surveys will most likely bring it closer to the more than 500 species recorded from neighbouring Venezuela (De Marmels 2015) and 300 from Suriname (Belle 2002; von Ellenrieder 2011).

Study sites and dates

Odonates were surveyed from 21 – 23 September 2014 at the Berbice River Camp and surroundings (sites 1-7), and from 28 September to 1 October 2014 at the Berbice White Sands Camp and surroundings (sites 8-17).

<u>Berbice River Camp (R.W. Garrison and J. Archer leg.):</u>

Site 1: road and trail near camp, 21 ix 2014 (4° 09' 06" N, 58°1 3' 44" W, 95 m)

Site 2: small stagnant creek at miner's camp, 21 ix 2014 (4° 09' 04" N, 58° 13' 35" W, 88 m)

Site 3: narrow sandy blackwater stream near camp, 21 ix 2014 (4° 09' 14" N, 58° 10' 45" W, 92 m)

Site 4: Berbice River, 22 ix 2014 (4° 09' 06" N, 58° 13' 44" W, 95 m)

Site 5: narrow sandy blackwater stream, 22 ix 2014 (4° 09' 14" N, 58° 10' 45" W, 92 m)

Site 6: Berbice River, 23 ix 2014 (4° 09' 04" N, 58° 14' 01" W, 83 m)

Site 7: narrow sandy blackwater stream, 23 ix 2014 (4° 09' 14" N, 58° 10' 45" W, 92 m)

<u>Berbice White Sands Camp (N. von Ellenrieder and J. Archer leg.):</u>

Site 8 (Fig. 1.2): flooded primary forest and trickles of water running into stream, 28 ix 2014 (4° 45' 22" N 58° 00' 21" W, 10 m)

Site 9 (Fig. 1.3): sandy blackwater stream in primary forest, 28 ix 2014 (4° 45' 17" N 58° 00' 24" W, 8 m)

Site 10: sandy blackwater stream in secondary forest before burned area, 29 ix 2014 (4° 45' 36" N 58° 00' 58" W, 8 m)

Site 11: sandy blackwater creek in primary forest with associated pools, upstream from camp, 29 ix 2014 (4° 45' 26 N 58° 00' 16" W, 28 m)

Site 12: narrow sandy blackwater stream with swampy area and roadside pool, c. 5 km from camp by logging camp, 29 ix 2014 (4° 41' 02" N 58° 00' 06" W, 7 m)

Site 13: wide sandy blackwater stream with open canopy, c. 30 km from camp, 30 ix 2014 (4° 58' 16" N 58° 02' 21" W, 5 m)

Site 14: sandy blackwater stream with open canopy and pond with floating macrophytes, by Chinese logging camp, 30 ix 2014 (4° 51' 17" N 58° 01' 40" W, 4 m)

Site 15: sandy blackwater stream, c. 15 km from camp, 30 ix 2014 (4° 39' 28" N 57° 59' 24" W, 5 m)

Site 16: sandy blackwater creek behind camp, 30 ix 2014 (4° 45' 13" N 58° 00' 32" W, 7 m)

Site 17: sandy blackwater creek with associated pools, 1 x 2014 (4° 45' 45" N 58° 00' 28" W, 16 m)

Methods and analysis

Odonata species from the Upper Berbice watershed in south-central Guyana were investigated by applying search-collecting methods. In order to provide a thorough inventory, sampling was conducted using aerial nets in as many habitats as possible, given the survey time. Searching, photographing, and collecting were carried out around each camp, in terra firme forest, forest swamps, streams, creeks, várzea forest, and rivers.

Presence/absence (incidence) information of species was recorded in a spatial-relational database (Table 1), where relative abundance for each species was noted as rare (1-3 specimens seen), frequent (4-20 specimens seen), or common (21-50 specimens seen). Specific richness, evenness [= H / ln (richness)], diversity (calculated according to Shannon and Simpson indices) per site are also presented in Table 1. Collected specimens are deposited at the Centre for the Study of Biological Diversity, University of Guyana (CSBD) and the California State Collection of Arthropods (CSCA).

Species accumulation curves and total species richness expected for the area according to the Chao 2 estimator (bias-corrected form) were calculated using PC-ORD (McCune and Grace 2002). Composition of odonate communities from the two areas was compared using percentage complementarity, which measures distinctness or dissimilarity (Colwell and Coddington 1994). Information on the distribution and habitat of the species found are provided (Table 2), as well as maps for those showing a significant range extension and conservation recommendations.

Results

The sites visited in the Upper Berbice region consisted of a mostly pristine forest system with some areas logged. Collecting of odonates occurred along various forested blackwater creeks, associated flooded forest, swampy areas within the forest, side pools at streams, and river margins of the Berbice River.

A total of 72 species of odonates were recorded including 31 species of damselflies in 16 genera and five families (Zygoptera: Calopterygidae, Coenagrionidae, Dicteriadidae, Perilestidae, Megapodagrionidae), and 41 species of dragonflies in 23 genera and three families (Anisoptera: Aeshnidae, Gomphidae, Libellulidae).

In detail, five families, 18 genera, and 31 species were collected at the Berbice River camp area, and eight families, 35 genera, and 57 species at the Berbice White Sands camp area.

Estimated species richness for the total area surveyed was 87.29, for the Berbice River camp area 35.45 and for the Berbice White Sands camp area 83.32. The species accumulation curve (see Fig. 1.1) did not approach the asymptote.

Species richness varied from 2 to 29 per site, with a mean and standard deviation of 11 ± 7.39 respectively; Shannon diversity ranged from 0.69 to 3.37 (2.20 ± 0.67), and Simpson diversity from 0.50 to 0.97 (0.86 ± 0.11). The localities with highest richness and diversity values in the Berbice River camp area corresponded to sites along the Berbice River (sites 4 and 6), and in the Berbice White Sands camp area to sites along the small blackwater creek running through primary forest near the camp (sites 9, 11, and 17) (see Table 1.1).

The number of odonate species found at the Berbice White Sands camp area was almost twice as high as that from the Berbice River camp area, and the species composition of the two areas differed considerably, with only 16 shared species and a resulting complementarity of 77.77%. The Berbice River camp hosted 15 species not found at the Berbice White Sands camp area, and 41 species were recorded only from the Berbice White Sands camp area (see Table 1.1).

The genus *Argia* is the most species-rich within the family Coenagrionidae in the New World, and it correspondingly showed its prevalence at all sites, being one the richest in species (five species). Three of these species were new to science when collected, and have been described in the meantime (Garrison and von Ellenrieder 2015). Other genera represented by several species were *Neoneura*, a genus of lotic damselflies, and *Orthemis*, including dragonflies common across Neotropical forests (see Tables 1.1, 1.2).

This represents the first inventory list completed for this region. None of the 72 species found is endemic to the study area or to Guyana, but six species constituted new records for the country when the survey took place, two damselflies: *Neoneura bilinearis* Selys, 1860, *Protoneura paucinervis* Selys, 1886 (Coenagrionidae), and four dragonflies: *Phyllogomphoides atlanticus* Belle, 1970, *Phyllogomphoides undulatus* (Needham, 1944) (Gomphidae), *Perithemis cornelia* Ris, 1910, and *Perithemis mooma* Kirby, 1889 (Libellulidae).

The odonate species found at the Upper Berbice area can be broadly categorized as a mixture of Guianan (GUI in Table 1.2, about 26%), Amazonian and Guianan (AMZ in Table 1.2, about 26%), and widespread Neotropical (NEO in Table 2, about 47%), as defined in von Ellenrieder (2017).

No odonates are listed on the CITES appendices. The conservation status of approximately one-quarter of the Neotropical species was recently assessed by the Odonata Specialist Group of IUCN (Clausnitzer et al. 2009), and 20 of the species recorded here are included among those assessed, all considered of Least Concern (see Table 1.2).

The richness of odonate species found during this survey (72) was lower than that found at other rainforest sites within the Guiana Shield, i.e. the Upper Potaro region in central western Guyana (80, von Ellenrieder 2017) and the Kwamalasamutu region in southwestern Suriname (94, von Ellenrieder 2011). However, this discrepancy only reflects the much shorter survey length, which comprised only seven collecting days at the Upper Berbice area, compared to 13 and 16 collecting days at the other two survey sites respectively. The composition and diversity of the odonate assemblage from the Upper Berbice area was similar to those of the other two sites, with a complementarity value of 68% with the Kwamalasamutu area and 66% with the Upper Potaro area. Subtracting the endemics from the Guiana Shield highlands (i.e. *Chalcothore*, *Dimeragrion*, *Iridictyon*, *Heteragrion pemon*), and from the western portion of the Guiana Shield (*Argia azurea*, *A. guyanica*, *A. joallynae*) found in the latter survey, the list of species from the Upper Berbice area is similar to that of the Upper Potaro area (von Ellenrieder 2017). *Rimanella arcana*, a species inhabiting the entire Guiana Shield, was not found during the present survey, but its specialized habitat (river rapids with Podostemataceae growing on exposed rocks) was not among those surveyed.

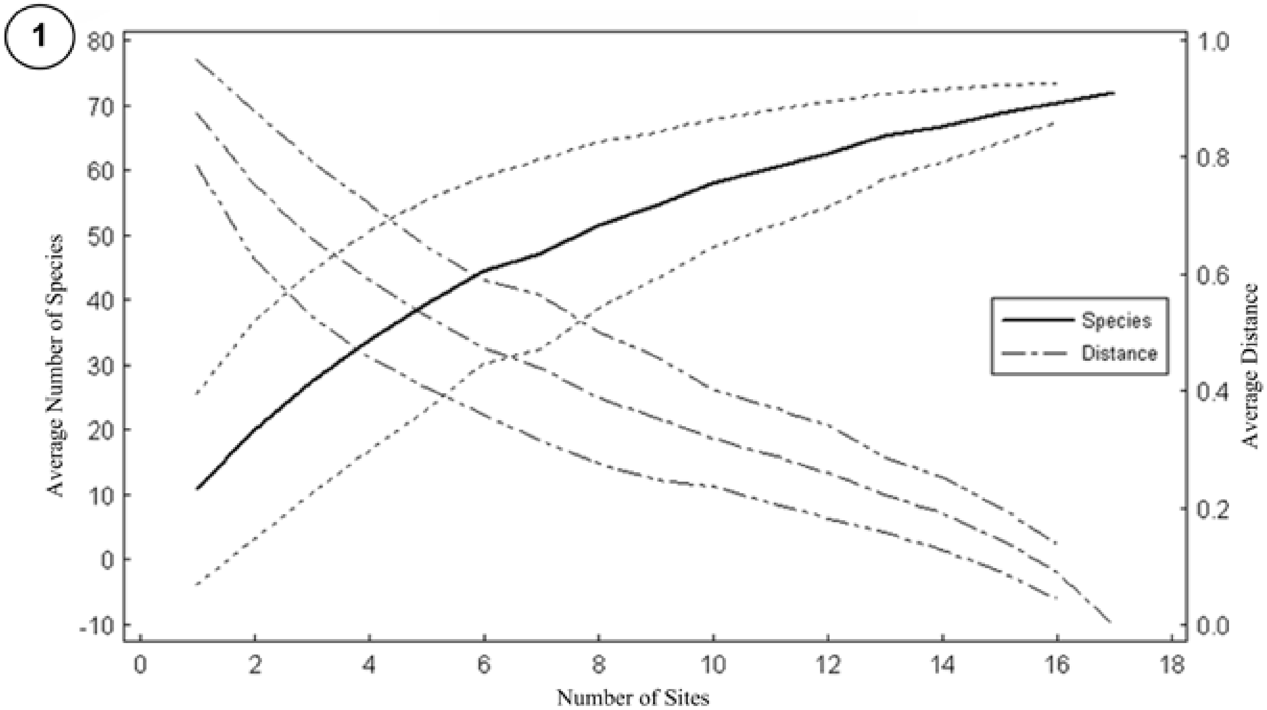


Figure 1.1 **Species accumulation curve of odonate species found in the Upper Berbice region.**

Table 1.1 **Checklist of Odonates recorded during the Upper Berbice River Region Biodiversity Assessment Team (BAT) Expedition**

Key
Square brackets after each family= [number of genera/number of species recorded].
Species in bold: new records for Guyana at the time the survey took place.
Relative abundance per site: R (rare = 1-3 specimens seen); F (frequent = 4-20 specimens seen); C (common = 21-50 specimens seen).
Incidence: Number of sites where each species was recorded.

SITES	UPPER BERBICE REGION																	INCIDENCE
	BERBICE RIVER CAMP							BERBICE WHITE SANDS CAMP										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Taxa																		
Zygoptera																		
Calopterygidae [2/3]																		
Hetaerina caja dominula Hagen in Selys, 1853					R	R			R		R							4
Hetaerina moribunda Hagen in Selys, 1853 (Fig. 1.4)									F	F	R	F	F		R		R	7
Mnesarete cupraea (Selys, 1853) (Fig. 1.5)									F		F		F		R		R	5
Coenagrionidae [10/22]																		
Acanthagrion apicale Selys, 1876																R		1
Acanthagrion indefensum Williamson, 1916				C		C												2
Acanthagrion rubrifrons Leonard, 1977									F		R							2
Argia deceptor Garrison & von Ellenrieder, 2015								R										1
Argia fumigata Hagen in Selys, 1865			F		F		F		F		R		F		R	R	R	9
Argia gemella Garrison & von Ellenrieder, 2015 (Fig. 1.6)								F		R								2
Argia meioura Garrison & von Ellenrieder, 2015 (Fig. 1.7)									R		R	F			R	R	F	6
Argia oculata Hagen in Selys, 1865									R									1
Epipleoneura capilliformis (Selys, 1886) (Fig. 1.8)									C		F		F			R	F	5
Mecistogaster linearis (Fabricius, 1776)												R						1
Mecistogaster lucretia (Drury, 1773)																	R	1
Metaleptobasis brysonima Williamson, 1915												R						1
Neoneura bilinearis Selys, 1860				F		F												2
Neoneura denticulata Williamson, 1917						F												1
Neoneura mariana Williamson, 1917									R		R						R	3
Neoneura myrthea Williamson, 1917				F														1
Neoneura rubriventris Selys, 1860				F		F												2
Phasmoneura exigua (Selys, 1886) (Fig. 1.9)								F			F	R					F	4
Protoneura calverti Williamson, 1915											R							1
Protoneura paucinervis Selys, 1886				F		F												2
Psaironeura tenuissima (Selys, 1886)								F			R							2
Telebasis simulata Tennessen, 2002														F				1

Table 1.1 **Checklist of Odonates recorded during the Upper Berbice River Region Biodiversity Assessment Team (BAT) Expedition (*cont'd*)**

SITES	UPPER BERBICE REGION																	INCIDENCE
	BERBICE RIVER CAMP							BERBICE WHITE SANDS CAMP										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Taxa																		
Dicteriadidae [1/1]																		
Heliocharis amazona (Selys, 1853) (Fig. 1.10)									R		F	R	R			R	R	6
Perilestidae [1/1]																		
Perilestes attenuatus Selys, 1886									R								R	2
Megapodagrionidae [2/4]																		
Heteragrion icterium Williamson, 1919 (Fig. 1.11)									F		F						F	3
Heteragrion silvarum Sjöstedt, 1918									R									1
Oxystigma cyanofrons Williamson, 1919 (Fig. 1.12)								F	F						F		F	4
Oxystigma petiolatum (Selys, 1862) (Fig. 1.13)												R						1
Anisoptera																		
Aeshnidae [1/2]																		
Gynacantha membranalis Karsch, 1891									R							R		2
Gynacantha nervosa Rambur, 1842	R																	1
Gomphidae [4/5]																		
Archaeogomphus hamatus (Williamson, 1918)													R					1
Desmogomphus tigrivensis Williamson, 1920									R									1
Phyllogomphoides atlanticus Belle, 1970			R															1
Phyllogomphoides undulatus (Needham, 1944)						F												1
Zonophora batesi Selys, 1869 (Fig. 1.14)									R								R	2
Libellulidae [18/34]																		
Diastatops pullata (Burmeister, 1839)				F		F												2
Dythemis nigra Martin, 1897	R	R	F				R							R				5
Elasmothemis williamsoni (Ris, 1919)									F			R				F		3
Elga leptostyla Ris, 1909													R					1
Erythemis haematogastra (Burmeister, 1839)		F				F												2
Erythemis vesiculosa (Fabricius, 1775)	R													R				2
Erythrodiplax amazonica Sjöstedt, 1918 (Fig. 1.15)								F	F		R				R			4
Erythrodiplax castanea (Burmeister, 1839) (Fig. 1.16)									F		C			R				3
Erythrodiplax fusca (Rambur, 1842) (Figs. 1.17, 1.18)		F							F	F	F	F		F	R		R	8
Erythrodiplax umbrata (Linnaeus, 1758)	R	R							R									3
Gynothemis pumila (Karsch, 1890)									R									1

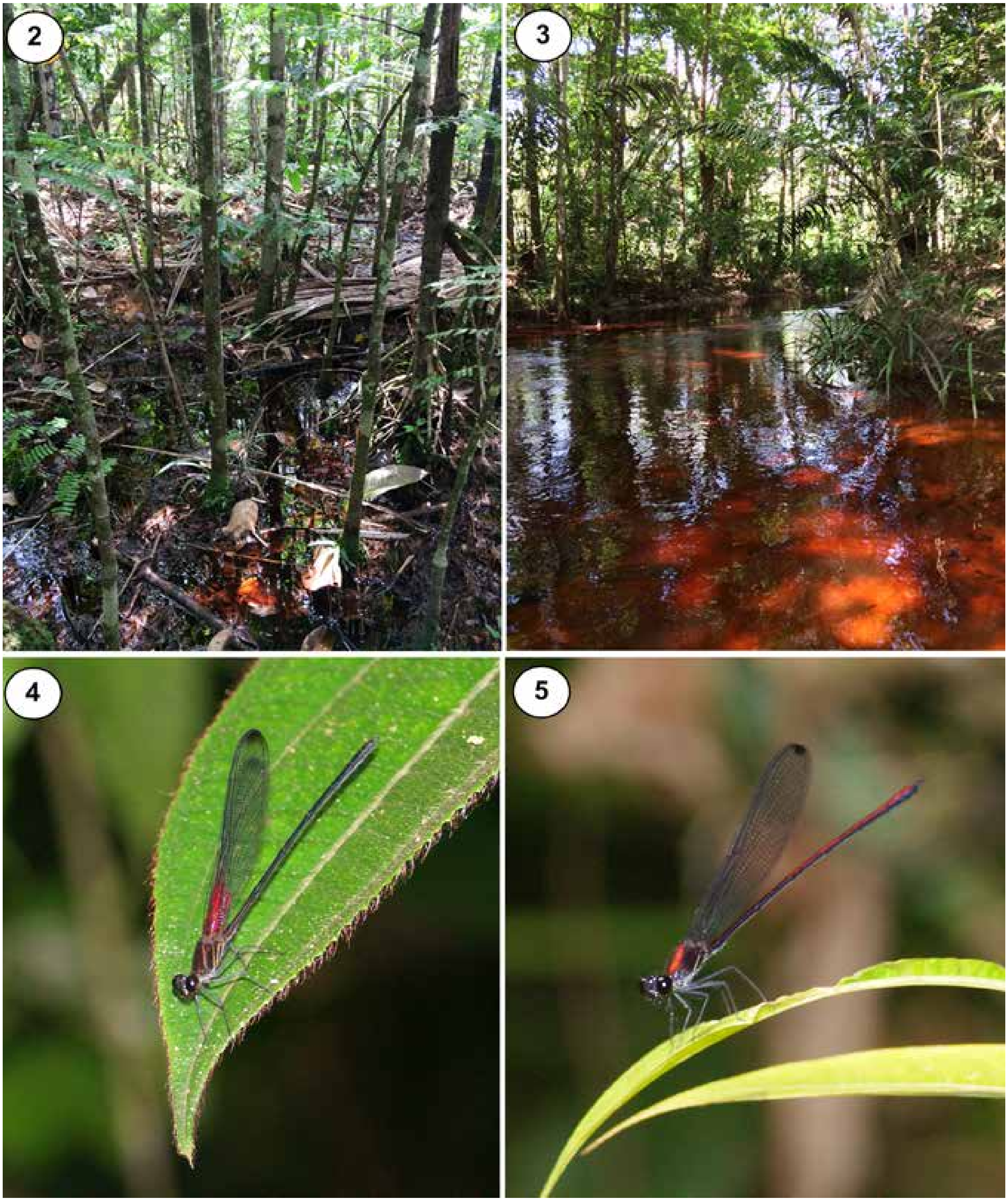
Libellulidae [18/34] (*cont'd*)																		
Macrothemis sp. (teneral)												R						1
Miathyria simplex (Rambur, 1842)						R												1
Micrathyria artemis Ris, 1911				R		F								R				3
Micrathyria atra (Martin, 1897) (Fig. 1.19)		F													R		R	3
Micrathyria catenata Calvert, 1909									R					R				2
Micrathyria pseudeximia Westfall, 1992		R									F							2
Misagria bimacula Kimmins, 1943															R			1
Nephepeltia phryne (Perty, 1833)		R																1
Oligoclada abbreviata (Rambur, 1842)						R					R							2
Oligoclada amphinome Ris, 1919 (Fig. 1.20)									R		F				R		R	4
Oligoclada pachystigma Karsch, 1890				F		C												2
Orthemis aequilibris Calvert, 1909 (Fig. 1.21)									R		F				F		R	4
Orthemis biolleyi Calvert, 1906									R		F							2
Orthemis cultriformis Calvert, 1899									R									1
Orthemis discolor (Burmeister, 1839)	R	R			F					R	F	R		F				7
Orthemis schmidti Buchholz, 1950 (Fig. 1.22)				R	R						F			F				4
Pantala flavescens Fabricius, 1798	F													R				2
Perithemis cornelia Ris, 1910				R	R	R												3
Perithemis lais (Perty, 1833)			R	F							R				F		F	5
Perithemis mooma Kirby, 1889 (Fig. 1.23)	R	R							R		F		R					5
Perithemis thais Kirby, 1889			F		F							R						3
Tramea binotata (Rambur, 1842)											R							1
Zenithoptera fasciata (Linnaeus, 1758)												R						1
Species Richness per Site	7	9	5	11	6	14	2	6	29	4	26	13	8	10	12	7	18	
Shannon Diversity per Site	1.95	2.2	1.61	2.40	1.79	2.64	0.69	1.79	3.37	1.39	3.26	2.57	2.08	2.30	2.49	1.95	2.89	
Simpson Diversity per Site	0.86	0.89	0.80	0.91	0.83	0.93	0.50	0.83	0.97	0.75	0.96	0.92	0.88	0.90	0.92	0.86	0.94	
Species Richness per area	31 (Chao2 = 35.45)							57 (Chao2 = 83.32)										
Species Richness of surveyed Region	72 (Chao2 = 87.29)																	

Table 1.2 **Odonates found during the Upper Berbice Biodiversity Assessment Team Expedition: Habitat where found, data on known larvae, distribution (from Paulson 2015 and material examined), and conservation status according to IUCN Red List**

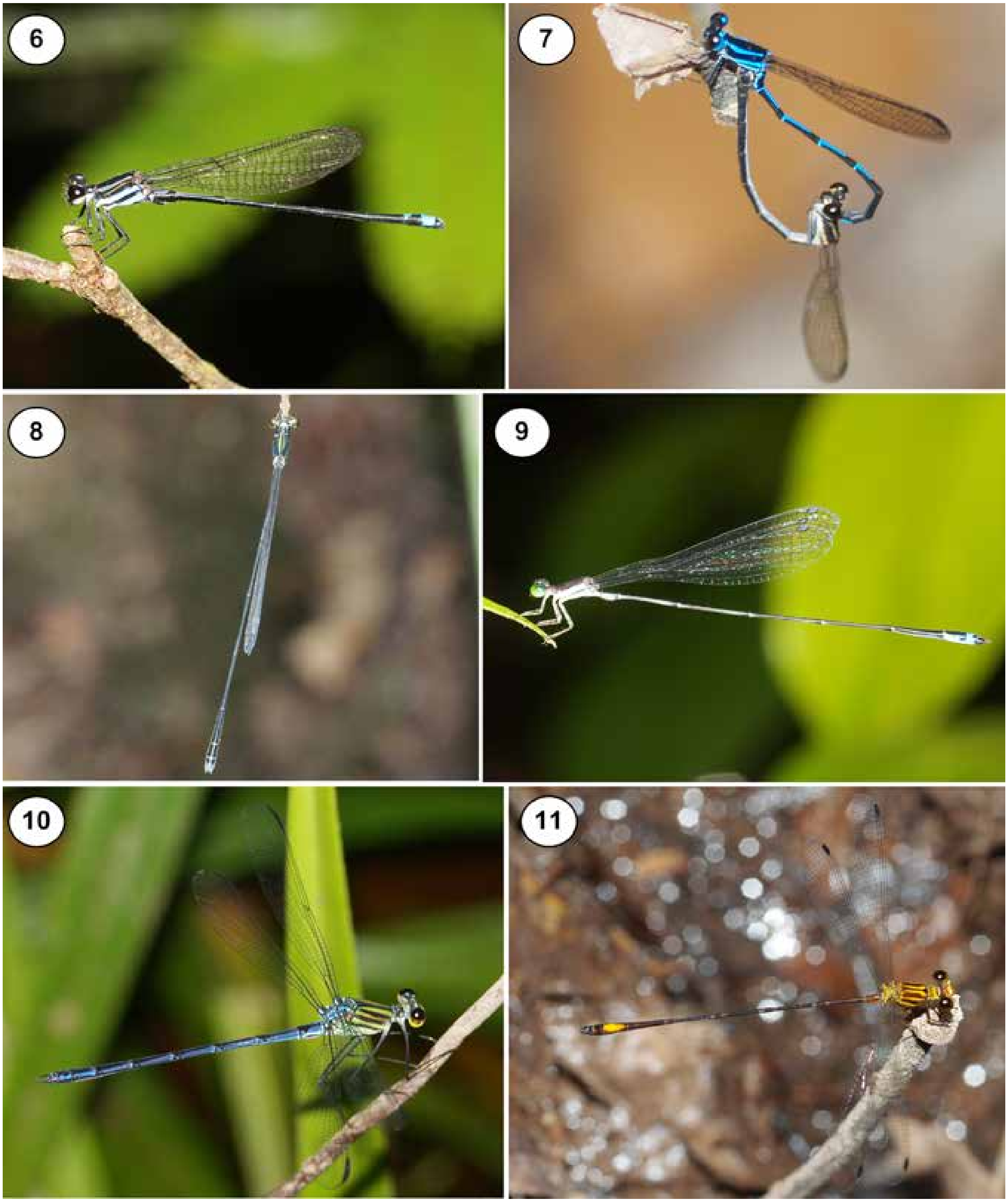
Key
In bold: new records for Guyana at the time the survey took place.
Distribution: AMZ: Guianan and Amazonian; GUI: Guianan; NEO: widespread in the Neotropical region.
Country codes in parenthesis:
AR: Argentina, BE: Belize, BO: Bolivia, BR: Brazil, CA: Canada, CO: Colombia, CR: Costa Rica, EC: Ecuador, FR: French Guiana, GU: Guatemala, GY: Guyana, ME: Mexico,
NI: Nicaragua, PA: Panama, PE: Peru, PY: Paraguay, SU: Suriname, TR: Trinidad/Tobago, US: United States, VE: Venezuela.
IUCN category: LC: Least Concern.

SPECIES	HABITAT	LARVA DESCRIBED	DISTRIBUTION	IUCN
Zygoptera				
Calopterygidae				
Hetaerina caja dominula	creeks/ river	Geijskes 1943	GUI (VE, GY, SU, FR, BR)	-
Hetaerina moribunda	creeks	Geijskes 1943 by supposition	GUI (VE, GY, SU, FR, BR)	-
Mnesarete cupraea	creeks	-	AMZ (VE, GY, SU, FR, PE, BO)	-
Coenagrionidae				
Acanthagrion apicale	creeks	De Marmels 1992	NEO (CO, VE, GY, FR, BR, EC, PE, BO)	-
Acanthagrion indefensum	river	Geijskes 1943	GUI (VE, GY, SU, FR, BR)	-
Acanthagrion rubrifrons	creeks	-	GUI (VE, GY, SU, FR, BR)	-
Argia deceptor	flooded forest	-	GUI (GY, SU, FR)	-
Argia fumigata	creeks	-	AMZ (VE, GY, SU, FR, BR, EC)	-
Argia gemella	creeks	-	GUI (GY, SU, FR, BR)	-
Argia meioura	creeks	-	GUI (VE, GY, SU, FR, BR)	-
Argia oculata	creeks	Limongi 1983 (1985)	NEO (ME to BO, GY)	-
Epipleoneura capilliformis	creeks	-	AMZ (GY, BR)	LC
Mecistogaster linearis	trail	Sahlén and Hedström 2005	NEO (NI to BR, BO)	-
Mecistogaster lucretia	trail	-	NEO (CO, VE, GY, SU, FR, BR, EC, PE, AR)	-
Metaleptobasis brysonima	creeks	-	AMZ (TR, VE, GY, SU, FR, BR, PE, BO)	-
Neoneura bilinearis	river	-	AMZ (VE, GY, SU, BR, PE)	-
Neoneura denticulata	river	-	AMZ (VE, GY, SU, EC, PE, BR)	-
Neoneura mariana	creeks	-	GUI (VE, GY, SU, FR)	-
Neoneura myrthea	river	-	AMZ (VE, GY, SU, FR, BO)	-
Neoneura rubriventris	river	-	AMZ (VE, GY, SU, EC, PE, BR)	-
Phasmoneura exigua	flooded forest/ creeks	-	AMZ (GY, SU, FR, PE, BR)	-
Protoneura calverti	creeks	-	GUI (VE, TR, GY, SU, FR, BR)	LC
Protoneura paucinervis	river	-	AMZ (VE, GY, BR, EC, PE)	-
Telebasis simulata	pools	Geijskes 1943 as *T. sanguinalis*	GUI (VE, TR, GY, SU, FR, BR)	-
Dicteriadidae				
Heliocharis amazona	creeks	Geijskes 1986, Santos and Costa 1988	NEO (Co, VE, to PY, AR)	-
Perilestidae				
Perilestes attenuatus	river	Neiss & Hamada 2010	AMZ (VE, GY, SU, FR, BR, PE, BO)	LC
Megapodagrionidae				
Heteragrion ictericum	creeks/trail	-	GUI (VE, GY, SU, FR, BR)	-
Heteragrion silvarum	creeks	-	GUI (GY, SU, FR, BR)	-
Oxystigma cyanofrons	creeks/trail	Geijskes 1943 as *O. petiolatum*	GUI (VE, GY, SU, FR)	-
Oxystigma petiolatum	trail	-	AMZ (VE, GY, SU, FR, BR, EC)	LC
Anisoptera				
Aeshnidae				
Gynacantha membranalis	trail	Santos, Costa and Pujol-Luz 1987	NEO (NI to BO, BR)	-
Gynacantha nervosa	trail	Williams 1937	NEO (SE US, Antilles, to Bolivia)	LC

SPECIES	HABITAT	LARVA DESCRIBED	DISTRIBUTION	IUCN
Gomphidae				
Archaeogomphus hamatus	creeks	-	AMZ (CO, GY, SU, BR)	-
Desmogomphus tigrivensis	creeks	Belle 1970, 1977	GUI (VE, GY, FR, BR)	-
Phyllogomphoides atlanticus	creeks	-	GUI (GY, SU, FG)	-
Phyllogomphoides undulatus	river	Belle 1970 by supposition	GUI (VE, GY, SU, FR, BR)	-
Zonophora batesi	creeks	Belle 1966	GUI (VE, GY, SU, FR, BR)	-
Libelullidae				
Diastatops pullata	river	Fleck 2003	NEO (VE, GY, SU, FR, BR, EC, PE, BO, AR)	LC
Dythemis nigra	creeks	De Marmels 1982, Westfall 1988, as *D. multipunctata*	NEO (ME to AR)	-
Elasmothemis williamsoni	creeks	Westfall 1988	AMZ (GY, SU, FR, PE)	-
Elga leptostyla	creeks	De Marmels 1990, Fleck 2003	NEO (PA to PE)	-
Erythemis haematogastra	pools	-	NEO (ME, BE to BR, PE)	LC
Erythemis vesiculosa	pools	Klots 1932, Needham and Westfall 1955	NEO (S US, Antilles, to AR)	LC
Erythrodiplax amazonica	flooded forest/creeks	De Marmels 1992	AMZ (VE, TR, GY, SU, FR, BR, PE)	-
Erythrodiplax castanea	creeks/ pools	-	NEO (GU to AR)	-
Erythrodiplax fusca	pools/ creeks	Santos 1967	NEO (ME to AR)	-
Erythrodiplax umbrata	pools	Calvert 1928, Costa, Vieira and Lourenço 2001	NEO (ME to AR)	-
Gynothemis pumila	creeks	Fleck 2004	AMZ (CO, VE, TR, GY, SU, FR, BR, PE)	LC
Macrothemis sp.	creeks			
Miathyria simplex	pools	Limongi 1991	NEO (ME to PE, BR)	-
Micrathyria artemis	pools	Santos 1972	NEO (VE, GY, SU, FR, BR, EC, PE, AR)	LC
Micrathyria atra	pools	Santos 1978	NEO (ME to AR)	LC
Micrathyria catenata	pools	-	NEO (CR to AR)	LC
Micrathyria pseudeximia	pools	-	NEO (GU to AR)	-
Misagria bimacula	creeks	-	GUI (VE, GY)	LC
Nephepeltia phryne	pools	De Marmels 1990	NEO (BE to AR)	LC
Oligoclada abbreviata	river/creeks	Machado and Machado 1993, Fleck 2003	AMZ (VE, GY, SU, FR, BR)	LC
Oligoclada amphinome	creeks	-	GUI (VE, GY, SU, FR, BR)	-
Oligoclada pachystigma	river	-	GUI (VE, GY, SU, FR, BR)	-
Oligoclada walkeri	river	-	AMZ (VE, TR, GY, SU, FR, BR, EC, PE)	-
Orthemis aequilibris	clearing/ pools	Fleck 2003	NEO (CR to AR)	-
Orthemis biolleyi	creeks	Fleck 2003	NEO (BE to BO)	LC
Orthemis cultriformis	clearing/ pools	Carvalho and Werneck de Carvalho 2005	NEO (CR to AR)	-
Orthemis discolor	clearing/ pools	-	NEO (ME to AR)	-
Orthemis schmidti	clearing/ pools	-	NEO (GU to BO, BR)	-
Pantala flavescens	clearing/ pools	Geijskes 1934	Circumtropical, in New World NEO (CA to AR)	LC
Perithemis cornelia	creeks/ pools/ river	-	AMZ (VE, GY, BR, PE, BO)	LC
Perithemis lais	creeks/ pools	Costa & Regis 2005	NEO (CO to AR)	LC
Perithemis mooma	creeks/pools	Santos 1973, von Ellenrieder and Muzón 1999	NEO (ME to AR)	-
Perithemis thais	creeks	Spindola et al. 2001	NEO (CR to AR)	-
Tramea binotata	clearing	Needham et al. 2000	NEO (ME to AR, GY)	-
Zenithoptera fasciata	pools	-	NEO (CR to BR)	LC

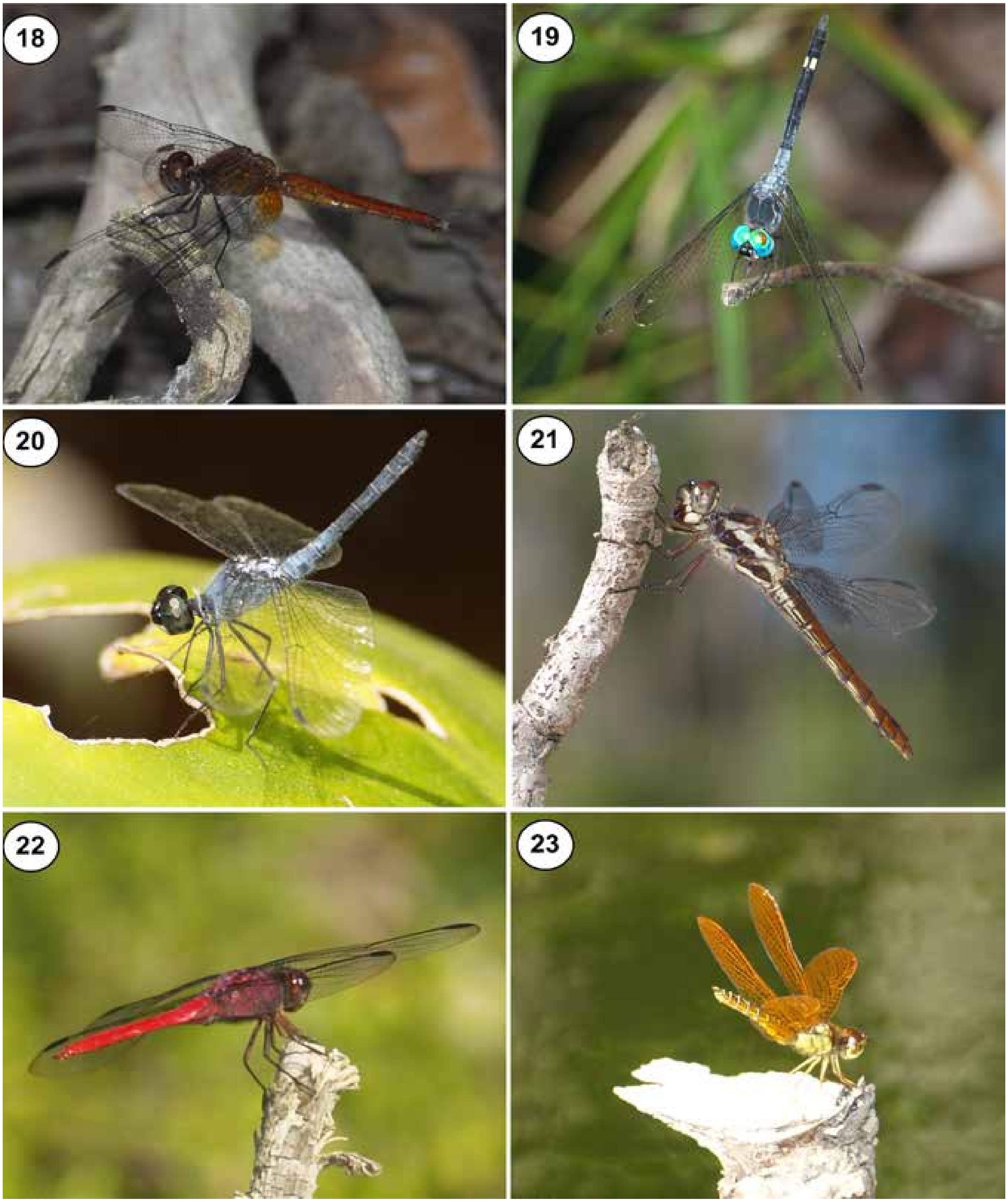


Figures 1.2-1.5
Figure 1.2 **Flooded forest and trickles of water running into blackwater stream near White Sands camp (site 8).**
Figure 1.3 **Blackwater stream near White Sands camp (site 9).**
Figure 1.4 ***Hetaerina moribunda*: Male at blackwater creek 5 km from White Sands camp (site 12).**
Figure 1.5 ***Mnesarete cupraea*: Male perching on sunlit vegetation overhanging blackwater creek upstream from White Sands camp (site 11).**



Figures 1.6-1.11
Figure 1.6 ***Argia gemella*: Male at flooded forest (site 8).**
Figure 1.7 ***Argia meioura*: Pair in copula on bank of blackwater stream (site 9).**
Figure 1.8 ***Epipleoneura capilliformis*: Male perching on shaded margin of blackwater stream (site 9).**
Figure 1.9 ***Phasmoneura exigua*: Male at shaded area of flooded forest (site 8).**
Figure 1.10 ***Heliocharis amazona*: Male at sandy blackwater stream (site 17).**
Figure 1.11 ***Heteragrion ictericum*: Male on blackwater stream upstream from White Sands camp (site 9).**

Figures 1.12-1.17.
Figure 1.12 ***Oxystigma cyanofrons*: Male at blackwater stream 15 km from White Sands camp (site 15).**
Figure 1.13 ***Oxystigma petiolatum*: Male at blackwater stream 5 km from White Sands camp (site 12).**
Figure 1.14 ***Zonophora batesi*: Male at its perch on blackwater stream (site 11).**
Figure 1.15 ***Erythrodiplax amazonica*: Male on sun patch in flooded forest (site 8).**
Figure 1.16 ***Erythrodiplax castanea*: Male at side pool (site 17).**
Figure 1.17 ***Erythrodiplax fusca*: Male at side pool (site 17).**



Figures 1.18-1.23
Figure 1.18 ***Erythrodiplax fusca*: Female at side pool (site 17).**
Figure 1.19 ***Micrathyria atra*: Male in obelisk position in sun at side pool (site 17).**
Figure 1.20 ***Oligoclada amphinome*: Male on sunlit leaf at blackwater stream 15 km from White Sands camp (site 15).**
Figure 1.21 ***Orthemis aequilibris*: Female at side pool (site 17).**
Figure 1.22 ***Orthemis schmidti*: Male on its perch at side pool (site 17).**
Figure 1.23 ***Perithemis mooma*: Male at side pool (site 17).**

Discussion

The difference in odonate species composition and diversity observed between the Berbice White Sands area and the Berbice River area can be explained in part by the different types of aquatic habitats sampled at each site. The Berbice White Sands camp area had a more diverse odonate community, probably reflecting the higher number of habitats sampled, including flooded forest, swampy areas, vegetated and open pools at streams, narrow and wide blackwater creeks with closed and open canopy, compared to the Berbice River camp area where only blackwater creeks, side pools, stagnant creeks, and the river were surveyed. Another factor contributing to the higher number of species is the larger area covered at the Berbice White Sands area, with streams 5 to 30 km away from the camp accounting for an additional nine species. Several of the species found only at the Berbice River camp were observed only at the river, which was not visited at the White Sands camp, i.e. *Acanthagrion indefensum*, *Neoneura bilinearis*, *N. denticulata*, *N. myrthea*, *N. rubriventris*, *Protoneura paucinervis*, *Phyllogomphoides undulatus*, *Diastatops pullata*, *Miathyria simplex*, and *Oligoclada pachystigma*. Odonate diversity and abundance at the Berbice River camp area creeks, especially of damselflies, was lower than expected for a primary forest system, which could be explained at least in part by the lower diversity and abundance characteristic of tropical rainforests during the dry season.

Almost a third (32%) of all the species recorded were rare, being found only once at only one locality. Coupled with the facts that additional odonate species were recorded each day at the different sites visited in both areas and that the curve of number of species found did not plateau indicates that many more species would likely have been recorded from this region had the survey time been longer. The results of this short dry season survey therefore show that a more extended study during both dry and wet seasons at the Berbice region would certainly render additional taxa.

Conservation recommendations

The diversity of odonate genera and species found in this study at the Upper Berbice is typical of well-preserved sites within Neotropical rainforests. Many odonate species require closed canopy forest to maintain the appropriate vegetation structure they need as adults. **Logging affects their occurrence and produces a marked decrease in their diversity, since it affects the vegetation structure needed by the adults, and the subsequent alteration of water bodies by ensuing erosion and siltation is detrimental for their larvae**. If logging continues in the Upper Berbice region, it is fundamental that approved practices for reduced impact of logging are enforced to help mitigate the impacts on the environment. To this end, the creation and preservation of 200 m buffer zones along the margins of the Berbice River and associated streams is recommended to preserve the integrity of this pristine forest and its freshwater habitats necessary to maintain the current odonate diversity.

Mining leads to increased turbidity, and probable siltation of streams, changing the substrate and reducing the habitat quality needed by odonate larvae. If any mining is allowed to take place in this area, catchment ponds should be built to contain tailings and by-products of mining operations, to prevent these being discharged into the river or streams which would cause excessive sedimentation downstream.

Surveys during the wet season are recommended to gain knowledge about the possible seasonality of the odonate community of South Central Guyana, and in order to gather a more representative baseline of what species of damselflies and dragonflies live in this region.

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CHAPTER 2

AMPHIBIANS AND REPTILES OF THE BERBICE RIVER CAMP AND WHITE SANDS CAMP, GUYANA

Andrew M. Snyder and Timothy J. Colston

Summary

THIS SURVEY PROVIDES THE FIRST RECORDS FOR A NUMBER OF AMPHIBIAN AND REPTILE SPECIES IN THE BERBICE FOREST

We recorded a total of 53 species including 20 species of amphibians and 33 species of reptiles for the entire study area during this survey. When compared to other better-sampled areas of the Guiana Shield, these numbers are low, but are similar to numbers recorded in previous surveys conducted in this region. Based on our data, however, sampling completeness estimates predict that the total number of amphibian and reptile species for that area should be closer to 110. Furthermore, **we provide the first records for a number of species in the Berbice forest.** All of the amphibians encountered belong to the order Anura. Almost half of the anurans were tree frogs (Hylidae) with eight species, followed by the "southern frogs" (Leptodactylidae) with five species, toads (Bufonidae, three species), and single representatives of the families Aromobatidae, Dendrobatidae, Pipidae, and Strabomantidae. Within reptiles, we recorded two species of crocodilian, three species of turtles and tortoises, 11 species of lizards, and 17 species of snakes. The two focal areas surveyed during this expedition differed in their herpetofaunal composition, with many species encountered being exclusive to a particular site. The habitats surveyed around the Berbice River camp were in pristine condition along roads, while the habitats surveyed at the White Sands camp included both intact and highly disturbed forest.

Introduction

Amphibians and reptiles (herein herpetofauna) are important components of lowland tropical rainforest ecosystems. The knowledge of Guiana Shield herpetofauna has been increasing rapidly, especially over the past decade as biodiversity surveys throughout the lowlands, uplands, and highlands have become more commonplace. **Surveys conducted throughout Guyana have revealed a rich herpetofauna and high levels of endemism predominantly associated with uplands and highlands** (e. g. Cole and Kok 2006; Kok et al. 2006; MacCulloch and Lathrop 2002). **Guyana hosts 324 described species (148 amphibians and 176 reptiles), 15% of which are endemic to Guyana** (Cole et al. 2013).

GUYANA HOSTS 324 DESCRIBED HERPETOFAUNA SPECIES (148 AMPHIBIANS AND 176 REPTILES), 15% OF WHICH ARE ENDEMIC TO GUYANA

Herpetofauna are often conspicuous, vital components of healthy Neotropical forests and the rivers that drain them. Within the amphibians, much of their inherent biology (e.g. large population sizes, small to intermediate body size, microhabitat requirements) makes them appropriate taxa for rapid assessments. Because amphibians are sensitive to impacts to their microhabitat and water quality, they are good indicators of environmental disturbance and health (Stuart et al. 2004). Additionally, amphibians are appropriate for rapid assessment surveys as hard to collect species (i.e. canopy-dwelling species) can be recorded passively via their species-specific vocalizations (Marty and Gaucher 2000). In primary forest, lizard community diversity is known to be higher than in secondary or altered (e.g. agriculture/plantation) forest (Gardner et al. 2007), also making lizards reliable indicators of disturbance. Though snake community structure has shown resilience to some degree of anthropogenic impacts (França and Araújo 2007), the presence of specialist predators and rare taxa (e.g. *Hydrodynastes bicinctus*) is evidence of a healthy ecosystem. It is also important to note that crocodilians, testudines, and both large lizards and large snakes are hunted and consumed by Amerindians, and thus the records of any of these species provide an indication of the region's hunting pressure (Peres 2000).

Herpetofaunal species diversity is related to habitat diversity, as many species demonstrate strict habitat requirements (Tews et al. 2004), as well as the degree of disturbance. Our two survey sites represented both ends of the spectrum, with the Berbice River Camp (BRC) being functionally pristine (excluding the logging road), and the White Sands Camp (WSC) disturbed due to human-induced fire. We observed stark differences between the herpetofaunal compositions at both sites that were consistent with their condition. At the White Sands camp, we recorded an abundance of cane toads (*Rhinella marina*) as well as emerald-eyed frogs (*Boana crepitans*), "weedy species" commonly associated with anthropogenic disturbance. Additionally, weather patterns affect reptile and amphibian activity patterns, and thus also their detectability. Although we recorded an impressive number of species for the dry season (time of lowest activity in a tropical rainforest), the actual

THIS AREA, ESPECIALLY AROUND THE BERBICE RIVER CAMP SURVEY SITE, SHOULD BE GIVEN HIGH CONSERVATION PRIORITY BECAUSE OF ITS PRISTINE CONDITION AND PRESENT LOW LEVELS OF HUMAN ACTIVITY, EXCLUDING THE BAI SHAN LIN LOGGING OPERATION

number of species for both sites is unquestionably much greater than our surveys recorded. **This area, especially around the Berbice River camp survey site, should be given high conservation priority because of its pristine condition and present low levels of human activity, excluding the Bai Shan Lin logging operation.**

As part of the WWF-Guianas and Global Wildlife Conservation's Biodiversity Assessment Team (BAT) survey in the Upper Berbice region of Guyana, we surveyed the herpetofauna in and around the Upper Berbice River camp and Upper Berbice White Sands camp for four and five days, respectively. Within these sites, herpetofaunal surveys covered the lowland rainforests and the associated water systems, as well as anthropogenically disturbed areas.

Survey sites and methods

Our team, typically consisting of the lead author and two local guides, surveyed amphibians and reptiles from the period of 21-30 September 2014 in two sites located along the Bai Shan Lin logging road. To maximize opportunities for encountering herpetofauna, preliminary surveys were conducted to identify areas of optimal habitat suitability in order to target search efforts. Except for one night-time survey along the Berbice River, all surveys were at an extended walking distance from the main camps, which are detailed in the results section. Our surveys included daytime and night-time visual encounter surveys over large areas of suitable habitat, and covered the primary lowland forest habitat and microhabitats, especially creeks and streams. The sampling methods also included breaking apart rotting logs, turning over stones and logs, and raking through the leaf litter in order to uncover less conspicuous species. Nocturnal acoustic monitoring of amphibians was also employed to document species often confined to the canopy (e.g. *Trachycephalus resinifictrix*). Additionally, observations made by other teams that were definitively verified by our team were included on our list. Given the short survey time, opportunistic surveys can be effectively employed to encounter as many species as possible (Donnelly et al. 2005a, 2005b).

When observed, reptiles and amphibians were captured by hand. For each specimen, a field number was assigned, and corresponding locality data, preliminary identification, and general descriptions of habitat were noted. When possible, specimens were photographed (by Andrew M. Snyder) prior to euthanasia. Individuals were euthanized via standard methods found acceptable by the Herpetological Animal Care and Use Committee of the American Society of Ichthyologists and Herpetologists (Beaupre et al. 2004), and fixed using 10% formol, and subsequently stored in 70% ethanol as museum voucher specimens. The collected specimens have been deposited in the collections of the Smithsonian National Museum of Natural History and the Centre for the Study of Biological Diversity, University of Guyana, Georgetown, where they will undergo final morphological verification. Prior to formalin fixation, samples of liver/muscle tissue were taken from each voucher specimen, which were preserved in 95% ethanol. These tissues were deposited in the University of Mississippi frozen tissue collection. Some photo voucher records of the herpetofauna were documented by other BAT team members, and were included in the list only if an accurate identification could be made. In this report, the amphibian and reptile taxonomy follows that of Vitt and Caldwell (2013). All species assignments were checked with AmphibiaWeb (www.amphibiaweb.org) and the ReptileDatabase (www.reptile-database.org), last accessed 9 May 2018.

Results

We recorded a total of 33 species of reptiles and 20 species of amphibians from both survey sites (Table 2.2, Figures 2.1-2.2, and Appendix 2). All species encountered were assignable to known species based on morphology except for one anole lizard, which has been designated by a "cf." until further verification. All amphibians encountered belong to the order Anura. Almost half were tree frogs (Hylidae) with eight species, followed by the "southern frogs" (Leptodactylidae) with five species, toads (Bufonidae, three species), and single representatives each of the families Aromobatidae, Dendrobatidae, Pipidae, and Strabomantidae. Within the reptiles, we recorded two species of crocodilian, three species of turtles and tortoises, 11 species of lizards, and 17 species of snakes. We did not record each individual of every species encountered, so quantitative assessments of species' relative abundance cannot be made. However, the species list was used to calculate an estimate of sampling completeness (Chao's 1984 estimator) following that of Cole et al. 2013. Based on our data, the total number of herpetofaunal species predicted to be present in the region we sampled was 108.1, meaning these surveys recorded 49% of the estimated herpetofauna. A previous, longer survey of a different portion of the forests along the Berbice River yielded 65 species, with an estimated fauna of 90 species (Cole et al. 2013). Thus, it is likely that the actual estimated herpetofauna is somewhere between both estimates.

The Upper Berbice River camp and Upper Berbice White Sands camp only shared nine species of amphibian and reptiles in common. Seventeen amphibian species and 27 reptile species were unique to only one site (85% and 82% uniqueness respectively; Table 2.2). Because the sampling time was not long enough for a complete herpetofaunal inventory of either site, the Simpson's (1960) equation was employed, correcting for incomplete sampling, to compare the amphibians and reptiles between each site (Table 2.4) and other lowland sites in Guyana.

Of the 53 species of reptiles and amphibians recorded from both survey sites, only two are classified by the IUCN Red List of Threatened Species (IUCN 2014, Table 2.1, and Appendix 2). The yellow-footed tortoise (*Chelonoidis denticulatus*) is listed as "Vulnerable" and the black caiman (*Melanosuchus niger*) is considered "Low Risk/Conservation Dependent". All other encountered species are either listed as "Least Concern" due to their broad geographic range or have not yet been evaluated.

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Adult yellow-footed tortoise (*Chelonoidis denticulatus*), a species listed as Vulnerable by IUCN, at the Berbice forest camp

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A black caiman (*Melanosuchus niger*) in the Berbice River

Additionally, eight species are currently included in the Convention on the International Trade of Endangered Species, CITES, (Table 2.1, Appendix 2), which provides special priority to listed species in order to ensure that their long-term survival is not affected by international trade. CITES listings fall into one of three categories depending on the degree of protection required: Appendix I- species threatened with extinction; Appendix II- species not necessarily facing extinction but requiring controlled trade to avoid impacting the species' survival; and Appendix III- species that are protected in at least one country. Of the species encountered during this survey, the black caiman (*Melanosuchus niger*), dwarf caiman (*Paleosuchus palpebrosus*), Amazon tree boa (*Corallus hortulanus*), rainbow boa (*Epicrates cenchria*), red-footed tortoise (*Chelonoidis carbonarius*), yellow-footed tortoise (*Chelonoidis denticulatus*), three-striped poison frog (*Ameerega trivittata*), and rocket frog (*Allobates femoralis*) are included in Appendix II of CITES, with the black caiman also included on Appendix I.

A juvenile rocket frog (*Allobates femoralis*) sits on top of a small Guyana one-dollar coin, which has a diameter of c. 1.5 cm.


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A rainbow boa (*Epicrates cenchria*) in habitat. Berbice Forest camp.

Table 2.1 **Species of conservation concern documented during the survey**

SPECIES	COMMON NAME	GROUP	IUCN	CITES
Melanosuchus niger	Black caiman	Reptile	Lower Risk/Conservation Dependent	Appendix I
Paleosuchus palpebrosus	Cuvier's smooth-fronted caiman	Reptile	Least Concern	Appendix II
Chelonoidis carbonarius	Red-footed tortoise	Reptile	Not Evaluated	Appendix II
Chelonoidis denticulatus	Yellow-footed tortoise	Reptile	Vulnerable	Appendix II
Corallus hortulanus	Amazon tree boa	Reptile	Not Evaluated	Appendix II
Epicrates cenchria	Rainbow boa	Reptile	Not Evaluated	Appendix II
Ameerega trivittata	Three-striped poison frog	Amphibian	Least Concern	Appendix II
Allobates femoralis	Rocket frog	Amphibian	Least Concern	Appendix II

Table 2.2 **Richness of amphibian and reptile species encountered at each locality, the site-specific percentage of the total species recorded, and uniqueness of each site for both taxonomic groups**

Camp abbreviations: Upper Berbice River Camp (BRC), Upper Berbice White Sands Camp (WSC)

COLLECTION SITE	BRC	WSC
# of reptile and amphibian species encountered (% of total)	41 (77%)	21 (40%)
# of amphibian species encountered (% of total amphibians [20 sp.])	16 (80%)	7 (35%)
# of amphibian species encountered that were unique (% unique)	13 (65%)	4 (20%)
# of reptile species encountered (% of total reptile species encountered [33 sp.])	25 (78%)	14 (44%)
# of reptile species encountered that were unique (% unique)	19 (59%)	8 (25%)

Table 2.3 **Herpetofaunal richness at seven lowland forest sites in the Guiana Shield, including data from a previous survey to the Berbice River** (Cole et al., 2013)

In each column, data are presented as raw species number/percentage of total herpetofauna.

SITE	AMPHIBIANS	REPTILES	TOTAL
Iwokrama	47/0.40	71/0.60	118
Nouragues	51/0.47	58/0.53	109
Upper Potaro BAT II	36/0.55	30/0.45	66
Konawaruk River	29/0.49	30/0.51	59
Berbice River	27/0.42	38/0.58	65
Berbice River Camp (this study)	16/0.39	25/0.61	41
White Sands Camp (this study)	7/0.33	14/0.66	21
Mean=	30	38	68

Table 2.4 **Comparisons of number of species of amphibians and reptiles found at eight lowland and upland localities, including those surveyed during the Upper Potaro Biodiversity Assessment Team expedition**

Key

Numbers in diagonal row (in bold italics) are numbers of species found at each site.

Numbers to the upper right of the diagonal are number of species common to sites where rows and columns meet.

Numbers to the lower left of diagonal are faunal resemblance indices with correction for small samples (% of species in the smallest sample found in common between the two samples).

Sites: BRC: Upper Berbice River Camp; WSC: Upper Berbice White Sands Camp; KoF: Konawaruk forest; BeF: Berbice forest; UP: Upper Potaro BAT survey II.

	BRC	WSC	KoF	BeF	UP
BRC	***40***	**9**	**19**	**24**	**17**
WSC	**43**	***21***	**8**	**11**	**12**
KoF	**46**	**38**	***59***	**31**	**29**
BeF	**59**	**52**	**53**	***65***	**27**
UP	**41**	**57**	**49**	**42**	***66***

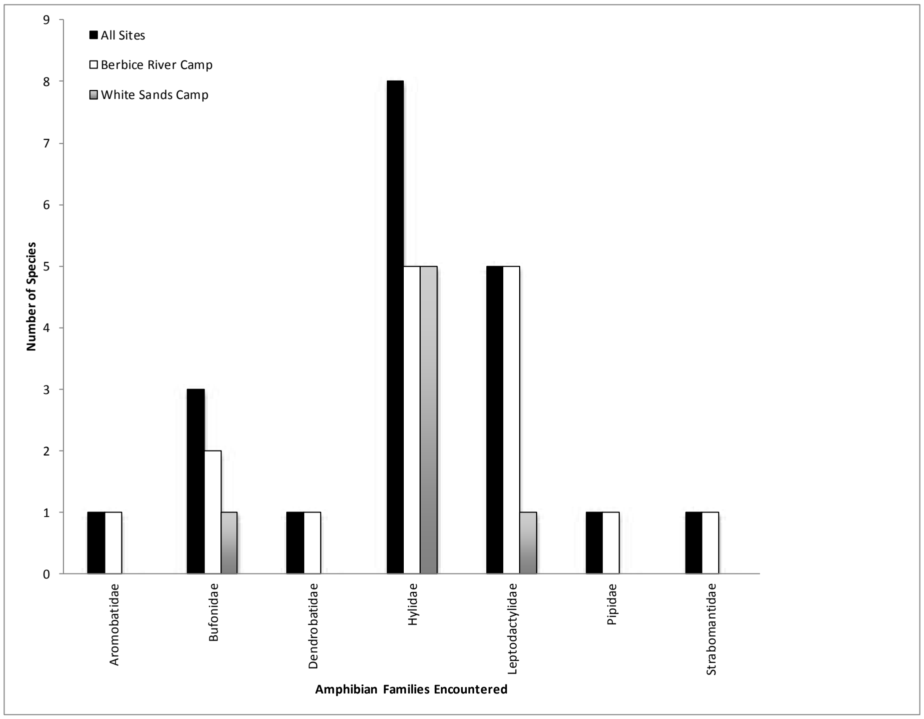

Figure 2.1 **Number of amphibian species, by family, recorded at each focal area during the 2014 BAT Survey of the Upper Berbice Region, Guyana.**

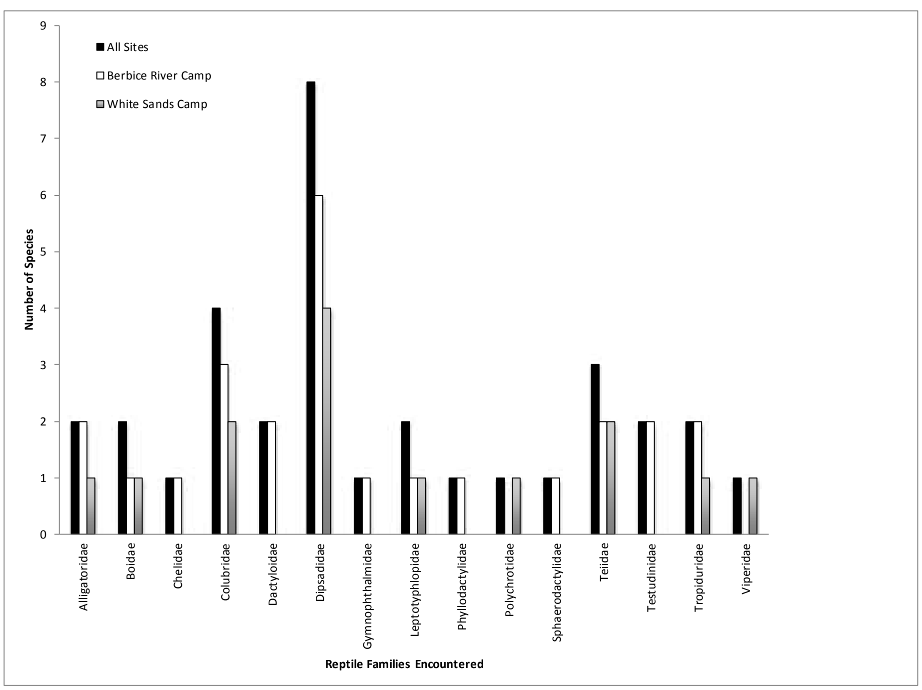

Figure 2.2 **Number of reptile species, by family, recorded at each focal area during the 2014 BAT survey of the Upper Berbice Region, Guyana.**

A full summary of all species encountered and sites is listed in Appendix 2
The focal areas explored during this survey show marked differences in the herpetofaunal composition recorded. The focal areas and their corresponding species compositions are discussed below.

Focal Area 1: Upper Berbice River Camp

The Upper Berbice River Camp (BRC) was located approximately 120 km south of the town of Kwakwani on the eastern half of the Upper Berbice River. The survey area covered approximately a 2 km radius around the camp, with an average elevation of approximately 110 metres above sea level (a.s.l.). Except for some recently constructed dirt roads, the area consisted of pristine tropical lowland rainforest on laterite soil, dominated by the tree species *Mora excelsa* and *Astrocaryum* sp. palms. Several wet and dry stream beds crossed the landscape between the campsite and the Berbice River. The forest had many very tall trees with large buttress roots, indicating that it is an old and unlogged forest. Surveys were conducted during the morning, afternoon and night around the base camp, along the main logging road extending in either direction from camp, and briefly along the Berbice River. All available habitats were surveyed, including rivers, creeks, streams, forest, and disturbed areas.

During our surveys at the BRC, a total of 16 species of amphibians were recorded, all being Anurans (Aromobatidae, Bufonidae, Dendrobatidae, Hylidae, Leptodactylidae, Pipidae, Strabomantidae). A total of 25 species of reptiles were recorded. These consisted of two species of caiman (Alligatoridae), seven species of lizards (Dactyloidae, Gekkonidae, Gymnophthalmidae, Teiidae, Tropiduridae), three species of turtles (Chelidae, Testudinae), and 11 species of snake (Boidae, Colubridae, Dipsadidae, Leptotyphlopidae). It is important to note that the forests around the BRC supported healthy populations of both red-footed tortoises (*Chelonoidis carbonarius*) and yellow-footed tortoises (*Chelonoidis denticulatus*), with many individuals of both species encountered daily by various BAT members. Additionally, the lead author spent one evening conducting a survey by boat along a short stretch of the Berbice River and documented eighteen large, adult black caiman (*Melanosuchus niger*). The presence of these taxa and many encounters provides further evidence of the pristine nature of the ecosystem around the BRC and the present lack of hunting pressure.

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A waxy monkey tree frog (*Phyllomedusa bicolor*) perched in the lowland rainforest

Focal Area 2: Upper Berbice White Sands Camp

The Upper Berbice White Sands Camp was located approximately 75 km north of the BRC along the main access logging road, and was approximately 60 meters a.s.l. The herpetofaunal surveys covered approximately a 2 km radius around the camp. The camp bordered a recently burned forest and a relatively pristine Wallaba/Dakama forest on white sand. Within the forest, the sand was covered with a thick mat of organic matter (leaves and roots), often up to 0.5 m deep. At this time of the year, the mat was very dry. A small black water creek ran through the forest near the camp towards the Corentyne River. The canopy trees of this forest were much shorter than at Camp 1, only up to 20 m tall. The wallaba forest around Camp 2 had three strata: canopy level dominated by dakama (*Dimorphandra conjugata*), mid-level dominated by soft wallaba (*Eperua falcata*), and lower level with many manoco (turu) palms (*Oenocarpus bacaba*). Surveys were conducted during the morning, afternoon and night in both the disturbed and intact forests around base camp, along black water creeks, and along the main access road.

During the surveys at the White Sands camp site, seven species of amphibians were recorded, all belonging to Anura (Bufonidae, Hylidae, Leptodactylidae). A total of 13 species of reptiles were recorded, including one species of caiman (Alligatoridae), four species of lizards (Polychrotidae, Teiidae, Tropiduridae), and eight species of snakes (Boidae, Dipsadidae, Colubridae, Leptotyphlopidae, Viperidae).

At the White Sands camp, an abundance of cane toads (*Rhinella marina*) as well as emerald-eyed frogs (*Boana crepitans*) were observed along the access road and the disturbed regions. These species are commonly associated with anthropogenic disturbance and are not typically encountered in pristine lowland tropical rainforest. However, at this site, one individual of the false water cobra (*Hydrodynastes bicinctus*) was photographed but not collected by another BAT team member. From Guyana, this snake was only previously known from one voucher specimen from Onora Falls (Cole et al. 2013).

A female Gladiator tree frog (*Boana boans*) sits above a black water creek at the White Sands camp.

A map tree frog (*Boana geographica*) in habitat at the White Sands camp.

Discussion

The herpetofauna encountered during these surveys, especially at the BRC, are mostly characteristic lowland rainforest species. However, these surveys were markedly brief and surely do not represent all species that occur here. Three species that are sources of food for Amerindian communities, the red-footed tortoise, yellow-footed tortoise, and black caiman, were presently abundant in great numbers. Collectively, the majority of the encountered species are sensitive to human-induced changes to the ecosystem. **Severe modification of this habitat due to logging will be detrimental to the persistence of much of the region's herpetofauna.**

For reptiles and amphibians, both community composition and species diversity are related to habitat diversity. An increase in habitat heterogeneity usually presents opportunity for an increase in species diversity. Despite the BRC containing the most homogenous habitat, it harboured the greatest richness of reptiles and amphibians, including unique species. This is likely a product of both the constant higher humidity levels and pristine condition of this site relative to the WSC. Weather patterns also influence reptile and amphibian activity patterns, and subsequently their detectability. Despite this short survey occurring during the dry season, the period of time associated with lowest herpetofaunal activity in a tropical rainforest, an impressive number of species were still recorded. However, the results from this survey of the Upper Berbice forests undoubtedly represent a fraction of the true herpetofaunal diversity at both sites. In order to reflect true species richness, additional sampling, especially during the rainy season, is recommended to provide a more thorough species list.

IT SHOULD BE NOTED THAT STACKS OF TORTOISE SHELLS WERE OBSERVED AT A FEW OF THE ESTABLISHED LOGGING CAMPS ALONG THE ACCESS ROAD

Conservation recommendations for each site

Before anything else, the first recommendation is to maintain the integrity of the undisturbed forests and stream habitats within and around the Berbice River survey site. Undoubtedly, these dry season surveys uncovered only a fraction of the herpetofauna that exists at both sites. More extensive sampling is required, especially during the wet season, in order to achieve a more accurate representation of the species richness at the sites. During the brief periods spent surveying at each site, new species were continuously being recorded, not reaching a plateau, leading us to believe that many more species would have been recorded had survey time allowed.

Notably, at the Berbice River camp, our teams encountered a high abundance of red-footed tortoises (*Chelonoidis carbonarius*) and yellow-footed tortoises (*Chelonoidis denticulatus*), as well as black caiman (*Melanosuchus niger*). These large-bodied reptiles are typically among the first reptile species that are overexploited in Guyana. The numbers that we encountered are a strong indicator of the current pristine condition of this ecosystem and the lack of severe hunting pressure. However, **it should be noted that stacks of tortoise shells were observed at a few of the established logging camps along the access road.**

To safeguard these populations, measures need to be taken to ensure that no hunting is allowed to take place in this region. Additionally, with the spread of logging along the Bai Shan Lin road, it is imperative that approved practices for reduced impact logging are enforced to help mitigate the destructive impacts to the environment. **Ideally, this region ought to experience no logging or mining at all, and be allowed to continue to exist as one of Guyana's last true remote, pristine frontiers.**

Acknowledgements

We thank Charles Hutchinson (WWF-Guianas), Aeisha Williams (WWF-Guianas), Major DeAbreu (Kwakwani Village), Fred Austin (Kwakwani Village), and Danny Gordon for assisting with field investigation and specimen collection.

IDEALLY, THIS REGION OUGHT TO EXPERIENCE NO LOGGING OR MINING AT ALL, AND BE ALLOWED TO CONTINUE TO EXIST AS ONE OF GUYANA'S LAST TRUE REMOTE PRISTINE FRONTIERS

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CHAPTER 3

A RAPID ASSESSMENT OF THE FOREST AVIFAUNA OF THE UPPER BERBICE REGION, GUYANA

Brian J. O'Shea

Abstract

This report presents the results of bird surveys carried out at two locations in the Upper Berbice region of Guyana in September and October 2014. Birds were surveyed over 11 field days, using 10-species lists to derive richness estimators for each site and to allow comparison of their bird communities with other sites in central Guyana. Sound recording was used to document the avifauna. During the expedition, **271 bird species were observed, including 38 Guiana Shield endemics, 15 species listed as either Near-Threatened or Vulnerable by the IUCN, and two species** (the Rufous Potoo, *Nyctibius bracteatus*; and Pelzeln's Tody-Tyrant, *Hemitriccus inornatus*) **with poorly known distributions in northeastern South America.** The bird communities of the two sites were generally more similar to other sites in central Guyana than they were to each other, indicating high diversity in the Upper Berbice region. Lower-stature forests on white sands were of particular interest, and represent a habitat type not currently included in Guyana's Protected Areas system. Aggressive monitoring of the new road through this region should mitigate threats from illegal mining and overharvesting of timber and wildlife.

271 BIRD SPECIES WERE OBSERVED, INCLUDING 38 GUIANA SHIELD ENDEMICS, 15 SPECIES LISTED AS EITHER NEAR-THREATENED OR VULNERABLE BY THE IUCN, AND TWO SPECIES WITH POORLY KNOWN DISTRIBUTIONS IN NORTHEASTERN SOUTH AMERICA

Introduction

The biodiversity of the great forests in the upper Demerara, Berbice, and Corentyne river basins remains virtually unstudied. Early explorers of the Guianas traversed this region, but Snyder (1966), in her pioneering book on the birds of Guyana, mentions few details regarding the travels of nineteenth and early twentieth century naturalists in this part of the country. John J. Quelch, curator of the British Guiana Museum from 1886-1900, apparently made trips up the Demerara and Berbice Rivers during that time, but his specimens are believed to have been destroyed in the 1945 fire that consumed the museum's natural history collections. The headwaters of the Berbice and Demerara are both far upriver from the nearest permanent human settlements, and until recently, despite the existence of forestry concessions in the region, only minimal infrastructure existed to provide overland access to most of the area. Consequently, there has been no recent documentation of the area's avifauna, although inventories exist for several sites to the east and west, including the Iwokrama Forest (Ridgely et al. 2005), the eastern Kanukus (Finch et al. 2002), and the Rewa Head (Pickles et al. 2011) in Guyana, and the Bakhuis Mountains (O'Shea and Ottema 2007) and Kwamalasamutu region in Suriname (O'Shea and Ramcharan 2011). Since the upper Berbice and Demerara are connected to these localities by continuous forest interrupted only by rivers, the avifauna is expected to be broadly similar, with an estimated alpha diversity between 450 and 500 species, and robust populations of species sensitive to hunting and trapping, such as parrots, guans and curassows, and large birds of prey.

Currently, the upper Berbice and Demerara watersheds are essentially uninhabited by people; there are no permanent settlements south of Kwakwani. In the Kwakwani area, small-scale logging has long been a mainstay of the economy. In 2013, Bai Shan Lin, a Chinese conglomerate, with a presence in Guyana since 2011, acquired large forestry concessions south of Kwakwani and began construction of a road to facilitate logging operations in the upper Berbice region. Today, despite the cessation of logging by Bai Shan Lin, this road remains, extending about 125 km south of Kwakwani between the Berbice and Corentyne Rivers. **Concerns about access to this region by hunters and miners, as well as potential impacts of large-scale logging, prompted the third WWF/GWC Biodiversity Assessment Team (BAT) survey of the area in September and October 2014.** This report presents findings from ornithology surveys conducted during the BAT expedition.

Study sites and methods

Birds were surveyed from 21-25 September 2014 within a 3-km radius around the Upper Berbice River camp (4.1540, -58.1771, ~105 m) and from 26 September – 1 October 2014 within 3 km of the White Sands camp (4.7550, -58.0072, ~55 m).

Logging roads through the forest provided good walking lines for bird surveys, particularly at the White Sands camp, where numerous side roads extended east and west of the main road through the concession. Although both sites were extensively forested, they differed dramatically in soil type and vegetation structure. The Upper Berbice River camp featured high rainforest with a canopy height of approximately 30 m and many large emergent trees, which imparted substantial heterogeneity typical of rainforest elsewhere in Amazonia. At the White Sands camp, the forest was more dense, with a lower canopy (15-20 m) and few emergents. The camp itself was situated next to a large (~350-hectare) burned area in which all trees had died but remained standing; small patches of scrub were scattered throughout this area, which was otherwise practically devoid of living vegetation. Forests around the White Sands camp grew on soils that were almost pure sand, in contrast to the red clay soils found at the Upper Berbice River site.

Birds were surveyed by walking trails and roads at both sites during most daylight hours. The "10-species list" technique (MacKinnon and Phillips 1993; Herzog et al. 2002, 2016) was used to estimate species richness at each site and to gather data in a standardized way to allow comparison to other sites across the Guiana Shield. Under this technique, individual birds are noted in the order in which they are observed; the overall list is later broken down into units of ten species to produce accumulation curves to estimate total diversity. This technique has the advantage of being robust with respect to observer biases and differences in experience (MacLeod et al. 2011). It is also the most thorough survey method in terms of the number of resident species detected, particularly in the tropics, and is the most flexible method logistically (Herzog et al. 2016). Data from ten-species lists were combined to derive an incidence-based asymptotic richness estimator (Chao2) for each site. To assess the degree of community similarity between these sites and others in the surrounding region, twenty lists were selected randomly and compared to twenty randomly selected lists from each of four localities in the Iwokrama Forest and Surama-titled land in central Guyana (Kabokalli, Turtle Mountain, Iwokrama Mill Site, and Rock Landing), which were surveyed in June and July 2016 (BJO *unpubl. data*). We chose the Chao-Sørenson index (Chao et al. 2005) as a measure of community similarity between all pairs of the BAT survey 3 (this survey) and central Guyana sites. All analyses were performed using EstimateS (Colwell 2013).

Birds were documented by sound recording, using a Marantz PMD-661 digital recorder and a Sennheiser ME-62 microphone. On several days, a stereo microphone pair (Sennheiser MKH-20 and MKH-30) were used to make general soundscape recordings for one to two hours, usually at dawn. All recordings are deposited at the Macaulay Library at the Cornell Lab of Ornithology, Ithaca, NY, USA.

Documenting birds by sound recording.

Results

During the expedition, 271 species of birds were recorded. Of these species, 38 are endemic to the Guiana Shield and 15 are listed on the IUCN Red List of Threatened Species (Table 3.1). A full species list is provided in Appendix 3.

Both sites had high bird diversity. **The Berbice River site yielded a slightly greater number of species (205), and more endemic and IUCN-listed species, than the White Sands site, where 196 species were observed.** Large birds that are frequently targeted by hunters, such as Great Tinamou (*Tinamus major*), Black Curassow (*Crax alector*), Marail Guan (*Penelope marail*), and Grey-winged Trumpeter (*Psophia crepitans*), were abundant and frequently seen at both sites.

THE BERBICE RIVER SITE YIELDED MORE ENDEMIC AND IUCN-LISTED SPECIES THAN THE WHITE SANDS SITE

Using 10-species lists to construct accumulation curves for both sites (127 lists from the Berbice River camp and 100 lists from the White Sands camp) yielded similar mean predicted species richness and broadly overlapping 95% confidence intervals (Figure 3.1, Table 3.2). Incidence-based estimators of species richness (Chao2) were similar at each site (Table 3.2).

Despite the similarity in mean predicted species richness, **the two sites differed in species composition. 141 species (52% of the total) were only observed at one of the two sites, indicating high regional diversity** (Table 3.2).

THE TWO SITES DIFFERED IN SPECIES COMPOSITION. 141 SPECIES (52% OF THE TOTAL) WERE ONLY OBSERVED AT ONE OF THE TWO SITES, WHICH INDICATES HIGH REGIONAL DIVERSITY.

We used incidence data from 20 randomly selected 10-species lists generated at each of four sites in central Guyana in June and July 2016 to calculate Chao-Sørensen indices of similarity between those sites, and to allow comparison of the BAT (survey 3) sites with other sites in the region (Chao et al. 2005; Colwell 2013; Table 3.3).

The Chao-Sørensen value for the Berbice River and White Sands sites (.668) was below the mean for all pairwise site comparisons (.711; standard deviation .108), and equal to or lower than pairwise values for any of the four central Guyana sites, indicating greater dissimilarity between the two BAT 3 sites relative to other pairs of forested sites in the region (Table 3.3). The Berbice River bird community was most similar to those at Kabokalli and Turtle Mountain, two sites along the Essequibo River that have broadly similar bird communities despite differences in their history of recent disturbance. The White Sands bird community showed a strong similarity to that found at the Iwokrama Mill Site, which is situated in sandy-soil forest along the Linden-Lethem highway, roughly seven kilometres southwest of the Essequibo River crossing at Kurupukari, and is the only one of the four central Guyana sites that is not subject to seasonal flooding. Of the four central Guyana sites, Rock Landing, which is situated along the Burro-Burro River near the edge of the northern Rupununi savannah, and is geographically most distant from the BAT 3 sites, had the lowest Chao-Sørensen values in comparison with both the Berbice River and White Sands sites.

During the expedition, 157 species were documented on 57 recordings. (Macaulay Library catalog numbers 225047-225103). Species documented by sound recording are indicated on the species list in Appendix 3.

The Reddish Hermit, *Phaethornis ruber*, a petite species of hummingbird found at both study sites.

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The Grey-breasted Sabrewing, *Campylopterus largipennis*, a relatively large hummingbird, described as uncommon by the IUCN.

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Blue-and-yellow Macaw, *Ara ararauna*, is one of 18 species of psittacids which were documented during the survey.

Table 3.1 **List of Guiana Shield endemic (END; X) and IUCN-listed (NT = Near-Threatened, VU = Vulnerable) bird species encountered during the Upper Berbice BAT survey**

SPECIES	ENGLISH NAME	END	IUCN
Tinamus major	Great Tinamou		NT
Penelope marail	Marail Guan	X	
Crax alector	Black Curassow	X	VU
Odontophorus gujanensis	Marbled Wood-Quail		NT
Patagioenas subvinacea	Ruddy Pigeon		VU
Topaza pella	Crimson Topaz	X	
Psophia crepitans	Grey-winged Trumpeter		NT
Agamia agami	Agami Heron		VU
Spizaetus ornatus	Ornate Hawk-Eagle		NT
Trogon violaceus	Guianan Trogon	X	
Notharchus macrorhynchos	Guianan Puffbird	X	
Monasa atra	Black Nunbird	X	
Capito niger	Black-spotted Barbet	X	
Ramphastos tucanus	White-throated Toucan		VU
Ramphastos vitellinus	Channel-billed Toucan		VU
Selenidera piperivora	Guianan Toucanet	X	
Pteroglossus viridis	Green Araçari	X	
Veniliornis cassini	Golden-collared Woodpecker	X	
Celeus torquatus	Ringed Woodpecker		NT
Pyrilia caica	Caica Parrot	X	NT
Pionus fuscus	Dusky Parrot	X	
Amazona dufresniana	Blue-cheeked Parrot	X	NT
Amazona farinosa	Mealy Parrot		NT
Thamnophilus punctatus	Northern Slaty-Antshrike	X	
Isleria guttata	Rufous-bellied Antwren	X	
Epinecrophylla gutturalis	Brown-bellied Antwren	X	NT
Herpsilochmus sticturus	Spot-tailed Antwren	X	
Herpsilochmus stictocephalus	Todd's Antwren	X	
Hypocnemis cantator	Guianan Warbling-Antbird	X	NT
Percnostola rufifrons	Black-headed Antbird	X	
Myrmoderus ferrugineus	Ferruginous-backed Antbird	X	
Gymnopithys rufigula	Rufous-throated Antbird	X	
Xiphorhynchus pardalotus	Chestnut-rumped Woodcreeper	X	

Table 3.1 **List of Guiana Shield endemic (END; X) and IUCN-listed (NT = Near-Threatened, VU = Vulnerable) bird species encountered during the Upper Berbice BAT survey (*cont'd*)**

SPECIES	ENGLISH NAME	END	IUCN
Lepidocolaptes albolineatus	Guianan Woodcreeper	X	
Zimmerius acer	Guianan Tyrannulet	X	
Phylloscartes virescens	Olive-green Tyrannulet	X	
Todirostrum pictum	Painted Tody-Flycatcher	X	
Phoenicircus carnifex	Guianan Red-Cotinga	X	
Perissocephalus tricolor	Capuchinbird	X	
Tyranneutes virescens	Tiny Tyrant-Manakin	X	
Corapipo gutturalis	White-throated Manakin	X	
Schiffornis olivacea	Olivaceus Schiffornis	X	
Iodopleura fusca	Dusky Purpletuft	X	
Pachysylvia muscicapina	Buff-cheeked Greenlet	X	
Cyanocorax cayanus	Cayenne Jay	X	
Cyanicterus cyanicterus	Blue-backed Tanager	X	
Euphonia plumbea	Plumbeous Euphonia	X	
Euphonia cayennensis	Golden-sided Euphonia	X	

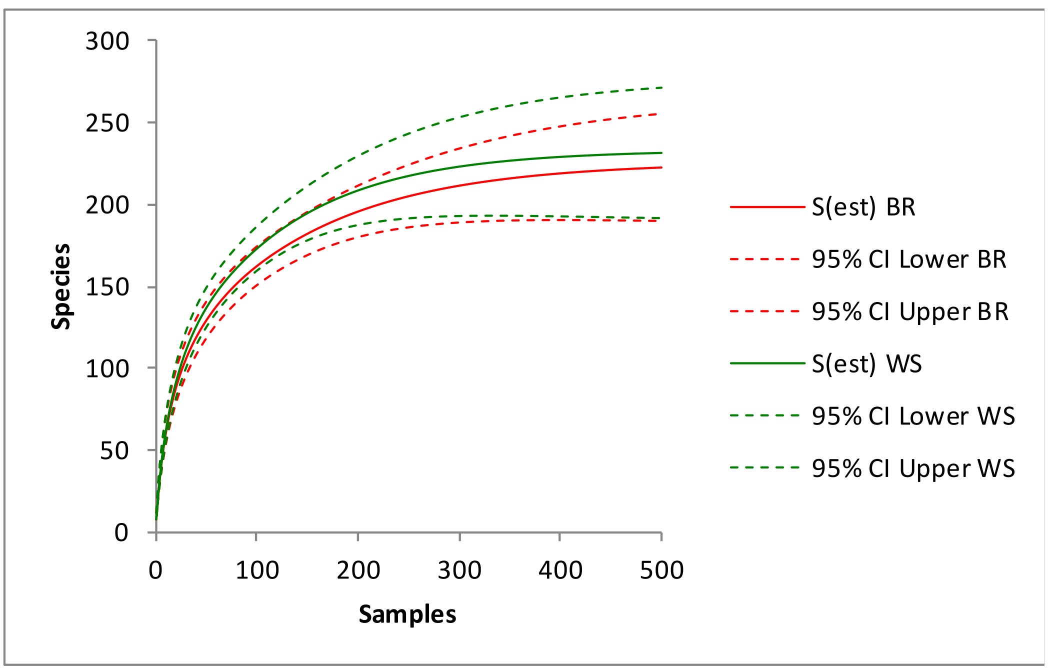

Figure 3.1 **Accumulation curves showing predicted number of species for the Berbice River (BR: red lines) and White Sands (WS: green lines) camps, based on extrapolations from 10-species lists generated during the BAT 3 survey. Both sites had similar species richness.**

Table 3.2 **Number of species observed and sampled by 10-species lists at each site, with incidence-based (Chao2) estimators of species richness extrapolated to 500 samples**

SITE	NUMBER OF SPECIES OBSERVED	NUMBER OF UNIQUE SPECIES	NUMBER OF SPECIES ON 10-SPECIES LISTS	Chao2 Mean (+/- 95% CI)
Berbice River	205	74	174 (n=127)	222.63 (197.69-273.72)
White Sands	196	67	173 (n=100)	229.66 (201.45-285.86)

Table 3.3 **Chao-Sørensen values for the two BAT 3 survey sites and four other sites in central Guyana, based on 20 randomly selected 10-species lists from each locality. Higher values indicate greater community similarity**

	KABOKALLI	TURTLE MOUNTAIN	MILL SITE	ROCK LANDING	BERBICE RIVER	WHITE SANDS
Kabokalli	-	-	-	-	-	-
Turtle Mountain	.749	-	-	-	-	-
Mill Site	.719	.788	-	-	-	-
Rock Landing	.856	.699	.668	-	-	-
Berbice River	.705	.701	.672	.520	-	-
White Sands	.663	.785	.938	.531	.668	-

Discussion

This survey of the Upper Berbice provides the first data on bird diversity from this region. A total of 271 species at the two survey sites is typical for a short, dry-season survey in lowland forest in the Guianas, although the actual number of species present in these forests is certainly much higher. Additional survey effort, particularly in different seasons, will undoubtedly reveal bird species that were not detected during this BAT 3 survey.

The BAT 3 survey yielded few surprises, but it did reveal a diverse forest avifauna, sightings of several relatively rare species, and one major range extension within Guyana (see Interesting Species, below). The bird communities of the two sites differed substantially, with 141 species, or more than half of the total found during the expedition, only observed at one of the survey sites. Certain other species, although found at both sites, were considerably more common at one site than the other. This was most often the case for typical Guianan forest birds – especially the Mouse-coloured Antshrike (*Thamnophilus murinus*), Grey Antbird (*Cercomacra cinerascens*), Ferruginous-backed Antbird (*Myrmoderus ferrugineus*), and Tiny Tyrant-Manakin (*Tyranneutes virescens*) – which were much more common in tall, structurally complex rainforest at the Upper Berbice River site than they were in the shorter, less stratified forest of the White Sands site.

THE SURVEY REVEALED A DIVERSE FOREST AVIFAUNA, SIGHTINGS OF SEVERAL RELATIVELY RARE SPECIES, AND ONE MAJOR RANGE EXTENSION WITHIN GUYANA

Mixed-species flocks, especially in the canopy, were common and diverse, indicating good habitat structure and connectivity. There were some notable differences in flock composition between sites, which contributed to overall diversity. Although the typical leaders of canopy flocks – Todd's and Spot-tailed Antwrens (*Herpsilochmus stictocephalus* and *H. sticturus*, respectively), Yellow-margined Flycatcher (*Tolmomyias assimilis*), and Buff-cheeked Greenlet (*Pachysylvia muscicapina*) – were common at both sites, their associates varied from one site to the next. Species such as the Fulvous Shrike-Tanager (*Lanio fulvus*) and Buff-throated Woodcreeper (*Xiphorhynchus guttatus*) were common members of canopy flocks at the Berbice River site, but were all but absent from the White Sands site. Conversely, some smaller tanagers such as the Yellow-backed Tanager (*Hemithraupis flavicollis*), Red-legged Honeycreeper (*Cyanerpes cyaneus*), and Bananaquit (*Coereba flaveola*), as well as the Olive-green Tyrannulet (*Phylloscartes virescens*) and Red-eyed Vireo (*Vireo olivaceus*), were common in mixed flocks in forest canopy on sandy soil at the White Sands site, but were not observed in flocks at the Berbice River site. Lastly, understory flocks composed primarily of *Thamnomanes* antshrikes and *Epinecrophylla* and *Myrmotherula* antwrens were common in tall forest at the Berbice River site, but were much less common and diverse at the White Sands site, where the forest was generally lower and less structurally complex.

We encountered 38 species considered to be endemic to the Guiana Shield under current taxonomy (Remsen et al. 2017), and 15 species listed as either Vulnerable or Near-Threatened by the IUCN (IUCN 2016; Table 1). This is typical for a Guianan lowland forest locality, where the proportion of endemics tends to be 10-15% (O'Shea and Ottema 2007; O'Shea 2008; O'Shea and Ramcharan 2011). We encountered several species that, while known to occur in Guyana, are seldom observed, including Rufous and Long-tailed Potoos (*Nyctibius bracteatus* and *N. aethereus*, respectively), the Rufous Nightjar (*Antrostomus rufus*), Racket-tailed Coquette (*Discosura longicaudus*), Amethyst Woodstar (*Calliphlox amethystina*), Rusty-breasted Nunlet (*Nonnula rubecula*), Spot-backed Antbird (*Hylophylax naevius*), Curve-billed Scythebill (*Campyloramphus procurvoides*), and Chestnut-belted Gnateater (*Conopophaga aurita*). Our data help to fill extensive gaps in the known distributions of these species in the Guiana Shield.

The main driver of the high overall diversity of birds found during the BAT 3 survey was the presence of sandy-soil forest at the White Sands site, which included an extensive burned area, roughly 350 hectares in size. Both the open scrub and adjacent forest at the White Sands site yielded many species that are common in the forest-savannah matrix of the coastal savannah belt in Guyana and Suriname, but are much less common, or absent entirely, in tall rainforest in the interior regions. Examples of these species, observed only at the White Sands site, are the Red-legged Tinamou (*Crypturellus erythropus*), Scaled Pigeon (*Patagioenas speciosa*), Bronzy Jacamar (*Galbula leucogastra*), White-fringed Antwren (*Formicivora grisea*), Black Manakin (*Xenopipo atronitens*), and Plumbeous Euphonia (*Euphonia plumbea*). These species and others comprise a distinct bird community in the Guianas, and one with a relatively limited distribution.

The availability of reference data from central Guyana allowed for comparison of the BAT 3 sites to other sites in the region, all of which are situated in forest contiguous with the upper Berbice region, interrupted only by the Essequibo River. Based on subsampling of 10-species lists generated at these localities, we found that all pairs of sites in central Guyana, especially those situated in extensive floodplains, had somewhat greater community similarity than we observed between the Berbice River and White Sands sites on the BAT 3 expedition. However, the Chao-Sørensen value of .938 between the White Sands and Iwokrama Mill Sites was the highest of any pair of sites, revealing substantial community similarity between lower-stature forests on sandy soils across the region. To some degree, the similarity of bird communities at these sites was likely due to the shared presence of extensive open areas – the housing and sawmill complex at Iwokrama, and the extensive patch of burned forest at the White Sands site – within which a predictable suite of non-forest bird species could be found, including Variable Chachalaca (*Ortalis motmot*), Swallow-winged Puffbird (*Chelidoptera tenebrosa*), Tropical Kingbird (*Tyrannus melancholicus*), and Silver-beaked Tanager (*Ramphocelus carbo*). A few species, including Northern Slaty-Antshrike (*Thamnophilus punctatus*) and Saffron-crested Tyrant-Manakin

(*Neopelma chrysocephalum*), occur primarily or only in sandy-soil forests, and the presence of these species at both the White Sands and Iwokrama Mill sites (and their absence elsewhere) further contributed to the similarity of bird communities at those sites.

As could be expected in a region with little recent history of human disturbance, we observed healthy numbers of game birds including curassows, tinamous, and trumpeters, many of which showed little fear of humans. We also found birds of prey to be common, especially the White Hawk (*Leucopternis albicollis*) and the four resident species of forest-falcon (*Micrastur* spp.), all of which were observed at both camps. The density of these raptors was reminiscent of our observations from the Bakhuis Gebergte in Suriname (O'Shea and Ottema 2007), not far from the Upper Berbice region, where we found these species to be more common than we have ever seen elsewhere. Although we do not know the cause of these birds' relative abundance in eastern Guyana and western Suriname, we suspect that the undisturbed forests in this region could support an unusually abundant and diverse leaf-litter herpetofauna, which provides these birds with much of their prey.

Both the total number of species observed (271) and the Chao2 richness estimators for the Berbice River and White Sands sites (222 and 229 species, respectively), although useful metrics for comparing short-term survey data among sites in the Guiana Shield, should not be considered realistic upper bounds for the number of species occurring in the region. Many of the bird species in these forests are rare enough that their detection cannot be expected during a single short survey. Some are more vocal at certain times of the year, and are thus more likely to be detected during those times; others are nomadic or migratory, and may be absent from a given site during part of the year. There are few comprehensive lists from lowland forest sites in the region, but more than 476 species have been recorded from the Iwokrama Forest, only 40 km west of the BAT 3 sites (Ridgely et al. 2005), and more than 400 species are known to occur in the Kanuku Mountains Protected Area (Guyana Protected Areas Commission, unpublished) and the Bakhuis Mountains of western Suriname (O'Shea and Ottema 2007). We expect that the upper Berbice region will eventually be found to have an avifauna that is comparably diverse.

Interesting species

The following species represent significant records for Guyana.

Rufous Potoo (*Nyctibius bracteatus*) – This enigmatic species has rarely been observed in Guyana and remains undocumented in adjacent Suriname. One was recorded pre-dawn at the Berbice River camp (audible between 13:20 and 13:50 on ML 225057). All Guyana records of *N. bracteatus* are from the middle Essequibo-Rewa region, suggesting that it is more common in southern-central Guyana than elsewhere.

Amethyst Woodstar (*Calliphlox amethystina*) – This hummingbird was observed in stunted forest along the road near the camp at the White Sands site. It is rarely seen and there are few previous Guyana records.

Pelzeln's Tody-Tyrant (*Hemitriccus inornatus*) – Previously known only from scattered localities in northern Brazil and a single site in Suriname, this species is restricted to forests growing on white sands or other nutrient-poor soils. Its occurrence in Guyana was not confirmed until 2010, when it was found during the Amaila Falls ESIA; although documented, the record remains unpublished (A. Whittaker *in litt*.). We found *H. inornatus* to be uncommon in stunted forest at the White Sands site, providing further evidence that the species occurs locally in white-sand forest and scrub in Guyana.

Conservation recommendations

The Berbice and Corentyne drainages are part of a larger landscape, extending into western Suriname, that appears to have especially rich bird communities, with high abundances of birds of prey, parrots, and guans and curassows, all of which are sensitive to human disturbance, either through direct persecution for food and the wildlife trade, or indirectly (in the case of birds of prey) through a reduction in the prey base by overhunting and habitat degradation. The richness of the fauna in this part of the Guiana Shield does not seem to be limited to birds – western Suriname is a popular and productive hunting ground for coastal Surinamese, and our previous surveys in the Bakhuis Mountains revealed exceptionally high densities of primates and large mammals, all of which have a major impact on the structure and floristic composition of the forest. Based on our limited time in the upper Berbice region, we surmise that the forests there, especially at the Berbice River site and farther south, have similarly high densities of both birds and mammals, and therefore represent a fully intact ecological community supporting the full suite of Guianan rainforest bird species.

CONSIDERING THAT THERE ARE CURRENTLY NO PROTECTED AREAS ON EITHER SIDE OF THE CORENTYNE RIVER IN THIS REGION, WE RECOMMEND THE PROTECTION OF THE FORESTS AROUND THE BERBICE RIVER SITE AS A RARE EXAMPLE OF VIRGIN RAINFOREST WITH VERY LARGE TREES

Considering that there are currently no protected areas on either side of the Corentyne River in this region, we recommend the protection of the forests around the Berbice River site as a rare example of virgin rainforest with very large trees. Reproductive individuals of valuable timber species should be conserved here to replenish those removed by logging elsewhere in the region. Forests on sandy soils, such as those around the White Sands site, are relatively limited in extent, and form a distinct ecosystem that should be represented in Guyana's network of protected areas. Many of the bird species encountered in white sand forest are patchily distributed and poorly known, a fact that argues for the protection of this habitat. **The creation of a protected area encompassing both forest types would serve well to preserve Guyana's natural heritage.**

Birdwatching could be promoted in this region, which features distinct forest types containing unique bird species, and therefore offers visiting birdwatchers the chance to see many of the endemic species of the Guiana Shield, all along a single road. Indeed, this may be one of the few benefits of road access to this region, which is otherwise a threat to the region's ecological integrity. **Regardless of the eventual protected status of this area, the road should be monitored aggressively to deter illegal logging, hunting, fishing, and removal of wildlife for the international trade.**

THE ROAD SHOULD BE MONITORED AGGRESSIVELY TO DETER ILLEGAL LOGGING, HUNTING, FISHING, AND REMOVAL OF WILDLIFE FOR THE INTERNATIONAL TRADE

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CHAPTER 4

SMALL MAMMALS OF THE UPPER BERBICE RIVER REGION IN GUYANA

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Abstract

The small mammal faunal community in the Upper Berbice River region of south-central Guyana has never been comprehensively sampled. As part of the Biodiversity Assessment Team (BAT) Expedition to this area from 21 September to 1 October 2014, small mammals (bats and rats) were surveyed with standardized methodology to estimate species diversity and relative abundance at two sites: the Upper Berbice River camp in pristine tall forest, and the White Sands camp in partially disturbed low forest. **A total of 34 species were documented** by 180 captures in mist nets and live traps. Most were bats comprised of 32 species and 176 individuals, whereas rats were represented by only two species and four individuals. **The two sites were quite different with only 22% overlap in species**. Although species richness estimators were higher for the river camp, species diversity indices were lower because the most abundant species of bat was only caught at this site. **The most interesting result was the discovery of a potential new species of round-eared bat.**

A TOTAL OF 34 SPECIES WERE DOCUMENTED. THE TWO SITES WERE QUITE DIFFERENT WITH ONLY 22% OVERLAP IN SPECIES.

THE MOST INTERESTING RESULT WAS THE DISCOVERY OF A POTENTIAL NEW SPECIES OF ROUND-EARED BAT

Introduction

Small mammals are defined as species less than 1 kg in body mass, such as all bats and most rodents and opossums. In lowland tropical areas of South America, this group typically accounts for over half of the mammalian species diversity. **There are 226 species of mammals known from Guyana, of which almost 80% are bats, rats, and opossums (Lim 2016).** More specifically, over half of the species of small-sized mammals from the Guiana Shield are bats.

This group of mammals is important for conservation because many are seed dispersers and flower pollinators responsible for ecosystem regeneration, especially bats. Others are primary predators of insects and keep in check these populations that may otherwise do damage to vegetation. Because of their high species diversity, relative abundance, and ease of capture, bats in particular are a good taxonomic group for the rapid assessment of biodiversity.

Our study is the first attempt to survey small mammals within south-central Guyana and the Berbice-Corentyne watershed. However, the well-surveyed Iwokrama Forest on the Essequibo River is only 40 km to the west at its closest point (Lim and Engstrom 2005). **The Upper Berbice area was previously inaccessible, but this is changing rapidly with road access and an increase in extractive activities of natural resources within the region.** Surveys were conducted from 21 September to 1 October 2014 to assess the species diversity and relative abundance of bats, rats, and opossums.

Survey sites and methods

Survey methods for small mammals included the use of Sherman live traps set on the ground and in trees to sample both terrestrial and arboreal rats, mice, and mouse opossums. Line transects were placed in both forest and open habitats, with traps set approximately 5 metres apart. There were a total of 1,001 Sherman trap-nights, and traps were checked each morning.

For bats, mist nets were set in the forest understory and in open areas, typically in pairs with a short 6-m mist net set perpendicular to a long 12-m mist net. Nets were opened from 6-10 p.m. and checked on a regular basis approximately every hour to remove any bats for identification (Figure 4.1). A total of 176 net-nights were sampled.

Figure 4.1 **Indranee Roopsind untangling a bat from a mist net during the 2014 survey of the Upper Berbice River region in Guyana.**

Two primary study sites were surveyed for small mammals. The first site (the Upper Berbice River camp) was located in a pristine primary forested area approximately 11 km from the Berbice River (N 04.15726, W 058.17619, 110 m elevation) and was surveyed for five nights from 21-25 September 2014. Two trap lines for small terrestrial mammals were set with one about 300 m along a trail in the forest. A second trap line of 400 m was set along the forest edge. Mist nets for bats were typically set in pairs in the forest.

The second site was located in a white sand area, close to a black water creek (N 04.75820, W 058.00593, 31 m elevation). It was surveyed for five nights from 27 September to 1 October 2014. One trap line of 100 m was set in the forest. Because of the absence of trails, most mist nets were set in the open area rather than in the forest.

Voucher specimens were prepared as whole animals fixed in 10% formalin with long-term storage in 70% ethanol. Tissue samples of liver, heart, kidney, and spleen were also collected and stored in ethanol for analysis of DNA variation.

Measures of biodiversity were analyzed with EstimateS (Colwell 2013). Estimations of diversity included species accumulation curves, richness estimators, and diversity indices.

Results

During the survey, we documented a total of 34 species of small mammals, represented by 180 individuals. This included 32 species of bats represented by 176 individuals and two species of rats documented by four individuals (Table 4.1). All rats were prepared as voucher specimens to document the small mammal diversity, but 67 of the more common bats were released unharmed at point of capture.

The larger fruit-eating bat *Artibeus planirostris* (Figure 4.2) was the most abundant species caught (23 individuals), but it was only documented at the Upper Berbice River camp. The next most common species was the darker fruit-eating bat *Artibeus obscurus* (21 individuals) that was caught almost equally at each site (Table 4.1). Both of these species are fig-eating specialists and important seed dispersers. They represented 23% of the total captures in mist nets. By contrast, nine of the 32 species of the bat species were caught only once.

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Figure 4.2 **The flat-faced fruit-eating bat (*Artibeus planirostris*) was the most common bat species caught during the 2014 survey of the upper Berbice River region in Guyana. However, it was captured at only the primarily forested Berbice River camp and not at the more open area White Sand camp.**

At four individuals, the trap success rate of the Sherman traps was low, as is usually typical in lowland areas of the Guiana Shield (Lim and Banda 2013). It took on average 250 traps to catch one rodent. Interestingly, three individuals of one species of the terrestrial spiny rat (*Proechimys guyannensis*) were caught at the Upper Berbice River camp site, whereas one species of a poorly known semi-aquatic rodent (*Nectomys rattus*) was caught in the Upper Berbice White Sand area (Table 4.1). However, the low species diversity and relative abundance precludes any meaningful interpretation of the small terrestrial mammal trapping data.

For bats, the Upper Berbice River camp area documented 21 species represented by 77 individuals, including a potentially undescribed species in the round-eared bat genus *Tonatia*. Species richness estimators averaged 29 species with a range from 25-33 (Table 4.2). The Upper Berbice White Sand area had 18 species and 99 individuals, including four species of aerial insectivorous bats in the family Molossidae (*Cynomops abrasus, Eumops hansae, Molossus molossus*, and *Molossus rufus*; Figure 4.3) that fly in open areas and are usually not caught in mist nets. Richness estimators averaged 20 species with a range of 19-22. Most (three of four) species diversity indices, however, were higher for the White Sand camp than for the Berbice River camp (Table 4.2). This was probably due to the high number and exclusive capture of *Artibeus planirostris* at the river camp that biased the unevenness of abundance. Species accumulation curves indicate that the White Sand camp was leveling off quicker than the Berbice River camp (Figure 4.4), based on the methodology used.

Only seven species of bats were caught at both sites, whereas 14 species were caught at only the Upper Berbice River camp area, and 11 species were caught at only the Upper Berbice White Sand area. The degree of overlap between the two sites is 22% based on the Jaccard Similarity Index.

Figure 4.3 **Free-tailed mastiff bat (*Molossus rufus*) *f*rom the Upper Berbice White Sand camp. Species in the family of free-tailed bats (*Molossidae*) are rarely caught in ground-level mist nets, but this was captured in a net set near water.**

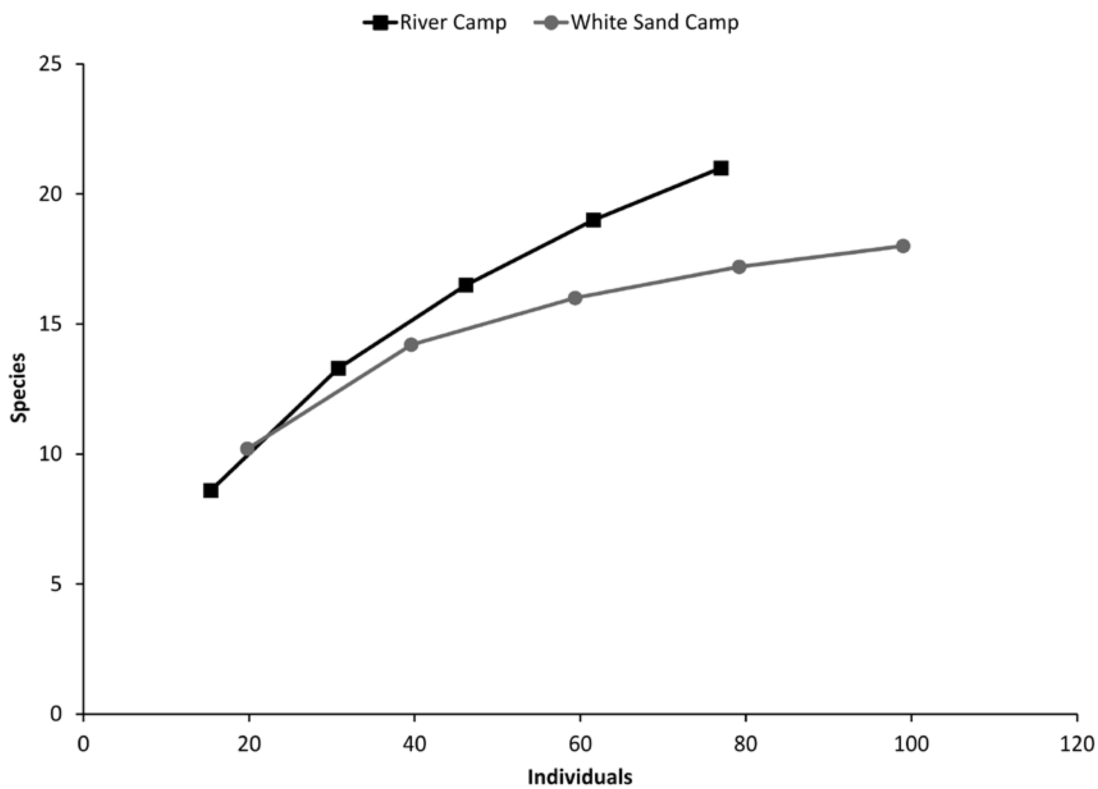

Figure 4.4 **Species accumulation curves for the two sites sampled during the 2014 survey of the Upper Berbice River region of Guyana.**

Table 4.1 **Species checklist of small mammals from the 2014 survey of the Upper Berbice River region of Guyana**

SPECIES		BERBICE RIVER CAMP	WHITE SAND CAMP	TOTAL
BATS				
Ametrida	*centurio*	2	6	**8**
Artibeus	*bogotensis*	0	6	**6**
Artibeus	*concolor*	0	7	**7**
Artibeus	*gnomus*	0	8	**8**
Artibeus	*lituratus*	6	6	**12**
–Artibeus	*obscurus*	10	11	**21**
Artibeus	*planirostris*	23	0	**23**
Carollia	*perspicillata*	8	7	**15**
Chiroderma	*villosum*	1	0	**1**
Chrotopterus	*auritus*	4	1	**5**
Cynomops	*abrasus*	0	5	**5**
Desmodus	*rotundus*	4	0	**4**
Eumops	*hansae*	0	9	**9**
Glossophaga	*sorcina*	2	0	**2**
Lophostoma	*silvicolum*	2	0	**2**
Molossus	*molossus*	0	8	**8**
Molossus	*rufus*	0	10	**10**
Myotis	*nigricans*	1	0	**1**
Noctilio	*leporinus*	1	0	**1**
Phylloderma	*stenops*	1	0	**1**
Phylloderma	*hastatus*	2	0	**2**
Phyllostomus	*discolor*	2	0	**2**
Phyllostomus	*elongatus*	3	2	**5**
Pteronotus	*parnellii*	0	2	**2**
Rhinophylla	*pumilio*	0	7	**7**
Saccopteryx	*leptura*	1	0	**1**
Sturnira	*lilium*	1	0	**1**
Tonatia	*saurophila*	1	1	**2**
Tonatia	sp.	1	0	**1**
Trachops	*cirrhosus*	1	0	**1**
Uroderma	*bilobatum*	0	1	**1**
Vampyressa	*bidens*	0	2	**2**
	sub-total	***77***	***99***	***176***
RATS				
Nectomys	*rattus*	0	1	**1**
Proechimys	*guyannensis*	3	0	**3**
	sub -total	***3***	***1***	***4***
	Total	**80**	**100**	**180**

Table 4.2 **Capture data for small mammals from the 2014 survey of the Upper Berbice River region of Guyana**

VARIABLE	BATS				SMALL NON-VOLANT MAMMALS		
	RIVER	WHITE SAND	TOTAL		RIVER	WHITE SAND	TOTAL
Observed data:							
Individuals	77	99	176		3	1	4
Species	21	18	32		1	1	2
Trap-nights	XX	XX	176		876	125	1001
Richness estimators:							
ACE	30	19	39		-	-	-
ICE	33	20	42		-	-	-
Chao 1	27	19	36		-	-	-
Chao 2	27	19	38		-	-	-
Jack 1	29	21	42		-	-	-
Jack 2	33	22	46		-	-	-
Bootstrap	25	20	37		-	-	-
Average richness	29	20	40		-	-	-
Diversity indices:							
Alpha	9.51	6.44	11.45		-	-	-
Shannon	2.48	2.7	3.03		-	-	-
Shannon Exponential	11.89	14.86	20.71		-	-	-
Simpson	7.42	13.52	15.69		-	-	-

Discussion

This survey was the first biodiversity assessment of small mammals in the Upper Berbice region of Guyana. The rising species accumulation curves for bats at the two sites indicate that five nights of sampling effort did not represent a complete inventory of species diversity based on the standardized mist netting methodology used. Although more bats were captured at the White Sand camp, the Berbice River camp revealed more species and had higher richness estimators (Table 4.2). However, most diversity indices were lower for the Berbice River camp than for the White Sand camp, but this was skewed by the high number of captures at only the river camp of the fruit-eating bat *Artibeus planirostris* (see Table 4.1). This species is a typical understory forager in forested habitats, which might explain why it was not caught in the open areas of the White Sand camp because of a lack of suitable trails in the forest at this site. However, if the nets are set near a fruiting tree or a roosting site, the capture of *Artibeus planirostris* may be biased.

THIS SURVEY WAS THE FIRST BIODIVERSITY ASSESSMENT OF SMALL MAMMALS IN THE UPPER BERBICE REGION OF GUYANA

The faunal composition of bats was quite different between the two survey sites with a Jaccard Similarity Index of 22%. Of the 32 species of bats documented during the complete survey, only seven species were shared between the two sites (see Table 4.1). More indication of faunal differences was the capture of four species of aerial insectivorous bats in the family Molossidae in open areas of the White Sand camp, but not in the closed forest habitats of the Berbice River camp.

In comparison to other general lowland localities in the Guianas that have been surveyed with standardized rapid assessment field methodology, our survey of the Upper Berbice River region was most similar to the survey of the South Rupununi in Guyana (Lim et al. 2016). Both localities had high species diversity for bats, but low species diversity for small non-volant mammals (Table 4.3). In terms of habitat types, Upper Berbice and South Rupununi both encompassed forest and open areas. The other three comparative localities were in primarily forested areas.

FORESTED HABITATS ARE IMPORTANT FOR THE SURVIVAL OF A POTENTIALLY UNDESCRIBED SPECIES OF ROUND-EARED BAT (*TONATIA* SP.) CAPTURED AT THE BERBICE RIVER SITE

Table 4.3 **Comparison of small mammal data from the Upper Berbice River region with other similarly surveyed sites in Guyana and Suriname**

LOCALITY	BATS			SMALL NON-VOLANT MAMMALS		
	NIGHTS	SPECIES	INDIVIDUALS	NIGHTS	SPECIES	INDIVIDUALS
Eastern Kanukus, Guyana	8	26	234	9	5	11
Kwamalasamutu, Suriname	16	26	223	16	12	152
Upper Palumeu, Suriname	16	28	334	16	11	20
South Rupununi, Guyana	11	35	248	11	2	9
Upper Berbice, Guyana	10	32	176	10	2	4

The most interesting capture was a potentially undescribed species of round-eared bat (*Tonatia* sp.) at the Berbice River camp. Species in this genus are gleaning insectivorous bats that use their large ears to listen for sounds of prey such as katydids or beetles before swooping in to grab them on the ground or on vegetation. **They typically roost in tree hollows, so forested habitats are important for their survival**. More study of the morphology and DNA variation are needed to confirm this discovery.

All other species of small mammals caught during these surveys have been previously documented in typical lowland rainforest of Guyana. However, **several interesting species include the water rat (*Nectomys rattus*), which is not commonly caught in traps, and four species of free-tailed bats in the family Molossidae (*Cynomops abrasus*, *Eumops hansae*, *Molossus molossus*, and *M. rufus*) that are high-flying aerial insectivores which are usually not captured in ground-level mist nets.** These nets were set near water, which may suggest that bats were coming down to the water to either drink or catch insects near the surface. **A notable observation was the increasing species accumulation on a daily basis**. With consideration given to the short duration of sampling, **this is indicative of high species diversity and that the survey at each site was not complete.**

There were distinctions in small mammal diversity between the two sample sites. Although the number of species of bats at each of the two sites were similar, over three-quarters (77%) were caught at only one of the sites, indicating high differences in bat species diversity. The Berbice White Sand camp had limited surveying for one night because of rain; however there was a higher (33%) relative abundance based on the number of captures in the nets. The terrestrial small mammal capture success rate was low with only rats caught and no opossums captured. Although the trapping in lowland areas of the Guianas is typically poor, the results from this trip were even notably lower, but this perhaps is a consequence of the short duration of the sampling and the surveying of only two primary sites.

Conservation Recommendations

The Berbice River camp had higher species richness for bats typical of relatively undisturbed tall forest in the Guiana Shield, whereas the more disturbed low forest of the White Sand camp had higher relative abundance. In addition, a putative new species of round-eared bat (*Tonatia* spp.) was documented at the Berbice River camp that requires detailed taxonomic analysis. **The more pristine habitat of the upper reaches of the Berbice River is diverse and harbours unknown discoveries of biodiversity that warrant further surveying and ecological study.**

THE MORE PRISTINE HABITAT OF THE UPPER REACHES OF THE BERBICE RIVER IS DIVERSE AND HARBOURS UNKNOWN DISCOVERIES OF BIODIVERSITY THAT WARRANT FURTHER SURVEYING AND ECOLOGICAL STUDY

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CHAPTER 5

LARGE AND MEDIUM MAMMALS OF THE UPPER BERBICE REGION, GUYANA

Meshach Pierre, Leroy Ignacio, Dexter Torres, Edmund Torres, and Evi Paemelaere

Summary

We conducted a baseline assessment of the large and medium mammal populations in the Upper Berbice region using camera traps and opportunistic sightings at one site, and track surveys along 2 km transects at a second site. At the first site we detected 14 species; at the second site we detected 10 species, resulting in a total between the two sites of 18 different mammal species. **Photographs, tracks and live sightings revealed several species that are threatened and sensitive to disturbance, including the giant anteater and giant armadillo.** Differences in species recorded between the two sites were largely due to differences in survey methodology. Based on capture-recapture analysis of photographs, we estimated a preliminary population density of jaguars in the area to be 3.17 individuals/100 km^2 (SE ± 1.18), and for ocelots 16.00 individuals/100km^2 (SE ± 3.79). Predator density and relative abundance of other mammals suggested a healthy mammal population. **Because of the recent influx of hunters for sport and commercial purposes, we recommend management and oversight of hunting and access to the area, in order to prevent overharvesting of wildlife resources in a region area where, until recently, wildlife has remained protected due to its inaccessibility.**

SEVERAL SPECIES THAT ARE THREATENED AND SENSITIVE TO DISTURBANCE, INCLUDING THE GIANT ANTEATER AND GIANT ARMADILLO, WERE DETECTED

Introduction

Large mammals are key contributors to healthy forest ecosystems. Frugivores such as monkeys and tapirs serve as seed dispersers; large carnivores make up the apex predators; and other species such as peccaries (*Tayassuidae*) function as habitat architects through their wallows and disturbance (Altrichter et al. 2012; Andresen 1999; Fragoso et al. 2003; Julliot 1997; Link and Di Fiore 2006; O'Farrill et al. 2013). Their reliance on large tracts of viable land and their sensitivity to environmental changes make large mammals good indicators of forest health. Large predators also require healthy populations of prey, and therefore their populations reflect the state of the ecosystems they inhabit (Aranda and Sánchez-Cordero 1996; Lopez and Miller 2002; Carbone 2016).

Large mammals have traditionally been a challenge to study due to their low abundance and elusive nature. With the improvement of camera-trapping technology, it has become easier to detect large mammals in the field. This has permitted their study in rapid assessments of remote habitats (Tobler et al. 2008; Wang and Macdonald 2009).

Guyana has historically maintained a large percentage of standing forest, mainly due to the inaccessibility of the interior (Environmental Protection Agency 2010). Nevertheless, **the interior is also host to a wealth of timber and mineral resources** (Guyana Lands and Surveys Commission 2013). The resulting **demand for natural resources, especially by transnational logging and mining companies, has led to the building of new roads, thus opening forests for access by miners.** In addition, **open roads also allow forests to be utilized by hunters now armed with more powerful weapons and vehicles equipped with high-powered lights to facilitate the detection of wildlife.**

Guyana's wildlife has remained largely understudied, especially in regard to large mammals. Although a growing body of scientific work exists, few studies have focused on sites that have not been previously disturbed (Paemelaere and Payán 2013; Paemelaere and Payán Garrido 2012; Pierre et al. Unpublished data). Our study evaluated medium-large mammal diversity, and abundance and species richness in what was a relatively untouched area in the process of being converted to a logging site.

Study sites and methods

Study sites

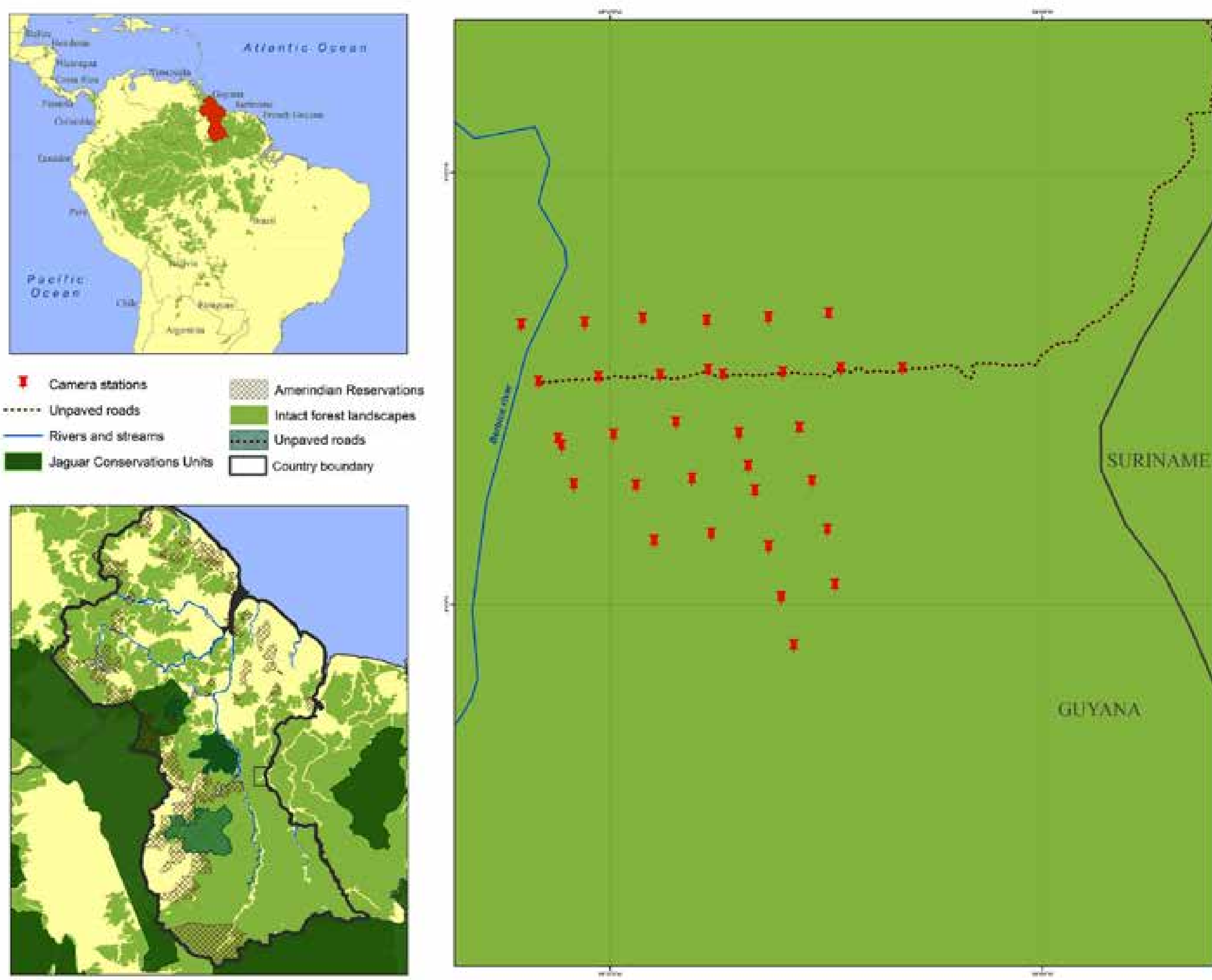
The study took place within a large, previously undisturbed, mixed lowland forest along the Upper Berbice River in eastern Guyana, where vegetation consisted mostly of Mora trees (*Mora excelsa*) and an understory of spiny palms. The area had no recent history of settlements, roads or other human activity. Between 2013 and 2014, however, road development expanded into southern wards, parallel to the Berbice River, to provide access to potential logging operations south of Kwakwani village. This, in turn, provided access to gold mining and exploration. Two sites were selected in this general area. The Upper Berbice River camp (N 4 09.236 W 58 10.640) was located on a more recently developed road, started in 2014, that diverted from the end of the main logging road to access the Berbice River. The Upper Berbice White Sands camp (N 4 45.323 W 58 00.430) was located along the main logging road, next to a kilometre-long stretch of dead, recently burnt forest.

Camera trapping

At the Berbice River camp, we set 32 cameras (Cuddeback Capture) at approximately 1.5 km apart (Figure 5.1.) The cameras were set between 18 and 24 September 2014, and remained on site until 9 to 13 November 2014, to achieve a minimum of 1000 trap nights (Tobler et al. 2008). Cameras were active during both day and night, and set to take one photo per trigger, with a 30-second delay before re-activation.

Live sightings and tracks

At both sites, we recorded live sightings, vocalizations and tracks. At the Berbice River camp these were recorded during camera trap set-up. At the White Sands camp, we established three track transects. One transect (A), 2 km long, followed a laterite road with sandy edges through burnt forest into the edge of the live forest. A second transect (B), also 2 km, consisted of a white sand road that branched off from the main logging road and ran through the burnt forest. The third transect (C), around 3 km long, followed a white sand logging track south of the White Sands camp through non-burnt dakama (*Dimorphandra conjugata*) forest. Each transect was traversed twice, covering 14 km in total. Repeat surveys occurred two to three days after the first survey.



Map source: ESRI, Panthera, Global Forest Watch, Natural Earth, GGMC, Haimwant Persaud

Figure 5.1 **Study site and camera trap array.**

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Meshach Pierre setting up camera trap.

© Meshach Pierre

A misty morning at the Berbice River camp. Camera traps were set in areas along the road.

Data analysis

From the camera trap data, we calculated relative abundance indices (RAI) of detected mammals. Relative abundance was calculated as the number of observations/(100* trap nights) (Carbone et al. 2001). Due to the difficulty in distinguishing the two species of deer (*Mazama americana* and *Mazama nemorivaga*), they were grouped under *Mazama* sp. The same was done for the smaller armadillo species, which were grouped under *Dasypus* sp. We also estimated species richness and diversity based on the photos using the software EstimateS (Colwell 2013). We used the recommended Jackknife 2 estimator (Tobler et al. 2008), and reported α and Simpson diversity values.

Density of spotted cats was estimated using both traditional and spatially explicit capture-recapture (SECR) methods. The unique spot pattern of each cat allowed for the identification of individuals (Silver et al. 2004); however, we were only able to identify them from either the left or right side. The side with the most individuals was used for analysis. We used the software program Capture for a traditional capture-recapture analysis (Rexstad and Burnham 1992). The population estimate from Capture was then divided by the effective trapping area to determine the density. The effective trapping area (ETA) was calculated by adding a buffer of half the mean maximum distance moved by the individuals to the area of the camera trap polygon (Wilson and Anderson 1985). This arguably overestimates jaguar density (Soisalo and Cavalcanti 2006). To allow for comparison with other studies, we also calculated the ETA using the full mean maximum distance moved. Additionally, we used DENSITY for SECR analyses of jaguar density (Efford 2012). However, SECR analysis could not be conducted on ocelot data due to software errors. Both methods of analysis assume that the population is closed and that the probability of capture is higher than zero. SECR analysis additionally assumes that all species have activity centres that do not exhibit any change over the survey period.

Results

At the Berbice River camp, our camera-trapping sample effort resulted in 1,325 trap nights. We recorded 236 independent photographs, including 207 photos of mammals and 25 photos of birds, and four that could not be identified. We detected 14 species of mammals with the camera traps at the Berbice River camp, while at the White Sands camp we detected 10 species of mammals in 14 km of transects.

Our species accumulation curve for the camera trap study at the Berbice River camp reached the asymptote, indicating sampling effort for the site had been sufficient. The Jackknife 2 estimate resulted in a mean of 13.75 ± SE 2.65 species (Figure 5.2). Agouti (*Dasyprocta leporina*) featured the highest RAI, while jaguarundi (*Puma yagouaroundi*) and acouchi (*Myoprocta acouchy*) featured the lowest RAI. Our diversity index result for the inverted Simpson index was 7.3, with an α mean of 3.08 (± 0.44).

Of the four spotted cat species known to occur in Guyana, we detected two: jaguar and ocelot. We identified three individual jaguars (two males and one female), and seven individual ocelots (three males, two females, and two of unknown sex). All individuals appeared to be healthy. Our effective sampling area for jaguars was 126.0 km², and 56.25 km² (MMDM/2) for ocelots. Based on population analyses, we estimated a preliminary population density of jaguars in the area to be 3.17 individuals/100 km²; for ocelots this was 16.00 individuals/100 km². Species detected are listed in Table 5.1 along with their RAI at the Berbice River camp; jaguar and ocelot population density estimates are presented in Tables 5.2 and 5.3

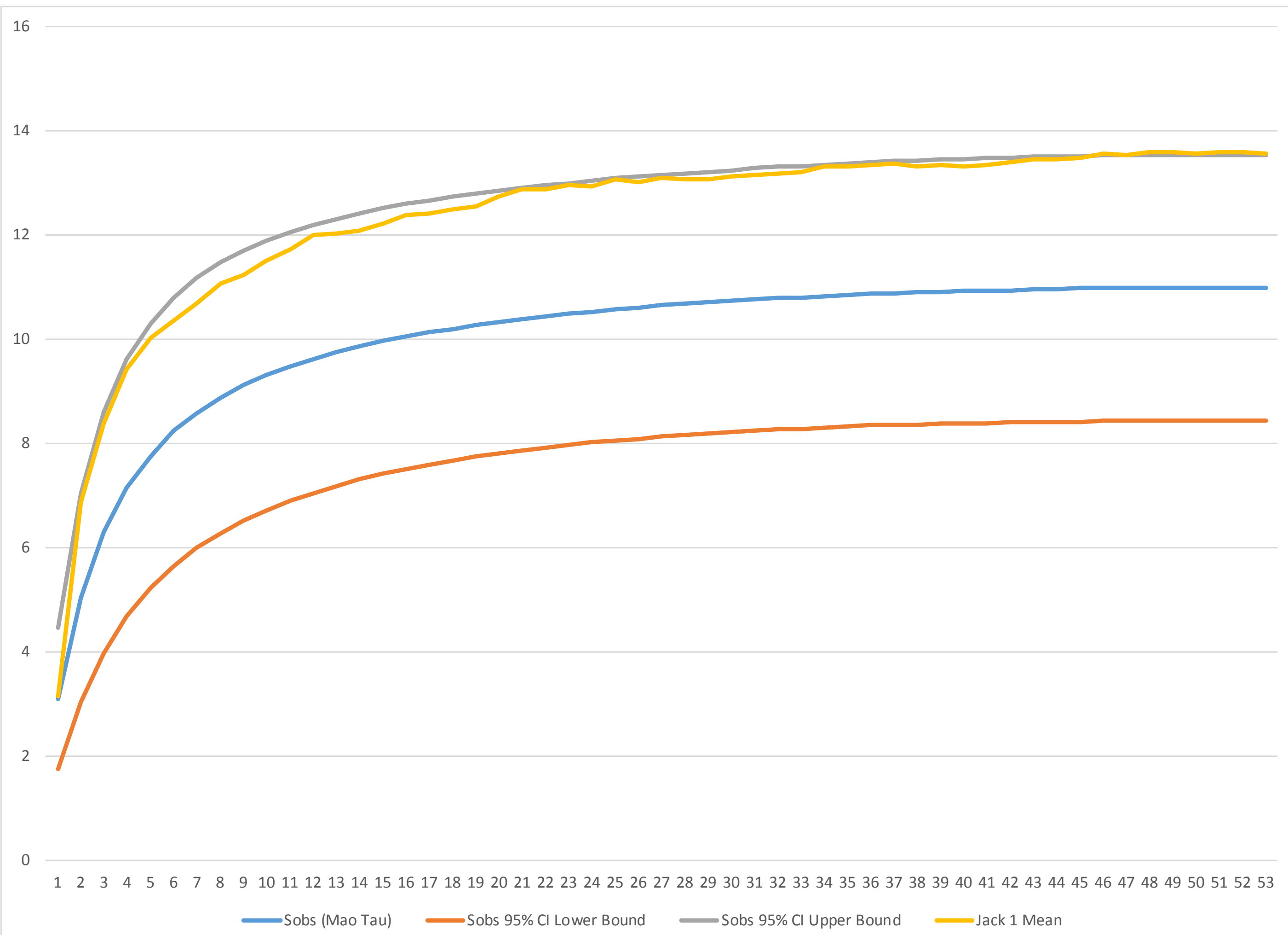

Figure 5.2 **Species accumulation curve.**

Table 5.1 Species detected at each camp and associated relative abundance indices (RAIs)

Key
NT - Near Threatened; **VU** - Vulnerable; LC - Least Concern; DD - Data Deficient
Bold type - near threatened or vulnerable species
* Denotes there was difficulty distinguishing between the *M. Americana* and *M. nemorivaga* species at the Berbice River camp, and these were grouped together under *Mazama* sp.

SCIENTIFIC NAME	COMMON NAME	BERBICE RIVER CAMP (RAI - # of photos/100 trap nights)	WHITE SANDS CAMP	IUCN RED LIST	CITES
CARNIVORA					
Panthera onca	**Jaguar**	**1.74**	**Tracks**	**NT**	**I/II**
Puma concolor	Puma	1.66		LC	I/II
Leopardus pardalis	Ocelot	2.34	Tracks	LC	I
Herpailurus yagouaroundi	Jaguarundi	0.15	Tracks	LC	I/II
Leopardus sp.		Tracks			
UNGULATES					
Tapirus terrestris	**Tapir**	**0.60**	**Tracks, faeces**	**VU**	**II**
Mazama sp.*	Brocket deer	2.57		-	
*Mazama americana**	Red brocket deer		Tracks	DD	-
Mazama nemorivaga *	Grey brocket deer		Tracks	LC	-
Pecari tajacu	Collared peccary	3.85		LC	II
XENARTHRA					
Myrmecophaga tridactyla	**Giant Anteater**	**0.30**		**VU**	**II**
Dasypus sp.	Armadillo	0.38	Tracks	LC	-
Priodontes maximus	**Giant armadillo**	**Burrow**	**Tracks**	**VU**	**I**
RODENTIA					
Cuniculus paca	Labba	Tracks	Tracks	LC	III
Dasyprocta leporina	Agouti	Tracks, live	Tracks	LC	-
Myoprocta acouchy	Acouchi	-		LC	-
PRIMATES					
Alouatta macconnelli	Red howler monkey	Vocalizations		LC	II
Ateles paniscus	**Red-faced spider monkey**	**Vocalizations**		**VU**	**II**
Sapajus apella	Brown capuchin	Vocalizations, live		LC	-
Pithecia pithecia	White-faced saki	Vocalizations, live		LC	II

Table 5.2 **Jaguar density estimate using both spatially explicit and non-spatially explicit methods**

Key

MMDM: Mean Maximum Distance Moved; **ETA**: Effective Trapping Area; **SE**: Standard Error; **CV**: Coefficient of Variation; M(o): Null Model which assumes no variation; M(th): Model which assumes variation over time and between sexes.

Jaguar Density Estimate							
Buffer	**ETA (km^2)**	**Model**	**Population Estimate**	**SE**	**Density (inds/100km^2)**	**SE**	**CV%**
MMDM	246.52	M(o)	3 (3 - 3)	0.15	1.22 (1.22 – 1.22)	0.06	4.93
		M(th)	4 (4 - 15)	1.49	1.62 (1.49 – 6.08)	0.6	37.93
MMDM/2	126.00	M(o)	3 (3 - 3)	0.15	2.38 (2.38 – 2.38)	0.12	4.93
		M(th)	4 (4 - 15)	1.49	3.17 (3.17 – 11.90)	1.18	37.23
		SECR	-	1.53	1.03 (0.13 – 8.56)	1.53	148.54

Table 5.3 **Ocelot density estimate using non-spatially explicit methods**

Key

MMDM: Mean Maximum Distance Moved; **ETA**: Effective Trapping Area; **SE**: Standard Error; **CV**: Coefficient of Variation; **M(o)**: Null Model which assumes no variation.

Ocelot Density Estimate							
Model	**Buffer**	**ETA (km^2)**	**Population Estimate**	**SE**	**Density (inds/100km^2)**	**SE**	**CV%**
M(o)	**MMDM**	63.18	9 (8 - 18)	2.13	14.24 (12.66 – 28.49)	3.37	23.67
	MMDM/2	56.25	9 (8 - 18)	2.13	16.00 (14.22 – 32.00)	3.79	23.67

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A puma looking on through the dense forest vegetation at the researchers.

Armadillo, *Dasypus* sp.

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Collared peccary, *Pecari tajacu*

Discussion

Our study offers a baseline assessment of the medium and large mammal populations in the upper Berbice region. In this newly-exposed lowland forest, we used camera traps, live sightings and tracks for a rapid assessment of terrestrial medium-to-large mammal richness and diversity. Overall, we detected 18 mammal species (14 semi-terrestrial mammal species and four primate species), including threatened species and top predators, albeit at comparatively low abundances. Differences in species detected at each camp can be explained by the differences in the survey techniques employed.

At both camps, we detected threatened species, such as the giant anteater (*Myrmecophaga tridactyla*), and the black spider monkey (*Ateles paniscus*). Since these species prefer intact forests, it suggests that the level of disturbance in the area was still low. This is further supported by the presence of red acouchy. Although not threatened, this species typically avoids disturbance (Dubost 1988). Further indication of low disturbance was the observation of large predators, both with camera traps and through live sightings. This not only indicates sufficient prey availability to support their presence, but also that human interference has been limited, and has therefore not yet instilled fear of humans in otherwise typically elusive animals. (Kilgo et al. 1998; Carter et al. 2012).

Nevertheless, relative abundance values of most species were comparatively low compared to other study sites in Guyana with varying degrees of disturbance, including lowland forest sites featuring logging, mining and hunting, and savannah (Paemelaere and Payán 2013; Paemelaere and Payán Garrido 2012, Pierre et al. Unpublished data). This could be explained by habitat variation or recent human disturbance or both. Indeed, we encountered few surface water bodies within the camera trap grid, and creek beds were mostly dry. Therefore, distribution of mammals in the area may have been skewed. **Additionally, with the recent opening of the road and introduction of hunting, wildlife may have, perhaps temporarily, redistributed away from this new disturbance.** On the other hand, **species diversity was equivalent or higher than the above mentioned studies that were conducted in forest habitats** (Paemelaere & Payán, 2013, Pierre et al. Unpublished data), and **as such the area is of high biodiversity value.**

The camera trap survey effort was sufficient for the capture of species that are relatively common (Tobler et al. 2008), and the plateau of the accumulation curve supported this notion (Figure 5.2). For density estimates, we achieved the recommended minimum effort; however, our polygon size was smaller than recommended for jaguar density estimation, and as a result, our density results may be inflated (Tobler and Powell, 2013). Although the M(th) model was recommended, our sample size was too small to reliably demonstrate temporal and behavioural variation on jaguar density. The coefficient of variation was higher than 20% for all estimates, except for that which utilized the M(o) model,

FOREST ACCESS HAS BEEN LINKED TO DECREASES IN WILDLIFE POPULATIONS. WHILE EXTRACTIVE ACTIVITIES ARE STILL LIMITED IN THE AREA, URGENT LAND-USE PLANNING, WHICH ALSO TAKES INTO CONSIDERATION WATER SOURCE ACCESS FOR WILDLIFE, IS RECOMMENDED.

rendering the estimates unreliable (Linkie et al. 2008). The high variability indicates a need for further data. While our methodology was constrained by the rapid inventory format, further studies will require a larger polygon size and higher camera trap effort in response to the low detection probability of jaguars in the area.

Track surveys were limited by a lack of clear trails and the presence of vehicular traffic. Distance covered was also limited due to time constraints in this rapid assessment. Camera traps are thus more efficient in detecting mammalian diversity than tracking (Silveira and Jácomo 2003), especially during these exploratory studies. Cameras, on the other hand, are limited to terrestrial species. Therefore, transects for tracks and live sightings offer an ideal complement in rapid assessments to detect the presence of other species.

Forest access has been linked to decreases in wildlife populations (Laurance et al. 2009). **An observation of hunters with multiple tapir carcasses made during the trip indicates that hunting was already present within this recently opened area.** However, the presence of threatened and disturbance-sensitive species shows that this forest is of high conservation value. **While extractive activities are still limited in the area, urgent land-use planning, which also takes into consideration water source access for wildlife, is recommended**. At this point, the most pressing management actions should be hunting regulations, wildlife management plans, and enforcement action that will help prevent overharvesting of wildlife resources in this area, where wildlife has become vulnerable because of recent accessibility to the area. Monitoring of the more sensitive species, including the tapir, jaguar, spider monkey, red acouchi, and others we may not have detected, will aid in adaptive management of the area.

Our results also highlight our still limited knowledge of mammals in the different habitats of the Guiana Shield. Due to the preliminary nature of these results, we recommend a more direct, longer-term study to build on the data collected thus far. **Further research is needed to understand mammalian (micro-) habitat selection, movement patterns, and the effects that land use may have on mammal populations. This is particularly important in sites such as our study areas in the Upper Berbice region, where frontier roads are providing access, and causing habitat conversion of a previously undisturbed area.**

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CHAPTER 6
FISHES OF THE UPPER BERBICE REGION, GUYANA

Donald Taphorn, Leanna Kalicharan, Elford Liverpool, Francesco Janzen and Jabaun Correia

Summary

We made a rapid assessment of the fish diversity in the Upper Berbice River in an area of virgin rain forest as part of the BAT survey in September 2014. The low water levels of the dry season concentrated fishes in the main channel of this small blackwater river. Nine collections made during five days yielded a total of **92 species.** Large aimara (*Hoplias aimara*) were abundant in the main channel near rock outcrops. **Of fifteen specimens checked for mercury in their flesh, ten were found to be contaminated, and three of these even had levels of mercury above those considered safe for human consumption.** One sampling site was in the Corentyne River drainage, and could include new species records for Guyana. **Gold mining and deforestation for lumber and are the immediate threats to fish biodiversity**. Overfishing of Aimara is more likely now that road access has been established by a logging company. Thus, **enforcing fishing regulations and educating fishermen about sustainable practices are needed to preserve the large fish species.** Protection of riparian vegetation and enforcement of mining and logging regulations are important for maintaining the aquatic ecosystems.

92 SPECIES OF FISH WERE RECORDED DURING THIS SHORT SURVEY

OF FIFTEEN *HOPLIAS* SPECIMENS CHECKED FOR MERCURY IN THEIR FLESH, TEN WERE FOUND TO BE CONTAMINATED, AND THREE OF THESE EVEN HAD LEVELS OF MERCURY ABOVE THOSE CONSIDERED SAFE FOR HUMAN CONSUMPTION

Introduction

THE LOWER PORTIONS OF THE BERBICE RIVER ARE SIGNIFICANTLY AFFECTED BY AGRICULTURE, BUT THE UPPER STRETCH WE SAMPLED RUNS THROUGH VIRGIN RAINFOREST, AND IS STILL IN PRISTINE CONDITION

Collecting efforts during the last two decades have significantly increased the number of freshwater fishes reported from Guyana to over 600 species, but most river drainages are still poorly sampled. As the fishes from more rivers are collected, Guyana's species list will continue to grow. The "Land of Many Waters" shares river basins with neighbouring countries. In the extreme north-western portion of Guyana, the ichthyofauna of the Orinoco River Basin (over 1,200 species) is shared with Venezuela. To the east, the Corentyne River forms Guyana's border with Suriname (where 481 species of fishes are reported for the entire country). Guyana's southwestern and southern regions are drained by tributaries of the Amazon River (for which fish species diversity estimates range from 2000-6000 species), and which continue on into Brazil. Besides these shared drainages, Guyana has several independent river basins of its own, such as the Essequibo, Demerara and Berbice, which empty into the Atlantic. Thus, the probability of increasing the list of species known from Guyana is quite high.

The Upper Berbice rapid biodiversity assessment team spent five days during September 2014 collecting in the Berbice River basin, which drains independently into the Atlantic Ocean in eastern Guyana, near Suriname, and into the Corentyne River basin near the Suriname border. **The lower portions of the Berbice River are significantly affected by agriculture, but the upper stretch we sampled runs through virgin rainforest, and is still in pristine condition.** We found very low water levels on this dry season expedition, which caused fishes to be therefore more concentrated than the rest of the year, when the waters are much higher and extend well into the adjacent river floodplain, flooding large sections of the forest.

Although the Berbice River today is a relatively small, independent coastal drainage tucked between the much larger Essequibo and Corentyne rivers, this was not always the case for most of the more than 100-million-year history of the South American continent, once it separated from Africa. Lujan (2008) cited the works of several geologists (Sinha 1968; McConnell et al. 1969; Berrangé 1975; Schaefer and do Vale 1997) who have hypothesized that for most of the last 65 million years a single river drained the Guiana Highlands' southern slopes, and emptied into the Atlantic Ocean via a main channel that flowed through the Rupununi Savannah and exited near the mouth of the modern Berbice River. That much larger river is called the "proto-Berbice", and it flowed for tens of millions of years before recent (in geological terms) periods of uplift of the Guiana Shield subsequently shifted watershed boundaries, due to tilting of the underlying basement. This completely re-drew the river system map, rejuvenating some river channels, de-watering others, chopping the headwaters off some ancient waterways, and reshuffling fish faunas as a result of stream piracy. At the same time, the uprise of the Andes Mountains reconfigured the rest of South America's drainages to create the modern drainage system, which has only existed in its current configuration for 9-12 million years. Figure B, the *Map of Guyana showing the major rivers of Guyana* (see under "Context: Ecological Importance of the Upper Berbice Region"), depicts the Berbice River Basin and surrounding river basins as they are today.

Methods

The primary method of fishing was a small drag seine net, (4 x 12 feet, with 3/16 inch mesh) which was used throughout the study to allow rough comparison of results. The drag seine was pulled by two workers through shallow (up to chest deep) water while fish were corralled to the middle of the net which was moved towards the shore to capture the fish. It was also set in the fast-flowing waters of rapids (or along the shore), while members of the team vigorously kicked the vegetation and rocks immediately upstream of the net to dislodge fishes. The drag seine was also used to come up under submerged tree branches hanging over from the shore. Small-meshed (1/2 to 2 inch) gillnets were deployed by boat in deeper water, targeting larger fishes. Gillnets used were made of monofilament nylon of varying mesh sizes which entangle fishes when they collide with it or try to pass through. Hook and lines were also used (but infrequently) to target larger species of fish such as the giant aimara. The nine sites sampled are listed in Table 6.1.

Table 6.1 **Fish collecting sites in the Berbice and Corentyne River basins**

Key

"Time" is the approximate duration of sampling, in minutes, or minutes and hours.

FIELD #	DATE	DRAINAGE	LOCALITY	LATITUDE	LONGITUDE	METRES ABOVE SEA LEVEL	TIME
BAT14-30	21/09/2014	Berbice River	Upper Berbice River at end of mining road	4.15648	-58.23227	68	1:01
BAT14-31	21/09/2014-22/09/2014	Berbice River	Upper Berbice River at future site of mining bridge	4.15648	-58.23227	68	18
BAT14-32	21/09/2014	Berbice River	Upper Berbice River in main channel	4.14845	-58.233667	70	1:20
BAT14-33	22/09/2014	Berbice River	Creek in forest near camp (downstream)	4.158283	-58.17705	68	2:18
BAT14-34	23/09/2014	Berbice River	Creek in forest near camp (upstream)	4.15655	-58.177333	75	1:08
BAT14-35	23/09/2014	Berbice River	Creek in forest near camp (upstream)	4.15655	-58.177333	75	3:05
BAT14-36	23/09/2014	Berbice River	Berbice River, main channel at rock outcrop, future bridge site	4.00648	-58.23227	68	1
BAT14-37	24/09/2014	Berbice River	Berbice River, main channel at rock outcrop, future bridge site	4.156483	-58.232267	68	2:00
BAT14-38	25/09/2014	Corentyne River	Creek in forest along logging road south of Kwakwani at campsite	4.758317	-58.00535	70	1:05

Specimens were hand-sorted and tentatively identified to species in the field in order to select specimens for tissue samples. Tissue samples were taken from selected individuals for DNA, mercury or isotope analysis. Fishes that were "tissued" were tagged with a unique catalogue label as voucher specimens in most cases, but when larger numbers of common large species were obtained (such as piranha), some specimens were photographed and not preserved as vouchers. "Tissuing" involves removing either a fin clip or a section of muscle tissue from the right side of the fish and preserving the sample in 95% ethanol for DNA analysis; in salt for isotope analysis; or frozen in liquid nitrogen when taken for mercury analysis. We generally attempted to tissue at least three specimens of a given species from each locality. In this way we capture both the taxonomic and genetic diversity of a given habitat or locality. Fish were anaesthetized in a clove oil solution, then preserved in a 10% formaldehyde solution for later cataloguing and taxonomic confirmation. Specimens and tissues were deposited in the fish collection of the Royal Ontario Museum in Toronto, Canada. Representative fish specimens (and any holotypes that might be named) will be returned to the Ichthyology Collection of the Centre for the Study of Biological Diversity of the University of Guyana (CSBD), when that facility is funded by the University of Guyana to adequately sustain scientific collections under proper curatorial conditions.

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The fish team immersed in their work, in the Berbice River.

Results

The Berbice River basin is small (5,102 km^2) when compared with the others in Guyana (Table 6.2). It originates surprisingly far south in Guyana, near the Rupununi Savannah highlands, and then flows northward for 370 miles (595 km), mostly through dense forest (until recently virgin) to the coastal plain. It empties into the Atlantic Ocean at New Amsterdam near the mouth of its only tributary of any size, the Canje River. (See Figure B, *Map of Guyana showing the major rivers of Guyana,* under "Context: Ecological Importance of the Upper Berbice Region").

Table 6.2 **Comparison of drainage areas of the major rivers in Guyana**

RIVER	DRAINAGE AREA km^2	MEAN ANNUAL DISCHARGE km^3
Essequibo	66,563	70.16
Cuyuni	53,354	33.54
Mazaruni	20,720	36.13
Potaro	6,203	16.46
Demerara	4,040	3.52
Berbice	5,102	1.26
Canje	227	0.08

Source: http://www.fao.org/nr/water/aquastat/countries_regions/GUY/print1.stm

As indicated above, for this rapid assessment fishes were sampled from eight localities in the blackwater Berbice River basin (from both the main channel and blackwater forest creek tributaries), and from one clearwater site in a tributary of the Corentyne River. (Figure 6.1.) Fish were abundant in the Berbice River main channel, concentrated by the low water levels of the dry season.

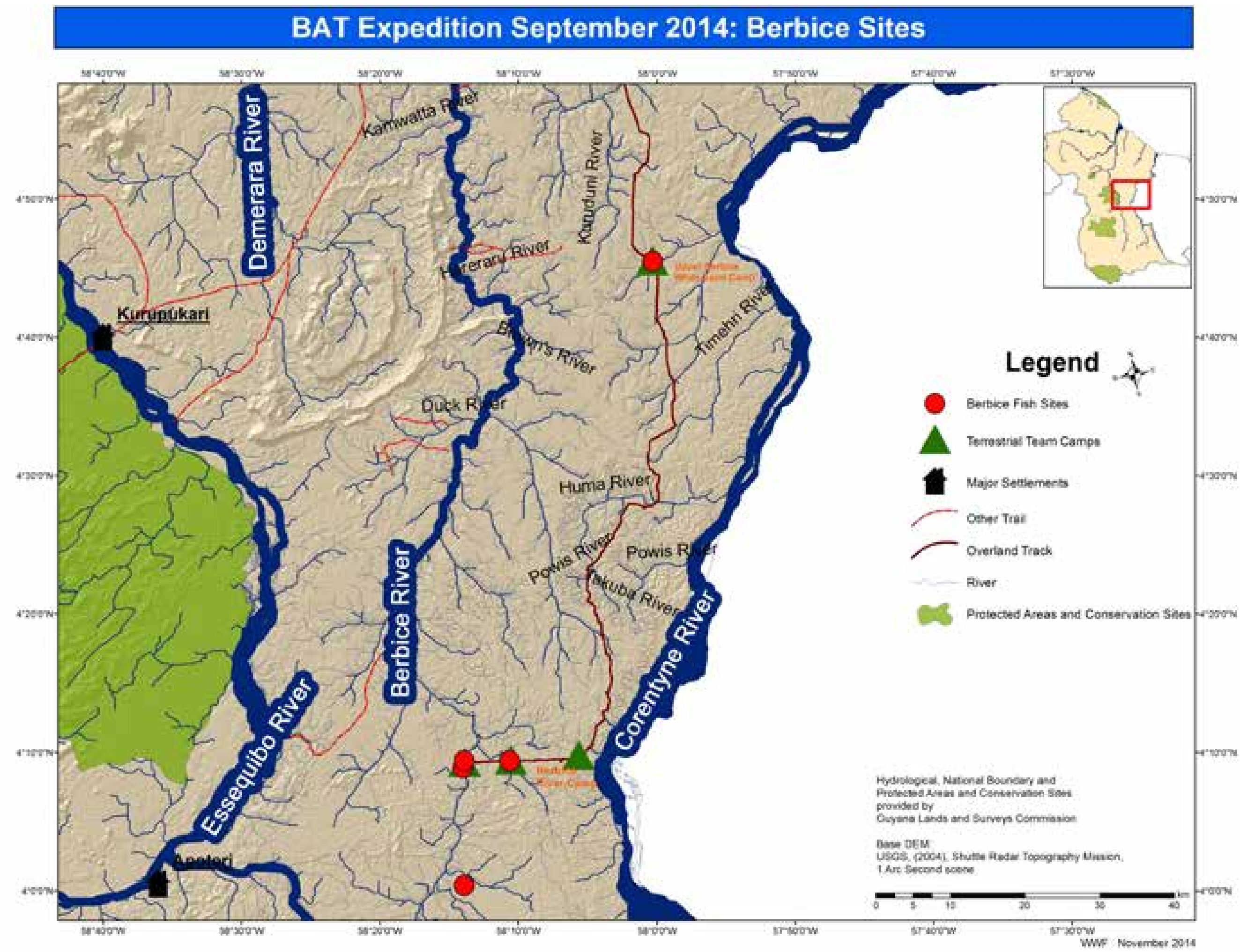

Figure 6.1 **Location of the fish sites sampled during the Upper Berbice 2014 survey.**

We collected a total of 92 species, 87 from the Berbice River and tributaries (about 65% of the 134 species so far reported), and 14 from the Corentyne tributary stream (See Appendix 6.) Nine species were found in both basins.

Mercury samples of 15 fish, the piscivorous *Hoplias aimara* and *H. malabaricus,* were sent for analysis by the Guyana EPA to an independent research laboratory in Trinidad (Kaizen Lab). The results of the mercury analysis in fish muscle tissue are given in Table 6.3. **Mercury contamination ranged from 0 (undetectable in 5 fish) to 0.653 mg/kg. The recommended (WHO) maximum level for human consumption is (0.05mg/kg), and three of the 15 sampled *Hoplias* exceeded this limit.**

From the 87 species of fishes of the Berbice River and its tributaries, we collected 355 tissue samples for DNA analysis, and 47 were obtained from the 14 species collected from the Corentyne clearwater stream.

Table 6.3 **Mercury concentrations in fishes from the upper Berbice River where gold mining was not as yet apparently present**

Key
0 indicates mercury levels were below the detectable level of 0.05mg/kg.
Mercury Concentration: Hg Conc. SL = Standard Length

TISSUE #	GENUS	SPECIES	Size cm SL	SITE	Hg Conc. mg/kg	Diet
T-18442	*Hoplias*	*aimara*	56	BAT14-31	0	Carnivore
T-18444	*Hoplias*	*aimara*	66	BAT14-31	0	Carnivore
T-18582	*Hoplias*	*aimara*	63	BAT14-31	0	Carnivore
T-18584	*Hoplias*	*aimara*	77	BAT14-31	0	Carnivore
T-18420	*Hoplias*	*malabaricus*	18	BAT14-33	0	Carnivore
T-18441	*Hoplias*	*aimara*	75	BAT14-31	0.054	Carnivore
T-18440	*Hoplias*	*aimara*	55	BAT14-31	0.124	Carnivore
T-18583	*Hoplias*	*aimara*	87	BAT14-31	0.231	Carnivore
T-18439	*Hoplias*	*aimara*	70	BAT14-31	0.371	Carnivore
T-18436	*Hoplias*	*aimara*	65	BAT14-31	0.412	Carnivore
T-18438	*Hoplias*	*aimara*	60	BAT14-31	0.436	Carnivore
T-18585	*Hoplias*	*aimara*	87	BAT14-31	0.458	Carnivore
T-18437	*Hoplias*	*aimara*	70	BAT14-31	0.525	Carnivore
T-18435	*Hoplias*	*aimara*	73	BAT14-31	0.584	Carnivore
T-18434	*Hoplias*	*aimara*	75	BAT14-31	0.653	Carnivore

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You can't wear this boot! ***Trachycorystes trachycorystes*** **from the Berbice River.**

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The giant aimara (*Hoplias aimara*) were so aggressive that they were easily caught on hook and line from the Berbice River.

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Red-eyed piranha, *Serrasalmus rhombeus*, were extremely abundant in the Berbice River, and complicated sampling efforts by attacking fishes caught in our gill nets.

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The piranha left only the head of this lukunani, *Cichla ocellaris*, in our gill net.

Discussion

During this BAT rapid biodiversity survey, fish collections were obtained from nine localities (eight Berbice, one Corentyne; see Table 6.1). **The expedition produced a total of 92 species and brings the total known freshwater fish diversity for the Berbice River to 154 species** (see Appendix 6). This preliminary diversity information indicates much lower diversity than the much larger Essequibo River Basin, but is still high given the relatively low area drained by the Berbice River. Fish diversity was relatively low per site in the Berbice River main channel (average = 10 species per site). Samples were fairly uniform in diversity, with most species found abundant at most sites (over 350 specimens collected per site), but due to limited mobility, most of our sites were concentrated in a relatively short stretch of river with somewhat uniform habitats. **All locality records are important documentation of the fish diversity of Guyana, especially in the face of emerging activities confronting the region visited. This upper section of the Berbice River had never before been sampled by ichthyologists, thus the locality records are novel for all species collected.** Tissue samples and whole specimens of these taxa collected permit taxonomic comparisons to determine their status, and whether or not they warrant description. Specimens from this expedition of the banded knifefish were used by Lehmberg (2015) in her Master's degree thesis, a biogeographical study of *Gymnotus carapo* populations of the Guianas. The Berbice River has already been shown to harbour endemic species, such as *Krobia petitella* (Steele et al 2015), and *Geophagus crocatus* (Hauser and López-Fernández 2013). This was somewhat unexpected, since such a small river could be dominated by species from the neighbouring, much larger rivers. However, the unique geological history and current isolation have apparently been sufficient to allow local species to evolve sufficiently to distinguish themselves from their nearby congeners.

The mercury samples obtained determined that some individuals (3 of 15) of top predators such as the aimara (*Hoplias aimara)*, which are eagerly consumed by people, contained levels of mercury that are of concern for human health, and over half of all the fish samples had been contaminated with varying levels of mercury. **These results pose a question about where these fish are consuming prey contaminated with mercury, since gold mines were not observed at the time of sampling in this region.** Further, more detailed studies of that species are needed to determine if its populations can sustain fishing pressure, and why some individual's flesh contained dangerous levels of mercury while others had no detectable amounts. Perhaps the predators migrate to places where gold miners are active, or consume migratory species that travel to and from such areas. Another possibility is that prevailing winds carry mercury-contaminated dust from nearby mining areas, as has been shown to be the case in Suriname (Ouboter et al. 2012). If the mercury in fish predators were of natural origin (from rock and sediments present in the Upper Berbice River basin), one would expect all fish examined to have similar levels of contamination.

THE EXPEDITION PRODUCED A TOTAL OF 92 SPECIES AND BRINGS THE TOTAL KNOWN FRESHWATER FISH DIVERSITY FOR THE BERBICE RIVER TO 154 SPECIES

SEVERAL SPECIES COLLECTED MAY PROVE TO BE NEW TO SCIENCE; THESE INCLUDE: *ANABLEPSOIDES* CF. *STAGNATUS* AND *LAIMOSEMION* SP. KILLIFISHES (FAMILY RIVULIDAE), AND A BEAUTIFUL RED-TAILED TETRA OF THE GENUS *BRYCONOPS* SP.

Implications for conservation

Our impression of the fish faunas visited is that those of the Berbice River are in pristine condition, as yet unaffected by human impacts. The stream in the Corentyne River drainage has been severely affected at the site sampled by deforestation and a nearby forest fire, but water quality was apparently still good there. However, recent development, along with planned expansion of extractive sectors into this intact area, opens access and increases the potential for detrimental impacts on the fish fauna, which may include overfishing, increased deforestation, and severe alteration of water quality by increasing sediment loads and temperature.

Interesting species

Finding so many very large aimara in just one small area of the Upper Berbice River was unexpected. We assume that these top predators were concentrated because of the low water levels of the dry season. Moderate- and small-sized fishes were extremely abundant as well in the main channel of the river, which was so low that it had no perceptible flow in most areas.

Several species collected may prove to be new to science; these include: *Anablepsoides* cf. *stagnatus* and *Laimosemion* sp. killifishes (family Rivulidae), and a beautiful red-tailed tetra of the genus *Bryconops* sp. The Corentyne River undoubtedly will add to the list of freshwater fish diversity of Guyana, since most of its tributaries in Guyana have never been sampled scientifically for fishes. It is known to harbour some endemic fishes such as *Hypostomus corantijni* Boeseman 1968, which was described from a site right on the border with Guyana.

Recommendations

The fish communities found in the upper Berbice River seem to be in good health upon first impression. To preserve the fish species diversity and promote sustainable fishing, logging and mining activities must be regulated to comply with current laws.

Fishermen tend to take as many fish as they can catch and carry in these remote areas. This practice will rapidly deplete the largest top predators such as the aimara. If no enforcement agents are present in the area, fishing (as well as hunting) will probably proceed unchecked and undocumented. Ideally, these activities would be regulated to comply with existing laws. **An attempt to educate local fishermen about sustainable fishing practices should be made in local villages and towns.**

To prevent damage from logging and mining there are **many restrictions and regulations in existing laws**. All of these **must be strictly enforced, especially those concerning the protection of riparian forests, to preserve a green belt along the river channel.**

It is especially important to guard against the following negative impacts on aquatic ecosystems:

- Tailings and other sediments from mining operations should be contained in sediment catchment ponds rather than discharged into the river or tributary streams to avoid the excessive sedimentation downstream that destroys benthic aquatic communities.
- Fuel, oil and other lubricants for machinery should not be allowed to enter the river.
- No mining should be permitted along the shores of the river. Shoreline vegetation must be maintained as required by law.
- Regulations to avoid overfishing must be enforced.
- Clearcutting of forests and recent forest fires were observed in the area. Clearcutting must be curtailed in favour of selective logging. Companies operating in the area must educate their employees as to proper procedures to prevent forest fires.

ALL LAWS MUST BE STRICTLY ENFORCED, ESPECIALLY THOSE CONCERNING THE PROTECTION OF RIPARIAN FORESTS, TO PRESERVE A GREEN BELT ALONG THE RIVER CHANNEL

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AN ATTEMPT TO EDUCATE LOCAL FISHERMEN ABOUT SUSTAINABLE FISHING PRACTICES SHOULD BE MADE IN LOCAL VILLAGES AND TOWNS

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CHAPTER 7

AQUATIC BEETLES OF THE UPPER BERBICE REGION, GUYANA

Andrew Short, Shari Salisbury, and Nelanie La Cruz

Summary

Aquatic beetles were surveyed in the Upper Berbice region of Guyana, sampling extensively around two sites. Most habitats consisted of primary tropical forest. More than 3,500 specimens were collected from 41 collecting events. **We identified 137 species of aquatic beetles in 55 genera. Two genera and at least 16 species are new to science, though additional new species are almost certain to be identified from the material.** The total observed species richness was comparable with other lowland tropical forest regions in the Guiana Shield. Species composition between the two camps was strongly dissimilar, given the relatively close proximity of the two sites. While some of these differences may be due to sampling artefacts or modest differences in microhabitat**, a number of species found in the White Sands camp suggest environmental disturbances have altered the water beetle community.**

137 SPECIES OF AQUATIC BEETLES IN 55 GENERA WERE IDENTIFIED. TWO GENERA AND AT LEAST 16 SPECIES ARE NEW TO SCIENCE.

A NUMBER OF SPECIES FOUND IN THE WHITE SANDS CAMP SUGGEST ENVIRONMENTAL DISTURBANCES HAVE ALTERED THE WATER BEETLE COMMUNITY

Introduction

Aquatic beetles are a diverse guild of insects with more than 13,000 species that occur in a broad range of habitats, including streams, lakes, and waterfalls (Short 2018). Species are distributed worldwide, and taxonomically spread across approximately 20 beetle families in four primary lineages: Myxophaga, Hydradephaga, aquatic Staphyliniformia (Hydrophiloidea and Hydraenidae) and the aquatic byrrhoids. Members of Myxophaga are small beetles that feed largely on algae as larvae and adults. The Hydradephaga (including the diving and whirligig beetles) are largely predators as adults and larvae; the aquatic Staphyliniformia are largely predators as larvae but scavengers as adults; the aquatic byrrhoids are largely scavengers or eat algae as both larvae and adults (Short 2013).

Aquatic insects (including some groups of aquatic beetles) are often used as effective indicators of water quality in freshwater systems. This is largely due to their varying response to ecological perturbations such as increasing sediment load, nutrient inputs, and loss of canopy cover. Aquatic beetle communities are also effectively used to discriminate among different types of aquatic habitat (e.g. between lotic and lentic; rock outcrops, substrate, etc.).

Aquatic beetles in Guyana are not well known, but recent efforts have significantly improved our knowledge of the regional fauna. Prior collecting for aquatic beetles in Guyana was conducted in 1983 (Takutu Mountains), 1994 and 1995 (both in the north Rupununi area), and more recently by the authors in the South Rupununi in 2013 and the Upper Potaro in 2014. Neighbouring Venezuela and Suriname have also received significant attention in recent years, and have been the subject of numerous survey efforts (e.g. Short and Kadosoe 2011; Short 2013). Still, the entire regional fauna is very understudied and many new species are being discovered and remain to be described. See Appendix 7 for a list of the species collected in this survey.

Methods and study sites

Field methods:

We employed both active and passive trapping methods to capture a range of aquatic beetle diversity. We made a total of 41 collections of aquatic beetles around two primary sites, as well as two small collections at a site near the entrance of the logging road (1 km from the main gate), which were grouped with the White Sands camp.

Traps and other passive methods. We erected a UV light on a white sheet suspended on the lab tent at both base camps. We did not utilize flight intercept or dung traps as we have on some prior surveys.

Active methods. Most collections focused on streams and rivers, and in the case of the White Sands camp, in artificial pools created during the construction of the road. We did not observe any marshes or significant larger natural standing water habitats. Aquatic dip nets were the most commonly used collecting tool. The nets are swept through marginal detritus, vegetation, and open water, and the contents subsequently placed on screens over white tubs to extract the beetles. Insects that float to the surface of the water were collected with a kitchen strainer. Partially or fully submerged stream debris was also placed into pans of water to extract insects living in this microhabitat. There were no hygropetric or rock-seep habitats observed at either camp.

Preservation and identification. The majority of aquatic beetles require detailed examination in the laboratory to identify to species. This is in part due to their small size (most are less than 6 mm). Consequently, we collected and preserved samples directly into 100% ethanol for subsequent study. Representative material from each collecting event was mounted and taxonomically sorted. While all specimens were identified to genus, assigning species names is difficult due to the fauna being very poorly known in the region, and consequently species counts are based on morphospecies. Specimens are deposited in the Snow Entomological Museum at the University of Kansas, and the Centre for the Study of Biological Diversity at the University of Guyana.

Site 1: Berbice River camp (Base camp: 4° 09.241' N, 58° 10.627' W) 21–25 September 2014

Situated about 10 km east of the Berbice River, the base camp area was adjacent to a newly-built mining road running through pristine primary lowland rainforest. The forest had an exceptionally tall canopy, with the understory dominated in large areas by spiny palm. We sampled several small- to medium-sized streams in the area, all of which were whitewater with sand, mud, and/or detrital substrates. Several larger streams had sandy banks and emergent sandbars. Several stream channels were reduced to isolated pools, and the water level in the flowing channels was generally very low. We sampled the margin of the Berbice River in several places where there was emergent vegetation or accumulated detritus. Though we did not observe any marshes or larger pond habitats, we did sample in a few small, artificial pools created in tire ruts and other areas alongside the road.

Site 2: White Sands camp (Base camp: 4° 45.297' N, 58° 00.431' W)
26 September – 1 October 2014

The camp was situated along a logging road at the margin of a large patch of recently burnt forest. The canopy of the forest was much lower than that of the Berbice River camp, and the soils were primarily composed of white sand. We sampled several small to medium creeks in the area that had a primarily sand substrate. All creeks sampled here were blackwater. There were many pits and dug-out areas along the road that were created when it was built, with many of these now filled with water. These ranged from small (c. 1 m wide) pools to rather extensive (c. 30 m long) ponds. Many contained detritus, though few had any kind of vegetation.

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Collecting aquatic beetles at one of the streams within our Berbice River camp site.

Results and discussion

Summary of taxa. In total, we found 137 species of aquatic beetles in 55 genera (Table 7.1). The Berbice River camp had 100 species in 46 genera, while 78 species in 41 genera were found around the White Sands camp. In total, **we estimate two genera and at least 16 species are new to science, though this is a very conservative number and likely to increase as the material is studied in more detail.**

A NEW SPECIES OF HYDROPHILID ALSO REPRESENTING A NEW GENUS WAS COLLECTED FROM STREAM MARGINS AT THE BERBICE RIVER SITE

Table 7.1 **Aquatic beetle species richness among sites**

	# GENERA	# SPECIES	T
Berbice River camp	46	100	59
White Sands camp	41	78	37
TOTAL:	**55**	**137**	-

Habitats of note. While we encountered a relatively typical and diverse array of aquatic habitats, there were no particularly unusual niches. Stream margins proved fruitful for less common species, though many taxa were also found in the artificial roadside pools. The many artificially-created pools along the road around the White Sands camp were unusual, in that these kinds of habitats are typically rare to absent in undisturbed forest regions.

Taxa of note:

Dryopidae: Four new species of a new genus of Dryopidae were found at the Berbice River site, mostly in stream habitats.

Epimetopidae*:* We found three species of the relatively rare family Epimetopidae in sand bars at several creeks, some of which may represent new species.

Hydrophilidae*:* gen. nov. and sp. nov. A new genus and species of hydrophilid (subfamily Acidocerinae) was collected from stream margins at the Berbice River site. Though this undescribed genus has been found in the Guiana Shield region before, it is relatively uncommon.

Elmidae: The minute riffle beetle genus *Elachistelmis* was collected at the UV light at the White Sands camp. **This is the second known only collection of the genus, which was first found during the Rapid Assessment of the Kwamalasamutu Region in southwestern Suriname** (Maier 2012).

THIS IS THE SECOND KNOWN ONLY COLLECTION OF THE GENUS *ELACHISTELMIS*

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A new species of water scavenger beetle, in the family Hydrophilidae, which was found during the survey. It also represents a new genus!

Community dissimilarity. While the overall species richness we found was in line with prior surveys in the region, e.g. 144 aquatic beetle species were recorded in the nearby Kwamalasamutu region by Short and Kadosoe (2011), the differences in actual species composition between the White Sands and Berbice River camps was striking. Only 30% of the 137 species recorded were found at both camps, which is an extremely low level of overlap given the close proximity between the two areas. **Most notable was the common occurrence of taxa at the White Sands camp that typically to exclusively prefer more open marsh habitats or more disturbed habitats and which were completely absent from the Berbice River camp. In our experience, these particular species are also not typically collected in areas of intact forest in the Guiana Shield.**

For example, *Berosus megaphallus* has only ever been collected in open marsh habitat, and was present at White Sands in artificial pools but not the Berbice River camp, and the same is true for species of *Celina*, *Megadytes*, and *Pachydrus*. Among the five observed *Thermonectus* species, none occurred at both camps: *T. leprieuri* and *T. variegatus* were found in the forested Berbice River camp, while *T. circumscriptus*, *T. nobilis*, and *T. succinctus* were found in disturbed areas at the White Sands camp. The three White Sands species are known to occur in mostly open lentic habitats and have a high tolerance for disturbed areas, while the two Berbice River species are more rare and generally restricted to forested areas.

Based on these observations, **it seems likely that at least some of the faunal differences between the Berbice River and White Sands camps are due to the habitat changes caused by road construction, specifically the creation of open-canopy lentic habitats that are not normally present.** A few similar artificial lentic habitats were present at the Berbice River camp, but as the disturbance is only weeks old, the communities have not yet been affected.

IT SEEMS LIKELY THAT AT LEAST SOME OF THE FAUNAL DIFFERENCES BETWEEN THE BERBICE RIVER AND WHITE SANDS CAMPS ARE DUE TO THE HABITAT CHANGES CAUSED BY ROAD CONSTRUCTION, SPECIFICALLY THE CREATION OF OPEN-CANOPY LENTIC HABITATS THAT ARE NOT NORMALLY PRESENT

Conservation recommendations

Overall, the species richness and diversity of the Upper Berbice area surveyed during this expedition is similar to other comparable sites in the region (e.g. Short and Kadosoe 2011; Short 2013) given the habitats and collecting methods employed. The aquatic habitats in the sampled areas were relatively uniform, and consequently the raw totals of species may be lower than in areas where there is significantly higher niche diversity (e.g. the South Rupununi, Short et al. 2017).

Despite their relatively close proximity, the fauna communities between the two primary camps exhibited some sharp differences in species composition which is likely attributable to human-mediated habitat alterations. The construction of roads, which has generated many open-water pits and non-native aquatic habitats, has likely resulted in a change in community composition in regions that have been disturbed. While the species found at the White Sands camp in these disturbed habitats are native to coastal and savannah areas of Guyana, they would not otherwise be found in pristine Guyana Shield forest.

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CHAPTER 8

ANTS OF THE UPPER BERBICE RIVER, GUYANA

Michael G. Branstetter and Leeanne E. Alonso

Summary

We provide a preliminarily list of ant species surveyed from the Upper Berbice River, deep in the interior of Guyana. During the survey, 164 separate collections were made from three sites, and these consisted of hand collections, baiting samples, leaf-litter samples, a Malaise trap, and light trap samples. From the hand collections and bait samples only, a total of **78 ant species from 37 genera and 8 subfamilies are reported**. One additional subfamily and 10 additional genera are also reported from leaf-litter samples, which still need to be processed to the species level. **Among identified species, at least nine are new records for Guyana**. One non-native species, *Paratrechina longicornis*, was collected from disturbed habitat in the small, river town of Kwakwani. Although more work is needed to document the ants from the Upper Berbice River our preliminary assessment suggests that the area has a very diverse and healthy ant fauna that likely includes new species. Thus, **new logging and mining efforts in the area should be monitored with care** to help reduce negative impacts to an otherwise pristine insect fauna.

78 ANT SPECIES FROM 37 GENERA AND 8 SUBFAMILIES ARE REPORTED SO FAR FROM JUST TWO COLLECTING METHODS. ONE ADDITIONAL SUBFAMILY AND 10 ADDITIONAL GENERA ARE ALSO REPORTED FROM LEAF-LITTER SAMPLES, WHICH STILL NEED TO BE PROCESSED TO THE SPECIES LEVEL.

Introduction

AMONG IDENTIFIED SPECIES, AT LEAST NINE ARE NEW RECORDS FOR GUYANA

The ants (Insecta: Hymenoptera: Formicidae) comprise the largest and most successful group of social organisms on Earth. They include over 13,000 described species (Bolton 2017) and are found in nearly all terrestrial ecosystems. Where they occur, ants frequently have a disproportionately high biomass and they are often dominant as predators, scavengers, and indirect herbivores (Hölldobler and Wilson 1990). **Ants are also ecologically important ecosystem engineers, acting as seed dispersers, litter decomposers, and soil bioturbators**. Because of their diversity, abundance, and relative ease of sampling, **ants are a useful arthropod group for biomonitoring programmes aimed at detecting fine-grained biodiversity patterns** (Agosti 2000). Including ants in conservation studies provides a much-needed balance to what is most often a vertebrate-centric endeavour.

As with most insects, the ant fauna of Guyana, and the Guyana Shield in general, is extremely diverse yet poorly known. Based on previous survey efforts and literature reviews, the ant fauna of Guyana almost certainly includes more than 500 ant species (Kempf 1972; Fernández and Sendoya 2004; LaPolla et al. 2007) and might exceed 1,000 species. Fernández and Sendoya (2004) reported 3,100 ant species/subspecies for the Neotropical region and listed >340 species for Guyana. More recent species lists, available online, put the total diversity for Guyana at >500 species/subspecies (<www.antweb.org;>;< www.antmaps.org>).

THE ANT FAUNA OF GUYANA ALMOST CERTAINLY INCLUDES MORE THAN 500 ANT SPECIES, AND MIGHT EXCEED 1,000 SPECIES

Focused surveys of the Guyana ant fauna are few, but concerted efforts have started to accumulate over the last 20 years. The most comprehensive study by LaPolla et al. (2007) focused on leaf-litter ants in wet forest, sampling a total of 150 litter samples from eight sites. They reported a total of 230 litter ant species from 44 genera, providing a baseline dataset from which to compare leaf-litter ant diversity at other sites in Guyana. Extending this work are several recent rapid survey efforts conducted in collaboration with the World Wildlife Fund (WWF-Guianas). The first of these studies was carried out in the savannah areas of the southern Rupununi (Helms et al. 2016). The second study focused on the ants of Kaieteur Falls and the Upper Potaro River (Branstetter and Alonso 2017). The third study, which is presented here, **provides the first record of ants from lowland rainforest along the Upper Berbice River, deep in the interior lowlands of Guyana**. This report is preliminary in that only a subset of samples have been fully processed and sorted to species. In addition, a comprehensive attempt to update the list of species for Guyana is not attempted. However, a diverse set of species are reported for the sampling area and compared with a preliminary list from the Kaieteur region (see Appendix 8). Several new records are also reported for the country.

Study sites and methods

Study sites

We visited three geographically separated sites along the Upper Berbice River. Sites 1 and 2 were located within a recently designated logging concession.

Site 1 (20-25 September 2014). The Upper Berbice Camp 1 was located within the Bai-Shan-Lin logging concession approximately 120 km SSW of the small logging/mining town of Kwakwani and 6 km E of the Berbice River (GPS coordinates: 4.15396 -58.17729). Except for recently constructed roads, the area consisted of virgin tropical rainforest sitting on sandy soil substrate. Between the expedition campsite and the Berbice River, there were multiple wet and dry stream beds crossing the landscape. The forest had many tall trees with large buttress roots, indicating that it was mature rainforest. Nearby areas with sandier soils had smaller trees and more palms, transitioning into scrub and white sand savannah habitats.

Site 2 (26 September 2014). The Upper Berbice Camp 2 was located approximately 60 km north of the first site and 55 km SSE of Kwakwani (GPS coordinates: 4.75579 -58.00762). The site was accessible from the main road within the Bai-Shan-Lin logging concession. The camp bordered a recently burned forest, and a more pristine tropical forest that had a small black water creek running through it. The trees were much shorter than at site 1, likely due to the more nutrient-poor, white sand substrate.

Site 3 (20 September 2014). Kwakwani (GPS coordinates: 5.27385 -58.08104). A small village along the Berbice River. Habitat consisted mostly of disturbed scrub vegetation bordering the river. Surrounding vegetation included low tropical forest and savannah. Only a couple of hand collections were made at this site.

Methods

Over the approximately seven-day field expedition, we sampled ants using the following collection methods: leaf-litter sampling (miniWinkler transects, and maxiWinkler samples), baiting, Malaise trap, light trap, and hand collecting. A brief description of each sampling method is provided below. To date, all samples have been sorted to genus, but only the hand collections and baiting samples have been sorted to species. All collected specimens were put into 95% ethanol and later stored in -20C freezers to preserve tissues and DNA.

MiniWinkler transect: This is a quantitative method used to measure ant diversity in the leaf litter microenvironment. It is repeatable and can be used to compare ant diversity among sites. We employed a slightly modified version of the Ants of the Leaf Litter (ALL) protocol (Agosti et al. 2000). For each transect, we used a compass and tape measure to mark a straight-line transect of up to 195 m (40 samples). Samples were taken at 5 m intervals along the transect, each 1 m to the right of the line. For each sample we lightly chopped and sifted 1 m^2 of leaf litter. After collection, each litter sample was brought back to camp and hung in a miniWinkler extraction bag for three days. Falling arthropods were collected into bags containing 95% ethanol.

MaxiWinkler sample: This is a subjective, non-quantitative way to sample leaf litter ants. In general, a site was chosen and leaf litter was sifted for one to two hours from anywhere within a 10-20 m radius of the GPS point. We tried to maximize species capture by collecting leaf litter from as many different microhabitats as possible, e.g. at the base of trees, in open areas, in treefall gaps, at the base of logs, etc. After collection, samples were brought back to camp and hung in maxiWinkler extraction bags for three days.

Baiting transect: This is a quantitative method for surveying ground-dwelling ants. Baiting transects were performed by laying out 20 white 3 x 5 cards, each spaced at ~5 m intervals along the edge of trails. A pinch of crumbled Pecan Sandies cookie bait was sprinkled on top of each card and in nearby soil. The transect of cards was monitored for a period of two hours with all ant species from each card collected into separate vials.

Malaise trap: Malaise traps are small tent-like structures that catch flying insects. This method is useful for collecting winged, reproductive ants, as well as arboreal ants that fall from trees.

Light trap: Black lights attract a diversity of night flying insects, including winged ants. It is a useful method for collecting ant males and queens. A single light was haphazardly monitored for ants over the course of several nights.

Hand-collecting: This method simply involves searching for ants in the environment. We searched a variety of habitats including rotting logs, under leaves, in specialized ant plants, in living wood, under bark, in the ground, in mud banks, and in rotting and live sticks. Stray ants, complete ant colonies, and partial ant colonies were collected.

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Winkler extraction bags hanging at camp. Each bag contains several litres of sifted leaf-litter from the forest floor. As the litter dries, ants and other insects crawl out of the litter and fall into cups of alcohol at the bottom. The litter is suspended for up to three days and the method is extremely efficient at collecting rare insects.

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Winkler-Transect: Kwakwani field participants Johnny Rob and Kellon Austin sifting leaf-litter for ants and other cryptic insects along a transect line. The Winkler transect involves chopping and sifting $1m^2$ quadrats of forest floor leaf litter every 5 m along a straight line transect. The method is exceptionally efficient at collecting rare insects that are hard to find by eye.

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The team searched in these ant plants (family Melastomataceae) to collect ants. *Pheidole* sp. ants nest in the swollen leaf bases and forage on the hairy leaf surfaces for food. The plants are common throughout the rainforests of South America.

Results and discussion

At Site 1 (located within the Bai-Shan-Lin logging concession), which was sampled for the most amount of time, we made a total of 143 separate collection events, separated into 74 hand collections, 40 mini-Winkler samples, 5 maxi-Winkler samples, 20 bait collections (1 bait transect), 1 Malaise trap collection, and 3 light trap collections. At Site 2 (located approximately 60 km north of the first site and 55 km SSE of Kwakwani), which was sampled for less than one day, we made a total of 18 separate collection events, consisting entirely of hand collections. We visited Site 3 (a small village along the Berbice River) for only a few hours and made two hand collections.

At the time of writing this report, material was still being processed and identified to species. All samples have been sorted to genus, but only the hand collections and baiting samples have been completely processed, with all ants identified to species or morphospecies. A final accounting of species diversity awaits additional work.

Considering the Berbice sites together, we report 78 ant species from 37 genera and 8 subfamilies (see Appendix 8). Myrmicinae was the most diverse subfamily (Figure 8.1), and the three most diverse ant genera were *Pheidole* (11 species), *Camponotus* (9 species), and *Neoponera* (6 species) (Figure 8.2). We also report one additional subfamily (Proceratiinae) and 10 additional genera (*Acanthognathus, Carebara, Discothyrea, Ectatomma, Lachnomyrmex, Neocerapachys, Octostruma, Probolomyrmex, Rhopalothrix, Wasmannia*) from leaf-litter samples. Among the identified species, we report a minimum of nine species that are likely new records for Guyana (*Gnamptogenys pleurodon, Pheidole* cf. *flavens, Pheidole* cf. *glomericeps, Pheidole* cf. *triconstricta, Pheidole jelskii, Pheidole pugnax, Pheidole vafra, Anochetus micans, Leptogenys pubiceps*) (Figure 8.3). This is a minimum number of new records because many species have so far only been sorted to morphospecies. **New species are likely present within the genera *Pheidole* and *Camponotus* and within the unsorted leaf-litter samples**, but additional comparative work is needed before anything can be confidently reported.

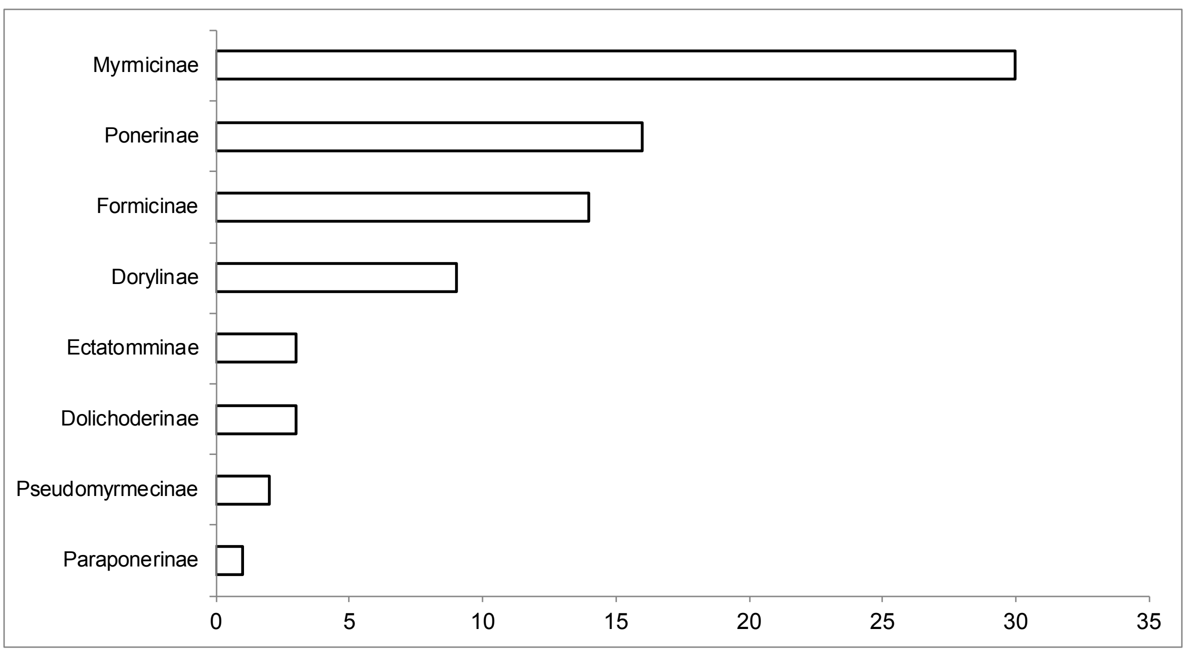

Figure 8.1 **Number of ant species by subfamily for all Berbice sites.**

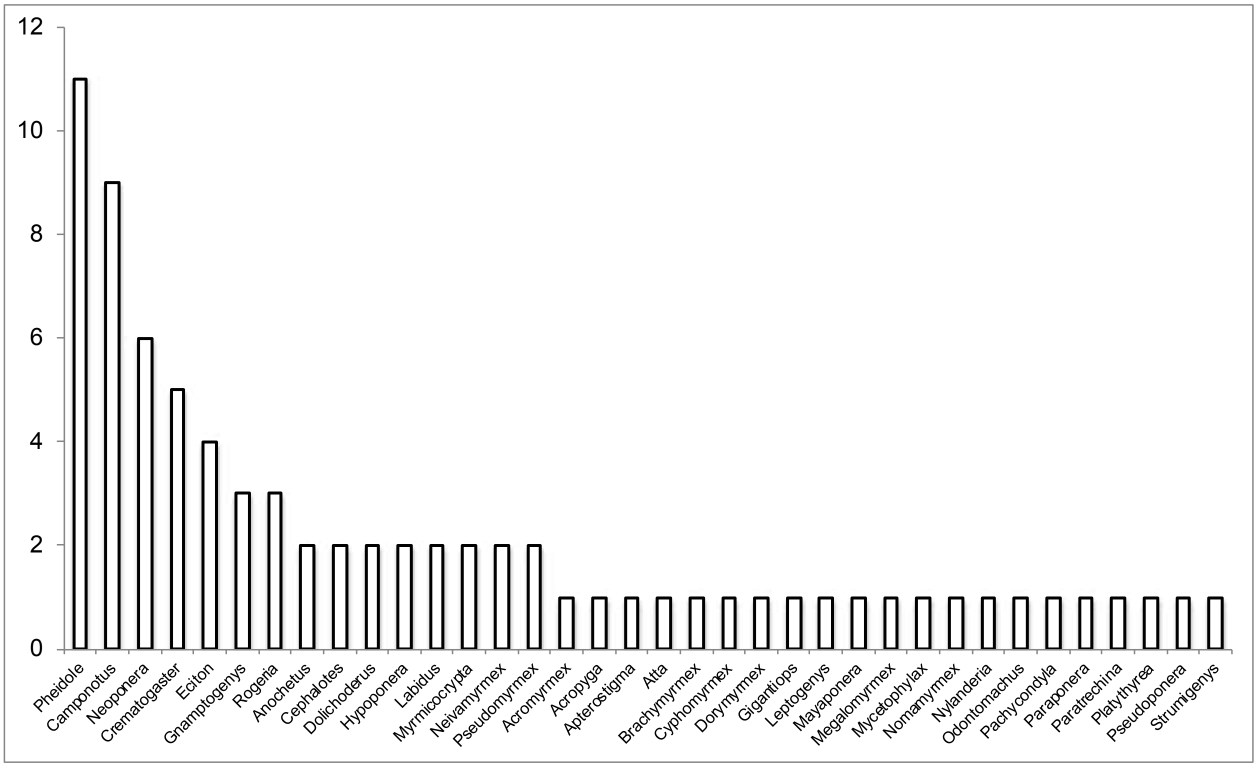

Figure 8.2 **Number of ant species by genus for all Berbice sites.**

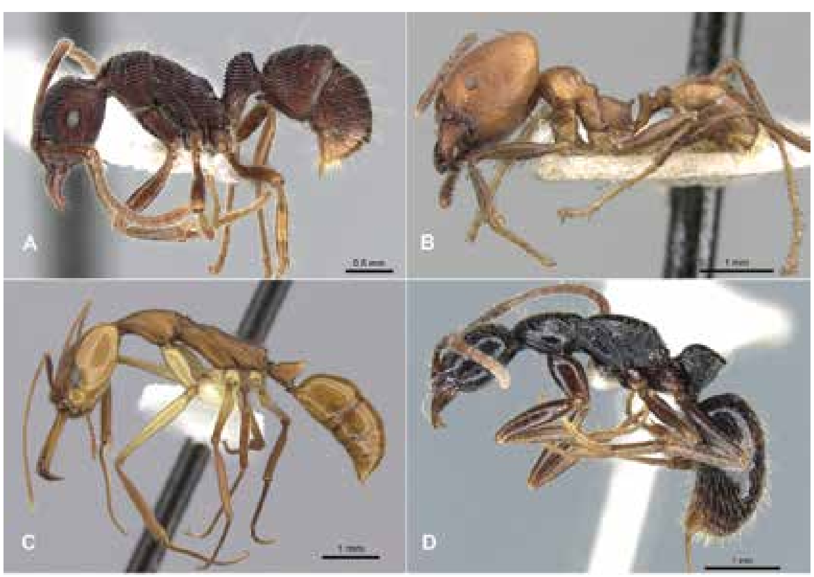

Figure 8.3 **Several examples of new country records for Guyana. A) *Gnamptogenys pleurodon* (imaged by: E. Ortega). B) *Pheidole pugnax* (imaged by: S. Hartman). C) *Anochetus micans* (imaged by: S. Hartman). D) *Leptogenys pubiceps* (imaged by: Z. Lieberman). All images from <www.antweb.org>.**

One non-native, introduced species was collected during the expedition from the town of Kwakwani. The species *Paratrechina longicornis*, known commonly as the "longhorn crazy ant," likely originated in the afrotropics, but has been spread around the world and is common in disturbed areas (Wetterer 2008). Given the disturbed habitat surrounding Kwakwani, it is not surprising that this species has been introduced there. No introduced species were found in the more pristine lowland rainforest areas, but given recent incursions by loggers, it is possible that invasions are now more likely.

For comparative purposes we provide an updated list to the ants of the Kaieteur Falls and Upper Potaro area, which was surveyed during the previous WWF-sponsored expedition (Branstetter and Alonso 2017) (see Appendix 8). For hand collections and bait samples from this survey, we found 165 species from 48 genera and 8 subfamilies, plus an additional 13 genera from litter samples (*Acanthognathus, Azteca, Carebara, Cryptopone, Discothyrea, Fulakora, Linepithema, Neocerapachys, Octostruma, Rhopalothrix, Tranopelta, Typhlomyrmex, Wasmannia*). Among these species, only 42 are shared between the Potaro and Berbice areas, leaving 36 species unique to the Berbice. This could either be a sampling artefact or a real pattern likely resulting from differences in elevation and/or habitat. The Potaro sites were all located above 400 m elevation, whereas the Berbice sites were all lowland at <150 m elevation. Better diversity comparisons will be made once all of the leaf litter samples have been processed to species.

Among the list of Berbice ants, we found an abundance of predatory army ants (Dorylinae), represented by nine species in the genera *Eciton, Labidus, Neivamyrmex,* and *Nomamyrmex*. Army ants play an important role as top predators in tropical ecosystems, and their nomadic hunting lifestyle and massive colonies require large territories. The presence of multiple species indicates large blocks of intact habitat, as well as the presence of adequate prey species. Additionally, the presence of many arboreal species (e.g. *Camponotus* spp., *Cephalotes* spp., *Pseudomyrmex* spp.), leaf litter species (e.g. *Apterostigma* spp., *Discothyrea* spp., *Lachnomyrmex* spp., *Rhopalothrix* spp., *Strumigenys* spp.), and specialized predatory species (*Hypoponera* spp., *Leptogenys* spp., *Odontomachus* spp., *Neoponera* spp., *Paraponera clavata*) is typical of healthy, diverse forests.

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Nest entrance of the dolichoderine ant *Dorymyrmex* sp. The nest was found in an area of recently burnt forest at the Upper Berbice Site 2. *Dorymyrmex* are common in open areas throughout the Neotropics.

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The hollow interior of a *Cecropia* sp. ant plant. *Cecropia* are specialized ant plants that provide ants with shelter and food in the form of glycogen-containing Müllerian bodies. Several species of *Azteca* ants are obligate inhabitants of *Cecropia*, but generalist species can also be found. *Cecropia* species are fast-growing plants with soft tissues that are commonly found in disturbed areas along rivers, in tree-fall gaps, or along roads. It is found throughout the Neotropical region.

Conservation recommendations

Given the high diversity of ants and the preliminary nature of the list presented here, no strong conservation recommendations can be made at this time. However, all Berbice sites, with the exception of Kwakwani, appeared to represent pristine lowland tropical forest with limited human impact. **The fact that these sites are currently being exposed to logging pressures, and possibly mining, should heighten concern about the long-term health of these areas.** Once all of the material collected in this study are processed and identified, it will be possible to assess whether there are species endemic to the region. **If such species are found, then more will need to be done to survey the fauna to ensure that continued resource extraction efforts will not lead to species extinction or endangerment.**

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We thank residents from the town of Kwakwani for helping with fieldwork, particularly Johnny Rob and Kellon Austin, who helped with ant sampling. We thank Rodolfo Probst and Jack Longino for help with ant identifications. We are also grateful to all of the staff of WWF-Guianas in Georgetown, Guyana for providing logistical support.

THE FACT THAT THESE SITES ARE CURRENTLY BEING EXPOSED TO LOGGING PRESSURES, AND POSSIBLY MINING, SHOULD HEIGHTEN CONCERN ABOUT THE LONG-TERM HEALTH OF THESE AREAS

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CHAPTER 9

DECAPOD CRUSTACEANS (CRABS AND SHRIMPS) AND WATER QUALITY OF THE UPPER BERBICE REGION, GUYANA

Cleverson R. M. dos Santos and Chetwynd Osborne

Summary

This BAT study presents a first look at the decapod crustacean community of the Upper Berbice region of Guyana. Nine species of decapod crustaceans, including four species of crabs and five species of shrimps were documented. A total of 168 individuals of crabs were collected, comprising three species from the Trichodactylidae family and one species from Pseudothelphusidae. In addition, 156 specimens of shrimps consisted of four species from the family Palaemonidae and one species from Euryrhynchidae. The crab *Valdivia serrata* (120 individuals) was the most abundant species collected. The shrimps, *Macrobrachium brasilense* (68 individuals), and *Palaemon carteri* (43 individuals), were next highest in abundance. **The species of crab *Microthelphusa* sp. is considered a new species record for Guyana.** Water quality at the surveyed sites of the Upper Berbice River (base camp 1) were (means, n=8): 28.9°C temperature, 44.4 µS/cm conductivity, and 4.31 mg/l dissolved oxygen (DO). Water quality at the single White Sand survey site (base camp 2) was: 26.40 °C temperature, 28.50 µS/cm conductivity, and 7.02 mg/l dissolved oxygen. Site 8 in the Upper Berbice River (base camp 1) area had the lowest DO value. More extensive sampling during different seasons is needed to fully document the species richness and ecology of decapod crustaceans, which will contribute to a sustainable management plan for aquatic resources of the area.

THE SPECIES OF CRAB *MICROTHELPHUSA* SP. IS CONSIDERED A NEW SPECIES RECORD FOR GUYANA

Introduction

Areas in and around the Upper Berbice River in eastern Guyana possess a diversity of habitats that sustain many groups of freshwater vertebrates and invertebrates. Since this area had not been previously accessible, it is considered a pristine site with much intact life, encompassing both terrestrial and freshwater biodiversity. Freshwater organisms include vertebrates, represented primarily by fishes, amphibians, and reptiles, as well as invertebrates, including insects, molluscs and decapod crustaceans (crabs and shrimps). Aquatic invertebrates in particular have a high richness in freshwater environments and exhibit complex patterns of biodiversity (Heino 2009).

AQUATIC INVERTEBRATE COMMUNITIES ARE EXCELLENT BIOINDICATORS BECAUSE THEY ARE SENSITIVE TO POLLUTION AND ABRUPT CHANGES IN THEIR ENVIRONMENT

Aquatic invertebrate communities are excellent bioindicators because they are sensitive to pollution and abrupt changes in their environment. Invertebrates used as bioindicators can be monitored to determine whether the community is changing over time due to natural or anthropogenic activities (Lenat 1988). Freshwater crustaceans are considered important predators, but are also key prey items for many animals, such as the crab-eating raccoon. In this way they are vital elements in the food chain of large rivers. Many species of crustaceans play a vital role in nutrient cycling, given their matter-energy exchange ability between trophic levels and between aquatic and terrestrial systems (Collins, Willner, and Giri 2007). Crustaceans are regularly used as bioindicators and biomonitors in various aquatic systems. They are a very successful group of animals, distributed in many habitats, and have varying responses to ecological perturbations (Rinderhagen, Ritterhoff, and Zauke 2000).

The knowledge of freshwater shrimps and crabs from Guyana is poor, particularly considering systematic and ecological studies. There are a few specific records for crabs (Magalhães and Rodríguez 2002; Santos, Osborne, and Benjamin 2017) and shrimps (Kensley and Walker 1982; Santos, Osborne, and Benjamin 2017), but no complete list of species for any site or for the country as a whole. **This study is the first inventory of decapod crustaceans of the Upper Berbice River.**

THIS STUDY IS THE FIRST INVENTORY OF DECAPOD CRUSTACEANS OF THE UPPER BERBICE RIVER

Materials and methods

The crustacean surveys were conducted over five days from 21 to 25 September 2014 within two survey areas. Eight sites were sampled around the Upper Berbice River (camp 1) (4° 09.241' N, 58° 10.627' W), where the streams were in dense as well as in sparse virgin forest. Areas of this nature are good for comparison with mining areas, since the only major anthropogenic activity that was taking place in this study site was logging. One site was sampled in the second area, the Upper Berbice White Sand (base camp 2) (4° 45.297' N, 58° 00.431' W) in the Corentyne River watershed, which was heavily impacted by logging. The single site surveyed was close to the base camp. This area comprised a lone whitewater creek, surrounded by sparse vegetation and a burnt-out patch of forest. Sample sites were the same as those of the fish team (see Chapter 6: Table 6.1; Figure 6.1).

Collections were made at various sites (four creeks[1] and five points along the Berbice River), with some being close together, while others were miles apart. The localities were accessed by means of trails, 4 x 4 trucks, and boats. The sampling effort at each sample point was approximately two hours. The survey was conducted in various creeks where some were downstream (1), upstream (2), and within logging sites; and in rivers where some were upstream (3), in the middle (1), and downstream (1), throughout the Upper Berbice River base camp 1 and Upper Berbice White Sand base camp 2 (Figure 9.1).

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Figure 9.1 **Sampling sites at the Upper Berbice base camp 1: sites 1 and 2 .**

[1]A creek is a narrow waterway that is a minor recess or tributary of a river.

Sampling was conducted using a net and/or sieve in shallow waters, capturing as many aquatic invertebrates as possible (Figure 9.2). Sampling was done for about 30 to 60 minutes on both sides of each creek and river, taking into consideration different microhabitats, including submerged leaves, rock, sand, and mud bottom types that were present. The samples were collected and preserved in ethanol to study in the laboratory for identification.

Figure 9.2 **Sampling methods used for decapod crustaceans during the BAT survey.**

The following abiotic variables were measured using two HACH multi-parameter probes, the HQd portable multimeter and the HQ40d portable multimeter: DO (dissolved oxygen, mg/l), conductivity (µS/cm) and water temperatures (°C). Other environmental aspects were also recorded, including water colour, vegetation type, bottom types, quantity of leaf litter, wind intensity, and other basic ecological data.

Decapod crustacean specimens required accurate examination of small systematic characters under a microscope for species identification. Decapod crustaceans were identified by genus and species using dichotomous keys from the literature (Kensley and Walker 1982; Rodriguez 1992; Rodriguez and Suarez 2004; Valencia and Campos 2007; Magalhães and Turkay 2008a; Magalhães and Turkay 2008b; Carvalho, Magalhães, and Mantelatto 2014; Pachelle and Tavares, 2018) and the reference collection from the Museu Paraense Emílio Goeldi, Pará, Brazil.

Results

Water quality

Table 9.1 shows the physicochemical water quality parameters recorded at each survey site. The means of the measured variables for the eight Upper Berbice River surveyed sites (base camp 1) were: 28.9°C Temperature, 44.4 µS/cm conductivity, and 4.31 mg/l dissolved oxygen (DO). The measured variables for the single Upper Berbice White Sand surveyed site (base camp 2) were: 26.40°C temperature, 28.50 µS/cm conductivity, and 7.02 mg/l dissolved oxygen. Site 8 in the Upper Berbice River base camp 1 area had the lowest DO value.

At the Upper Berbice River base camp 1, the substrates were mainly sandy, muddy or rocky bottom with accumulated leaves and roots in some places, providing a diversity of microhabitats for many macroinvertebrates. At the Upper Berbice River White Sand base camp 2, most of the substrates were sand and rock with leaves on the bottom, sometimes with mud.

Table 9.1 **Water quality parameters recorded at each survey site**

Key

Values in blue are the lowest recorded; values in green are the highest recorded.

Water Quality Variables	Upper Berbice River Base Camp 1 (WGS 84 UTM Zone 21 N)								Upper Berbice White Sand Base Camp 2 (WGS 84 UTM Zone 21 N)
Sites and UTM	S1 4.15648 -58.23227	S2 4.15648 -58.23227	S3 4.14845 -58.23366	S4 4.158283 -58.17705	S5 4.15655 -58.17733	S6 4.15655 -58.17733	S7 4.00648 -58.23227	S8 4.156483 -58.23226	S9 4.758317 -58.00535
Water temperature (°C)	28.9	28.9	25.8	28.9	28.9	28.9	31.4	30.3	26.4
Mean (°C)	28.9 ± 1.59								26.4
Conductivity (µS/cm)	50.4	50.4	35.9	50.4	34.0	34.0	50	50.1	28.5
Mean (µS/cm)	44.4 ± 8.11								28.5
Dissolved oxygen (mg/l)	2.78	2.78	7.01	2.78	6.78	6.78	3.01	2.59	7.02
Mean (mg/l)	4.31 ± 2.11								7.02

Species richness

During this rapid BAT survey of the Upper Berbice River region, 156 individuals representing five shrimp species were collected, including four species from the family Palaemonidae and one species of the family Euryrhynchidae. In addition, a total of 168 individuals from four crab species were documented, three from the family Trichodactylidae and one from Pseudothelphusidae. The data are not comprehensive enough to make comparisons between sites, especially since only one site was sampled at the White Sand base camp 2.

Table 9.2 **Decapod crustacean species documented at the two biodiversity assessment sites surveyed in the Upper Berbice River area**

				Number of individuals collected	
Group	Family	Genus	Species	Upper Berbice River Base Camp 1	Upper Berbice White Sand Base Camp 2
Crab	Pseudothelphusidae	*Microthelphusa*	sp.	5	
Crab	Trichodactylidae	*Sylviocarcinus*	*pictus*	32	
Crab	Trichodactylidae	*Valdivia*	*serrata*	120	2
Crab	Trichodactylidae	*Poppiana*	*dentata*	9	
Subtotal				166	2
Shrimp	Euryrhynchidae	*Euryrhynchus*	*wrzesniowskii*	5	
Shrimp	Palaemonidae	*Macrobrachium*	*brasiliense*	68	9
Shrimp	Palaemonidae	*Macrobrachium*	*amazonicum*	2	
Shrimp	Palaemonidae	*Macrobrachium*	*olfersii*		29
Shrimp	Palaemonidae	*Palaemon*	*carteri*	43	
Subtotal				118	38
Total				**284**	**40**

Species abundance

The crab, *Valdivia serrata,* had the highest species abundance (122 individuals) during the survey, followed by the shrimps *Macrobrachium brasiliense* (77 individuals) and *Palaemon carteri* (43 individuals). Likely due to the difference in sampling effort, the Upper Berbice River (base camp 1) had greater species abundance (n=284) than the Upper Berbice White Sand (base camp 2) (n=40). Across the nine sites surveyed between the Upper Berbice River base camp 1 and the Upper Berbice White Sand base camp 2, site 1 (S1) had the highest crustacean abundance, while site 4 (S4) had the lowest abundance (Figure 9.3). Shrimps and crabs varied in size, with some individuals measuring less than 10 mm and others reaching up to 100 mm. For crustaceans, all observations are considered notable due to this being the first inventory list for the upper Berbice River area.

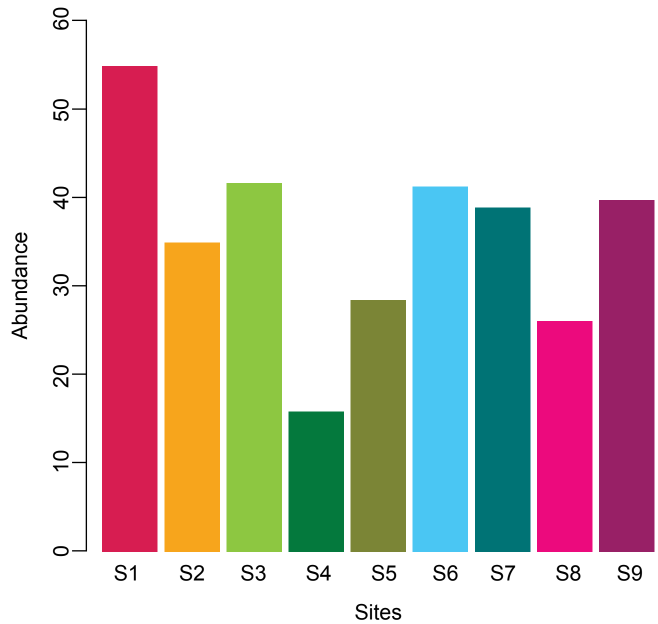

Figure 9.3 **Barplot of total species abundance across sites.**

Discussion

The Palaemonidae shrimp family is a minor representative group of decapods that successfully colonized estuaries, rivers, and oceans within the tropics and subtropics of the Americas (Kensley and Walker 1982). Palaemonid shrimps are always the most diverse shrimp group (Magalhães and Pereira 2007), and this diversity was evident for the upper Berbice region which consists of lowland tropical forest, peculiar white sand savannahs and shrublands, and several clear, black and white water creeks and rivers.

Species of the genus *Macrobrachium* play vital roles in aquatic ecosystems food chains, since they contribute in part to the diet of many turtles, fishes, aquatic birds, and mammals (Valencia and Campos 2007). Further, many of these shrimp species belonging to the Amazon basin forage on aquatic larvae of Plecoptera, Diptera, Trichoptera, and Ephemeroptera (Valencia and Campos 2007). Some species of the genus *Macrobrachium* have economic importance, and are native to the Indo-Pacific region (Valencia and Campos 2007). The trichodactylid showed a higher number of species in the upper Berbice region than the pseudothelphusids. This was expected since the former family is characteristically a lowland group, while the latter is typically a montane fauna (Magalhães and Pereira 2007). Pseudothelphusidae are a family of freshwater crabs which contribute in a major way to tropical medicine, since the majority of the species in this family act as secondary hosts for many species of lung flukes belonging to the genus *Paragonimus* (Rodríguez and Magalhães 2005). Further, in many rural communities of the Neotropics, these crabs are a food staple and play key roles within the food chains of the aquatic ecosystems (Rodríguez and Magalhães 2005). **This sort of interrelationship between crabs and other animal groups warrants the need for their conservation within Guyana and South America.**

EVEN THOUGH A WIDE VARIATION DOES NOT EXIST FOR CRAB AND SHRIMP SPECIES RICHNESS BETWEEN DIFFERENT AREAS IN GUYANA, GEOGRAPHY AND THE MAGNITUDE OF ANTHROPOGENIC ACTIVITIES ARE POSSIBLY INFLUENCING THE DISTRIBUTION OF CRABS AND SHRIMPS

The number of species of shrimps (5) and crabs (4) documented during this BAT survey is as was expected, considering the range of area sampled. For example, in all Amazonian Brazilian forest there are 23 species of shrimps and 22 freshwater crabs (Magalhães 2003). This survey recorded higher species richness and abundance of crabs compared to the survey of the Kaieteur Plateau and Upper Potaro, Guyana (dos Santos, Osborne, and Benjamin 2017), indicating that the microhabitats of the Upper Berbice River had higher food abundance to support a high composition of crabs. However, the abundance of shrimps for this Upper Berbice River survey was lower than the Kaieteur Plateau and Upper Potaro survey (Santos, Osborne, and Benjamin 2017), indicating that these latter microhabitats may have had a higher food abundance to support a high composition of shrimps. It should also be taken into consideration as well that the sampling effort in the Kaieteur-Upper Potaro region was also higher than that for the Upper Berbice region. Crustacean surveys conducted by Lasso et al. (2013) in the Upper Essequibo basin utilized similar methods to those used in surveys of the Kaieteur Plateau and Upper Potaro and Upper Berbice River. This sort of similar methodology may yield similar species richness among sites. However, crab and shrimp species richness varied between the BAT-surveyed areas and the Upper Essequibo Basin which had six (6) species of crabs and two (2) species of shrimps (Lasso et al. 2013). Assessments of the Guiana Shield Region have shown higher crab and shrimp species richness for the Amazon and Orinoco River Basin, as compared to the Suriname and Cuyuni River Basin. This high species richness was expected due to the size, age and heterogenic nature of these aquatic environments, as well as their long and complex geological history (Magalhães and Pereira 2007). **Even though a wide variation does not exist for crab and shrimp species richness between different areas in Guyana, geography and the magnitude of anthropogenic activities are possibly influencing the distribution of crabs and shrimps.**

All observations for crustaceans were considered notable, since this was the first inventory list for the upper Berbice River area. **Further, the specimens collected of the crab *Microthelphusa* were considered a new record for the Upper Berbice area. The genus *Microthelphusa* is distributed within the Guiana Shield, which is one of the most remote and unknown areas in the world (Cumberlidge 2007).** Species belonging to this genus are distributed in the highlands of eastern and western Venezuela, and western Guyana (Suárez 2006; Cumberlidge 2007). This sort of high-altitude distribution may in part account for the *Microthelphusa* sp. recorded for the upper

Berbice River survey. *Microthelphusa* sp. occupy habitats along the banks of streams where a lot of forest litter exists, and this sort of forest floor composition allows *Microthelphusa* sp. to act as detritivores and cycle nutrients for aquatic ecosystems (Cumberlidge 2007). The shrimp *Euryrhynchus wrzesniowskii* has an Amazonian River basin distribution, and has been reported from surface waters in Brazil, French Guyana, Guyana, and Suriname (Magalhães 1988; De Grave 2007). Additionally, *E. wrzesniowskii* occupies areas in leaf litter accumulated in small creeks and streams (De Grave et al. 2013). The Upper Berbice River base camp 1 had this sort of habitat composition, and this in part may account for the presence of *E. wrzesniowskii*. The IUCN Red List of Threatened Species considers *E. wrzesniowskii* as Least Concern (LC), since this species is widely distributed and does not face any major threats (De Grave et al. 2013). *E. wrzesniowskii* has the ability to reinforce the biological importance of estuaries by maintaining a regular flow of food, which facilitates the structuring of a complex food web (Nóbrega, Bentes, and Martinelli-Lemos 2013).

Water quality values were as expected for a healthy tropical river system (Lasso et al. 2013). Temperatures higher than 20 °C were enough to sustain a good freshwater biodiversity. Dissolved oxygen showed a general average of 4.31 mg/l which provides excellent support for aquatic life, and most of the creeks and rivers had values higher than 6.0 mg/l. The values of conductivity were normal for freshwater with a general average of 44.4 µS/cm. All these abiotic values were compared with parameters discussed by Mcdonald, Smart, and Wissmar (1991).

Conservation recommendations

The results from this rapid BAT survey of decapod crustaceans indicate that the habitat was healthy with good conditions for conservation. The high abundance of crabs as compared to the Kaieteur Plateau and Upper Potaro survey suggests a complex ecological network with interactions among micro and macro invertebrates and other vertebrate species.

The Guiana Shield region houses a diversified fauna of freshwater decapod crustaceans, constituted of several species belonging to two families of crabs (Pseudothelphusidae and Trichodactylidae), and four families of shrimps (Atyidae, Euryrhynchidae, Palaemonidae and Sergestidae) (Magalhães and Pereira 2007). This sort of species diversity was evident among sites surveyed within the Upper Berbice region and exemplifies conservation priorities for this region.

The results of this wet season BAT survey likely do not represent the complete richness of decapod crustaceans of these areas. More extensive sampling is required, including during the dry season, in order to reflect more accurately the abundance and the species richness at these sites. Sampling in different seasons will provide data on the ecology of these species to determine if some organisms have seasonal or year-round reproduction, and what roles they are playing in the ecosystem. Given the importance of decapod crustaceans as both predators and prey in freshwater ecosystems, these data will be useful for the development of a sustainable management plan for aquatic resources of the Upper Berbice River region. Moreover, continued biological and ecological studies will contribute to management actions for sustainable use and conservation of aquatic resources. The presence of a peculiar environment in the form of a pristine forest with much intact freshwater and terrestrial life would favour diversity of other crustacean groups.

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CHAPTER 10

VEGETATION IN THE BERBICE RIVER DRAINAGE, GUYANA

Santos Miguel Niño, Isaac Johnson and Zola Narine

Abstract

Plants were studied at two sites within the Upper Berbice River region in September 2014. From a collection of 218 plant specimens, a total of 89 species representing 77 genera and 45 families were identified. At Berbice Camp 1, the forest is multi-layered, with trees up to 40 m in height; lianas are common, while epiphytes, lichens and mosses are scarce. The upper layer forms a compact canopy that protects the soil; dominant trees include *Mora excelsa*, *Eschweilera* sp., *Aspidosperma excelsum* (yaruru), *Goupia glabra* (kabukalli) and *Swartzia leiocalycina* (wamara). The forest at the Berbice White Sands Camp 2 was very different from Camp 1. This forest grows on white sand soil and has three strata: canopy level (up to 20 m tall) dominated by dakama (*Dimorphandra conjugata*), a middle level dominated by soft wallaba (*Eperua falcata*), and a lower level with many turu palms or manoco (*Oenocarpus bacaba)*. Three plant species are new records for the Berbice region**. The forested areas of the Berbice River basin should be studied in much more detail, since several rare species were found in this preliminary study.**

THERE ARE STILL LARGE PARTS OF GUYANA THAT HAVE NOT BEEN STUDIED, PARTICULARLY IN THE LOWLANDS, AND THE ECOLOGICAL AND FUNCTIONAL ROLES OF GUYANA'S PLANT COMMUNITIES ARE POORLY UNDERSTOOD

Introduction

Plants form the basis of forests, and as primary producers they play an important part of any ecosystem (terrestrial and aquatic). Plants are also high in diversity - in the Neotropics more than 90,000 species of seed plants (approximately 35% of the world's species) have been documented (Antonelli and Sanmartín 2011). Floristic and plant communities in the Guiana Shield region have been studied independently in Brazil, Colombia and Venezuela (Anderson 1981; Boubi 2002; Clark et al 2000; Aymard et al 2009). In Guyana, the greatest effort to understand plant diversity has been made by the Smithsonian Institution USA (e.g. Kelloff and Funk 1998 and 2004; Funk et al. 2007) and by researchers from Utrecht University in the Netherlands (e.g. Jansen-Jacobs and ter Steege 2000). However, **there are still large parts of Guyana that have not been studied, particularly in the lowlands, and the ecological and functional roles of Guyana's plant communities are poorly understood.**

The upper and middle reaches of the Berbice River are poorly studied because there was no road access until very recently. At the time of this study, a new road was being built to facilitate activities within logging concessions recently granted by the government. Plant collections were made along this road during its construction, and from the forests along the shores of the Berbice River.

Methods and sites

Two sites were surveyed during this expedition: the Upper Berbice River camp, 4° 09.241' N, 58° 10.627' W and the Berbice White Sands camp, 4° 45.297' N, 58° 00.431' W. Surveys were carried out during 21 September to 1 October 2014.

Plant surverys were carried out using two methods: 1) walking two to three miles a day along forest trails, in forest areas around the campsites, and 2) sampling vegetation along the river banks from a boat, collecting all plant material only in the reproductive stage. Since there was no tree-climber, the method of sampling 1 ha plots, as was used in previous BAT assessments, was not done. Samples were prepared in newspapers with as many as four (4) duplicates per specimen, preserved with 75% ethanol, and transported in plastic bags. The botanical material was processed and is currently deposited in the Herbarium of the University of Guyana for species identification and distribution to other herbaria. The Angiosperm Phylogeny Group IV classification system was used for family designation.

Results

At the two sites in the Berbice River basin (Camps 1 and 2), a total of 218 plant collections were made. Table 10.1 shows the sites, their respective coordinates and the total number of collections.

Table 10.1 **Summary of plant collection results**

SITE	COORDINATES	COLLECTED PLANTS
Berbice Camp 1	4° 09.241' N, 58° 10.627' W	
Berbice Camp 2	4° 45.297' N, 58° 00.431' W	
Total for both camps:		**218**

From these collections, a total of 89 species representing 77 genera and 45 families were identified. The most abundant family was Fabaceae which includes plants known as legumes. Rubiaceae, Arecaceae, and Cyperaceae followed in abundance and represent an important indicator of the dominant diversity at the sites visited. Appendix 10 shows the list of vascular plants collected.

Vegetation and floristic aspects of the Berbice sector

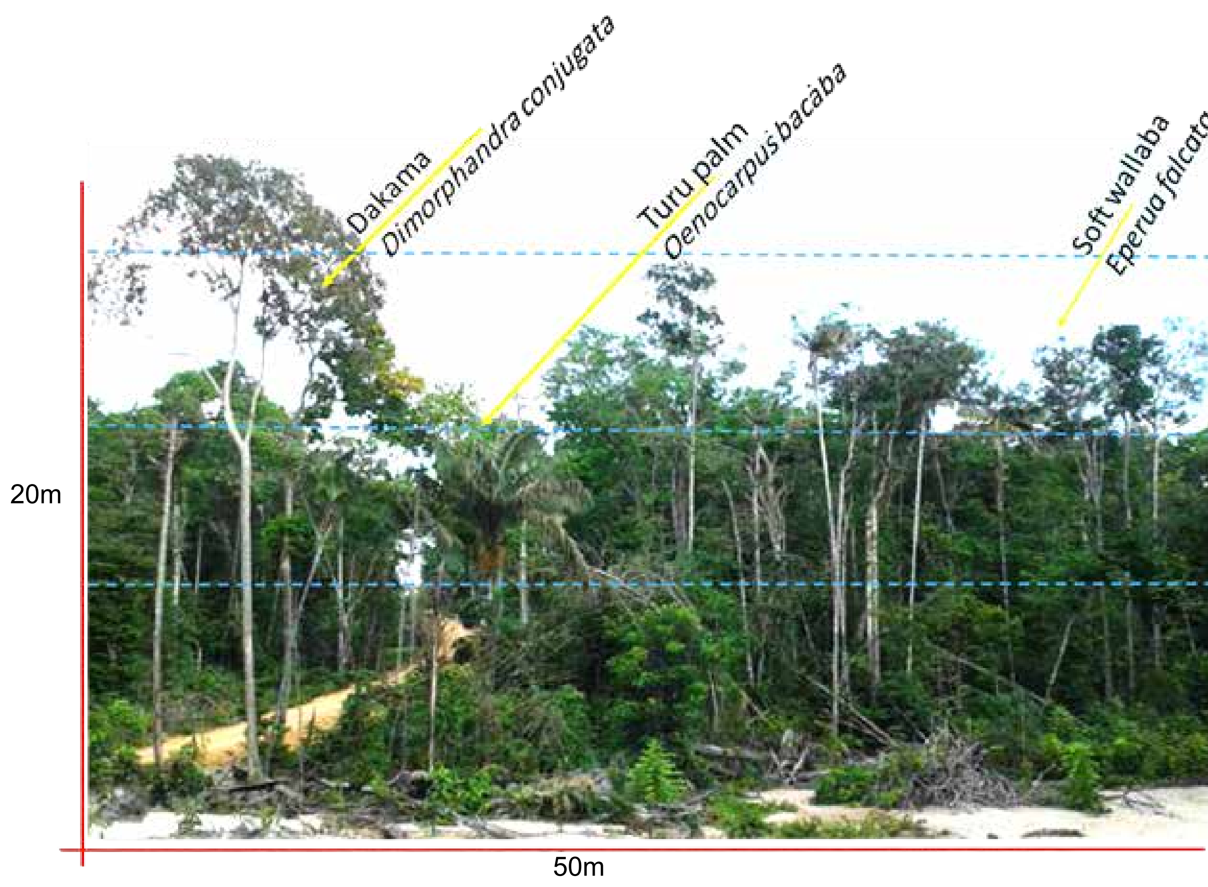
The Berbice River basin consists of forests, classified as evergreen macrothermic ombrophilous (Huber et al. 1995), most of them set on white sands. [Macrothermic: mean annual temperature always > 24ºC. Ombrophilous: mean annual rainfall 1,500 – 2,500 mm, maximum three dry months with <50 mm/month; Zinck et al. 2011]. Until now their structure and diversity was unknown (Huber et al. 1995).

Camp 1 was established in the southern part of the basin, where there is a multilayered forest, with trees up to 40 m in height (Polak 1992). Lianas are common, while epiphytes, lichens and mosses are scarce. The upper layer forms a compact canopy that protects the soil; dominant trees are *Mora excelsa*, *Eschweilera* sp., *Aspidosperma excelsum* (yaruru), *Goupia glabra* (kabukalli) and *Swartzia leiocalycina* (wamara). Other trees include *Bactris elegans*, *Bactris* sp., *Astrocaryum sciophylum*, *Attalea regia, Socratea exorrhiza*, and at least three species of *Geonoma*, and a wide variety of palms, many with thorns. Some epiphytes and climbers were collected, including *Prostechea aemula*, *Tillandsia* sp., *Vanilla* sp., *Ipomoea* sp., and *Monstera adansonii*, among others.

PROSTECHEA AEMULA, AN ORCHID, IS INCLUDED IN APPENDIX II OF CITES (2017) AS REQUIRING SPECIAL CONSIDERATION FOR PROTECTION

The forest at the Berbice White Sands Camp 2 had three strata: a canopy level (up to 20 m tall) dominated by dakama (*Dimorphandra conjugata*); a middle level dominated by soft wallaba (*Eperua falcata*), and a lower level with many turu palms (manoco) (*Oenocarpus bacaba)*. The strata of the forest indicated that it was a disturbed/ secondary forest, since *Dimorphandra conjugata* dominated the canopy level. In an undisturbed state, *Eperua falcata* would be the dominant species.

Soft wallaba seems to prefer extreme soil types – from very wet soils to dry soils but is usually considered a generalist species. It is often dominant on white sand soils. The soil within the forest is organic matter with many leaves and roots that can reach up to 0.5 m deep. (Figure 10.1.)



Forest in geologic formation of white sands in the Berbice River Basin: has 3 levels or strata. Medium height trees dominate (up to 20 m). The soil is organic matter that can be up to 0.5 m deep.

Figure 10.1 **Schematic of a disturbed forest structure at the Berbice White Sands Camp 2.**

***Prostechea aemula*, an orchid, is included in Appendix II of CITES (2017) as requiring special consideration for protection.**

Cedrela odorata, Pterocarpus santalinoides, and *Hymenaea courbaril* are forestry species currently utilized for their wood. These are common in the Berbice River basin and are given special protection in Venezuela and Colombia, where they are included in the Red Data Book as vulnerable because of the danger of over-harvest (Llamozas et al. 2003).

IT IS VERY LIKELY THAT NEW SPECIES RECORDS WILL BE FOUND AMONG THE SPECIMENS COLLECTED THAT ARE YET TO BE IDENTIFIED

New records for the region

In Table 10.2 the species that represent new records for the Berbice River region are listed. It is possible that there are additional new species records among the still unidentified specimens that remain in the herbarium in the Centre for the Study of Biological Diversity at the University of Guyana.

Table 10. 2 **Botanical novelties for the Berbice Region**

COLLECTION NUMBER	SPECIES	REGION
4784	*Heliconia stricta* (new for region)	Berbice
4791	*Calathea legrelleana* (new for region)	Berbice
4866	*Chamissoa* sp. (new for country)	Berbice

Interesting Species

Oenocarpus bacaba: A palm tree, 15-20 m tall, that grows on land prone to flooding. In sandy soil forests, it is dominant and forms dense colonies. Its fruits are food for many species of toucans, and for the fishes of the region's rivers and streams.

Eperua falcata: A tree in the legume group that grows up to 25 m in height. Its flowers are a favourite of many species of parrots and macaws. The fruits are consumed by herbivores, especially mammals, including monkeys and deer.

Recommendations

The forested areas of the Berbice River basin should be studied in much more detail, since several rare species were found in this preliminary study**. If deforestation is allowed to occur in in these forests, it will change the forest structure and surely cause irreversible damage to local biodiversity. Even selective logging involves the removal of a high diversity of climbers along the tops of the tall trees from the canopy of these forests. The epiphyes, though not abundant, are very poorly studied, and their role in the dynamics of the forest are virtually unknown.**

IF DEFORESTATION IS ALLOWED TO OCCUR IN THESE FORESTS, IT WILL CHANGE THE FOREST STRUCTURE AND SURELY CAUSE IRREVERSIBLE DAMAGE TO LOCAL BIODIVERSITY

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Appendix 1a

Checklist of Odonates recorded during the Upper Berbice River Region Biodiversity Assessment Team (BAT) Expedition

Key

Square brackets after each family [number of genera/number of species recorded].

Species in bold: new records for Guyana at the time the survey took place.

Relative abundance per site: R (rare = 1-3 specimens seen); F (frequent = 4-20 specimens seen); C (common = 21-50 specimens seen).

Incidence: Number of sites where each species was recorded.

Sites	Upper Berbice Region																	Incidence
	Berbice River Camp							Berbice White Sands Camp										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Taxa																		
Zygoptera																		
Calopterygidae [2/3]																		
Hetaerina caja dominula Hagen in Selys, 1853					R	R			R		R							4
Hetaerina moribunda Hagen in Selys, 1853 (Fig. 1.4)									F	F	R	F	F		R		R	7
Mnesarete cupraea (Selys, 1853) (Fig. 1.5)									F		F		F		R		R	5
Coenagrionidae [10/22]																		
Acanthagrion apicale Selys, 1876																R		1
Acanthagrion indefensum Williamson, 1916				C		C												2
Acanthagrion rubrifrons Leonard, 1977									F		R							2
Argia deceptor Garrison & von Ellenrieder, 2015								R										1
Argia fumigata Hagen in Selys, 1865			F		F		F		F		R		F		R	R	R	9
Argia gemella Garrison & von Ellenrieder, 2015 (Fig. 1.6)								F		R								2
Argia meioura Garrison & von Ellenrieder, 2015 (Fig. 1.7)									R		R	F			R	R	F	6
Argia oculata Hagen in Selys, 1865									R									1
Epipleoneura capilliformis (Selys, 1886) (Fig. 1.8)									C		F		F			R	F	5
Mecistogaster linearis (Fabricius, 1776)												R						1
Mecistogaster lucretia (Drury, 1773)																	R	1
Metaleptobasis brysonima Williamson, 1915												R						1

Sites	Upper Berbice Region																	Incidence
	Berbice River Camp							Berbice White Sands Camp										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Taxa																		
Neoneura bilinearis Selys, 1860				F		F												2
Neoneura denticulata Williamson, 1917						F												1
Neoneura mariana Williamson, 1917									R		R						R	3
Neoneura myrthea Williamson, 1917				F														1
Neoneura rubriventris Selys, 1860				F		F												2
Phasmoneura exigua (Selys, 1886) (Fig. 1.9)								F			F	R					F	4
Protoneura calverti Williamson, 1915											R							1
Protoneura paucinervis Selys, 1886				F		F												2
Psaironeura tenuissima (Selys, 1886)								F			R							2
Telebasis simulata Tennessen, 2002														F				1
Dicteriadidae [1/1]																		
Heliocharis amazona (Selys, 1853) (Fig. 1.10)									R		F	R	R			R	R	6
Perilestidae [1/1]																		
Perilestes attenuatus Selys, 1886									R								R	2
Megapodagrionidae [2/4]																		
Heteragrion icterieum Williamson, 1919 (Fig. 1.11)									F		F						F	3
Heteragrion silvarum Sjöstedt, 1918									R									1
Oxystigma cyanofrons Williamson, 1919 (Fig. 1.12)								F	F						F		F	4
Oxystigma petiolatum (Selys, 1862) (Fig. 1.13)												R						1
Anisoptera																		
Aeshnidae [1/2]																		
Gynacantha membranalis Karsch, 1891									R							R		2
Gynacantha nervosa Rambur, 1842	R																	1

Appendix 1a

Checklist of Odonates recorded during the Upper Berbice River Region Biodiversity Assessment Team (BAT) Expedition (*cont'd*)

Sites	Upper Berbice Region																	Incidence
	Berbice River Camp							Berbice White Sands Camp										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Taxa																		
Gomphidae [4/5]																		
Archaeogomphus hamatus (Williamson, 1918)													R					1
Desmogomphus tigrivensis Williamson, 1920									R									1
Phyllogomphoides atlanticus Belle, 1970			R															1
Phyllogomphoides undulatus (Needham, 1944)						F												1
Zonophora batesi Selys, 1869 (Fig. 1.14)									R								R	2
Libellulidae [18/34]																		
Diastatops pullata (Burmeister, 1839)				F		F												2
Dythemis nigra Martin, 1897	R	R	F				R							R				5
Elasmothemis williamsoni (Ris, 1919)									F			R				F		3
Elga leptostyla Ris, 1909													R					1
Erythemis haematogastra (Burmeister, 1839)		F				F												2
Erythemis vesiculosa (Fabricius, 1775)	R													R				2
Erythrodiplax amazonica Sjöstedt, 1918 (Fig. 1.15)								F	F		R				R			4
Erythrodiplax castanea (Burmeister, 1839) (Fig. 1.16)									F		C			R				3
Erythrodiplax fusca (Rambur, 1842) (Figs. 1.17, 1.18)		F							F	F	F	F		F	R		R	8
Erythrodiplax umbrata (Linnaeus, 1758)	R	R							R									3
Gynothemis pumila (Karsch, 1890)									R									1
Macrothemis sp. (teneral)												R						1
Miathyria simplex (Rambur, 1842)						R												1
Micrathyria artemis Ris, 1911				R		F								R				3
Micrathyria atra (Martin, 1897) (Fig. 1.19)		F													R		R	3
Micrathyria catenata Calvert, 1909									R					R				2
Micrathyria pseudeximia Westfall, 1992		R									F							2

Sites	Upper Berbice Region																	Incidence
	Berbice River Camp							Berbice White Sands Camp										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Taxa																		
Libellulidae [18/34]																		
Misagria bimacula Kimmins, 1943															R			1
Nephepeltia phryne (Perty, 1833)		R																1
Oligoclada abbreviata (Rambur, 1842)						R					R							2
Oligoclada amphinome Ris, 1919 (Fig. 1.20)									R		F				R		R	4
Oligoclada pachystigma Karsch, 1890				F		C												2
Orthemis aequilibris Calvert, 1909 (Fig. 1.21)									R		F				F		R	4
Orthemis biolleyi Calvert, 1906									R		F							2
Orthemis cultriformis Calvert, 1899									R									1
Orthemis discolor (Burmeister, 1839)	R	R			F					R	F	R		F				7
Orthemis schmidti Buchholz, 1950 (Fig. 1.22)				R	R						F			F				4
Pantala flavescens Fabricius, 1798	F													R				2
Perithemis cornelia Ris, 1910				R	R	R												3
Perithemis lais (Perty, 1833)			R	F							R				F		F	5
Perithemis mooma Kirby, 1889 (Fig. 1.23)	R	R							R		F		R					5
Perithemis thais Kirby, 1889			F		F							R						3
Tramea binotata (Rambur, 1842)											R							1
Zenithoptera fasciata (Linnaeus, 1758)												R						1
Species Richness per Site	7	9	5	11	6	14	2	6	29	4	26	13	8	10	12	7	18	
Shannon Diversity per Site	1.95	2.2	1.61	2.40	1.79	2.64	0.69	1.79	3.37	1.39	3.26	2.57	2.08	2.30	2.49	1.95	2.89	
Simpson Diversity per Site	0.86	0.89	0.80	0.91	0.83	0.93	0.50	0.83	0.97	0.75	0.96	0.92	0.88	0.90	0.92	0.86	0.94	
Species Richness per area	31 (Chao2 = 35.45)							57 (Chao2 = 83.32)										
Species Richness of surveyed Region	72 (Chao2 = 87.29)																	

Appendix 1b

Odonates found during the Upper Berbice Biodiversity Assessment Team Expedition: Habitat where found, data on known larvae, distribution (from Paulson 2015 and material examined), and conservation status according to IUCN Red List

__Key__

In bold: new records for Guyana at the time the survey took place.

Distribution: AMZ: Guianan and Amazonian; GUI: Guianan; NEO: widespread in the Neotropical region.

Country codes in parenthesis:

AR: Argentina, BE: Belize, BO: Bolivia, BR: Brazil, CA: Canada, CO: Colombia, CR: Costa Rica, EC: Ecuador, FR: French Guiana, GU: Guatemala, GY: Guyana, ME: Mexico, NI: Nicaragua, PA: Panama, PE: Peru, PY: Paraguay, SU: Suriname, TR: Trinidad/Tobago, US: United States, VE: Venezuela.

IUCN category: LC: Least Concern.

Species	Habitat	Larva described	Distribution	IUCN
Zygoptera				
Calopterygidae				
Hetaerina caja dominula	creeks/ river	Geijskes 1943	GUI (VE, GY, SU, FR, BR)	-
Hetaerina moribunda	creeks	Geijskes 1943 by supposition	GUI (VE, GY, SU, FR, BR)	-
Mnesarete cupraea	creeks	-	AMZ (VE, GY, SU, FR, PE, BO)	-
Coenagrionidae				
Acanthagrion apicale	creeks	De Marmels 1992	NEO (CO, VE, GY, FR, BR, EC, PE, BO)	-
Acanthagrion indefensum	river	Geijskes 1943	GUI (VE, GY, SU, FR, BR)	-
Acanthagrion rubrifrons	creeks	-	GUI (VE, GY, SU, FR, BR)	-
Argia deceptor	flooded forest	-	GUI (GY, SU, FR)	-
Argia fumigata	creeks	-	AMZ (VE, GY, SU, FR, BR, EC)	-
Argia gemella	creeks	-	GUI (GY, SU, FR, BR)	-
Argia meioura	creeks	-	GUI (VE, GY, SU, FR, BR)	-
Argia oculata	creeks	Limongi 1983 (1985)	NEO (ME to BO, GY)	-
Epipleoneura capilliformis	creeks	-	AMZ (GY, BR)	LC
Mecistogaster linearis	trail	Sahlén and Hedström 2005	NEO (NI to BR, BO)	-
Mecistogaster lucretia	trail	-	NEO (CO, VE, GY, SU, FR, BR, EC, PE, AR)	-
Metaleptobasis brysonima	creeks	-	AMZ (TR, VE, GY, SU, FR, BR, PE, BO)	-
Neoneura bilinearis	river	-	AMZ (VE, GY, SU, BR, PE)	-
Neoneura denticulata	river	-	AMZ (VE, GY, SU, EC, PE, BR)	-
Neoneura mariana	creeks	-	GUI (VE, GY, SU, FR)	-
Neoneura myrthea	river	-	AMZ (VE, GY, SU, FR, BO)	-
Neoneura rubriventris	river	-	AMZ (VE, GY, SU, EC, PE, BR)	-
Phasmoneura exigua	flooded forest/ creeks	-	AMZ (GY, SU, FR, PE, BR)	-
Protoneura calverti	creeks	-	GUI (VE, TR, GY, SU, FR, BR)	LC
Protoneura paucinervis	river	-	AMZ (VE, GY, BR, EC, PE)	-

Species	Habitat	Larva described	Distribution	IUCN
Telebasis simulata	pools	Geijskes 1943 as *T. sanguinalis*	GUI (VE, TR, GY, SU, FR, BR)	-
Dicteriadidae				
Heliocharis amazona	creeks	Geijskes 1986, Santos and Costa 1988	NEO (Co, VE, to PY, AR)	-
Perilestidae				
Perilestes attenuatus	river	Neiss & Hamada 2010	AMZ (VE, GY, SU, FR, BR, PE, BO)	LC
Megapodagrionidae				
Heteragrion ictericum	creeks/trail	-	GUI (VE, GY, SU, FR, BR)	-
Heteragrion silvarum	creeks	-	GUI (GY, SU, FR, BR)	-
Oxystigma cyanofrons	creeks/trail	Geijskes 1943 as *O. petiolatum*	GUI (VE, GY, SU, FR)	-
Oxystigma petiolatum	trail	-	AMZ (VE, GY, SU, FR, BR, EC)	LC
Anisoptera				
Aeshnidae				
Gynacantha membranalis	trail	Santos, Costa and Pujol-Luz 1987	NEO (NI to BO, BR)	-
Gynacantha nervosa	trail	Williams 1937	NEO (SE US, Antilles, to Bolivia)	LC
Gomphidae				
Archaeogomphus hamatus	creeks	-	AMZ (CO, GY, SU, BR)	-
Desmogomphus tigrivensis	creeks	Belle 1970, 1977	GUI (VE, GY, FR, BR)	-
Phyllogomphoides atlanticus	creeks	-	GUI (GY, SU, FG)	-
Phyllogomphoides undulatus	river	Belle 1970 by supposition	GUI (VE, GY, SU, FR, BR)	-
Zonophora batesi	creeks	Belle 1966	GUI (VE, GY, SU, FR, BR)	-
Libelullidae				
Diastatops pullata	river	Fleck 2003	NEO (VE, GY, SU, FR, BR, EC, PE, BO, AR)	LC
Dythemis nigra	creeks	De Marmels 1982, Westfall 1988, as *D. multipunctata*	NEO (ME to AR)	-
Elasmothemis williamsoni	creeks	Westfall 1988	AMZ (GY, SU, FR, PE)	-
Elga leptostyla	creeks	De Marmels 1990, Fleck 2003	NEO (PA to PE)	-
Erythemis haematogastra	pools	-	NEO (ME, BE to BR, PE)	LC
Erythemis vesiculosa	pools	Klots 1932, Needham and Westfall 1955	NEO (S US, Antilles, to AR)	LC
Erythrodiplax amazonica	flooded forest/ creeks	De Marmels 1992	AMZ (VE, TR, GY, SU, FR, BR, PE)	-
Erythrodiplax castanea	creeks/ pools	-	NEO (GU to AR)	-
Erythrodiplax fusca	pools/ creeks	Santos 1967	NEO (ME to AR)	-

Appendix 1b

Odonates found during the Upper Berbice Biodiversity Assessment Team Expedition: Habitat where found, data on known larvae, distribution (from Paulson 2015 and material examined), and conservation status according to IUCN Red List (*cont'd*)

Species	Habitat	Larva described	Distribution	IUCN
Erythrodiplax umbrata	pools	Calvert 1928, Costa, Vieira and Lourenço 2001	NEO (ME to AR)	-
Gynothemis pumila	creeks	Fleck 2004	AMZ (CO, VE, TR, GY, SU, FR, BR, PE)	LC
Macrothemis sp.	creeks			
Miathyria simplex	pools	Limongi 1991	NEO (ME to PE, BR)	-
Micrathyria artemis	pools	Santos 1972	NEO (VE, GY, SU, FR, BR, EC, PE, AR)	LC
Micrathyria atra	pools	Santos 1978	NEO (ME to AR)	LC
Micrathyria catenata	pools	-	NEO (CR to AR)	LC
Micrathyria pseudeximia	pools	-	NEO (GU to AR)	-
Misagria bimacula	creeks	-	GUI (VE, GY)	LC
Nephepeltia phryne	pools	De Marmels 1990	NEO (BE to AR)	LC
Oligoclada abbreviata	river/creeks	Machado and Machado 1993, Fleck 2003	AMZ (VE, GY, SU, FR, BR)	LC
Oligoclada amphinome	creeks	-	GUI (VE, GY, SU, FR, BR)	-
Oligoclada pachystigma	river	-	GUI (VE, GY, SU, FR, BR)	-
Oligoclada walkeri	river	-	AMZ (VE, TR, GY, SU, FR, BR, EC, PE)	-
Orthemis aequilibris	clearing/ pools	Fleck 2003	NEO (CR to AR)	-
Orthemis biolleyi	creeks	Fleck 2003	NEO (BE to BO)	LC
Orthemis cultriformis	clearing/ pools	Carvalho and Werneck de Carvalho 2005	NEO (CR to AR)	-
Orthemis discolor	clearing/ pools	-	NEO (ME to AR)	-
Orthemis schmidti	clearing/ pools	-	NEO (GU to BO, BR)	-
Pantala flavescens	clearing/ pools	Geijskes 1934	Circumtropical, in New World NEO (CA to AR)	LC
Perithemis cornelia	creeks/ pools/ river	-	AMZ (VE, GY, BR, PE, BO)	LC
Perithemis lais	creeks/ pools	Costa & Regis 2005	NEO (CO to AR)	LC
Perithemis mooma	creeks/pools	Santos 1973, von Ellenrieder and Muzón 1999	NEO (ME to AR)	-
Perithemis thais	creeks	Spindola et al. 2001	NEO (CR to AR)	-
Tramea binotata	clearing	Needham et al. 2000	NEO (ME to AR, GY)	-
Zenithoptera fasciata	pools	-	NEO (CR to BR)	LC

Appendix 2

Amphibians and reptiles recorded during BAT Survey

<u>Key</u>

General geographic distribution: AGR: Amazo-Guianan sub-region; **GS**: Guiana Shield; **W**: Widespread

IUCN threat status: CD: Conservation Dependent; **LC**: Least Concern; **LR**: Lower Risk; **NE**: Not Evaluated

CITES status:

Appendix I: species threatened with extinction which are or may be affected by trade

Appendix II: species not necessarily now threatened with extinction but may become so unless trade in specimens of such species is subject to strict regulation; and other species which must be subject to regulation.

		Per Locality		**Distribution**	**IUCN Threat Status**	**CITES Status**
Taxon	**cf.?**	**Berbice River Camp**	**White Sands Camp**			
Amphibia-Anura (20 species total)		**16**	**7**			
Aromobatidae						
Allobates femoralis		**x**		AGR	LC	Appendix II
Bufonidae						
Rhaebo guttatus		**x**		AGR	LC	
Rhinella marina			**x**	W	LC	
Rhinella martyi		**x**		GS	LC	
Dendrobatidae						
Ameerega trivitatta		**x**		AGR	LC	Appendix II
Hylidae						
Boana boans		**x**	**x**	AGR	LC	
Boana calcarata		**x**				
Boana crepitans			**x**			
Boana geographica			**x**	AGR	LC	
Osteocephalus leprieurii		**x**		AGR	LC	
Osteocephalus taurinus			**x**	AGR	LC	
Phyllomedusa bicolor		**x**		AGR	LC	
Trachycephalus resinifictrix		**x**	**x**	AGR	LC	
Leptodactylidae						
Adenomera andreae		**x**		W	LC	
Leptodactylus guianensis		**x**		W	LC	
Leptodactylus knudseni		**x**	**x**	W	LC	
Leptodactylus mystaceus		**x**		AGR	LC	
Leptodactylus petersii		**x**		AGR	LC	

Appendix 2

Amphibians and reptiles recorded during BAT Survey (*cont'd*)

		Per Locality		**Distribution**	**IUCN Threat Status**	**CITES Status**
Taxon	**cf.?**	**Berbice River Camp**	**White Sands Camp**			
Amphibia-Anura (20 species total)		**16**	**7**			
Pipidae						
Pipa pipa		**x**		W	LC	
Strabomantidae						
Pristimantis zeuctotylus		**x**		AGR	LC	
REPTILIA (33 species total)		**25**	**14**			
CROCODYLIA (2 sp.)						
Alligatoridae						
Melanosuchus niger		**x**		W	LR/CD	Appendix I & II
Paleosuchus palpebrosus		**x**	**x**	W	LR/CD	Appendix I & II
SQUAMATA-GEKKOTA (2 sp.)						
Sphaerodactylidae						
Gonatodes humeralis		**x**		W	NE	
Phyllodactylidae						
Thecadactylus rapicauda		**x**		W	NE	
SQUAMATA-LACERTIFORMES (4 sp.)						
Teiidae						
Ameiva ameiva		**x**		W	NE	
Cnemidophorus lemniscatus			**x**			
Kentropyx calcarata		**x**	**x**	AGR	NE	
Gymnophthalmidae						
Tretioscincus agilis		**x**			NE	
SQUAMATA-IGUANIA (5 sp.)						
Dactyloidae						
Anolis chrysolepis	cf.	**x**			NE	
Anolis punctatus		**x**				
Polychrotidae						
Polychrus marmoratus			**x**		NE	
Tropiduridae						
Plica umbra		**x**			NE	
Uranoscodon superciliosus		**x**	**x**		NE	

		Per Locality		Distribution	IUCN Threat Status	CITES Status
Taxon	**cf.?**	**Berbice River Camp**	**White Sands Camp**			
Amphibia-Anura (20 species total)		**16**	**7**			
SQUAMATA-SERPENTES (17 sp.)						
Boidae						
Corallus hortulanus			**x**	W	NE	Appendix II
Epicrates cenchria		**x**				Appendix II
Colubridae						
Chironius fuscus		**x**	**x**	W	NE	
Chironius multiventris		**x**		W	NE	
Oxybelis fulgidis			**x**	W	NE	
Rhinobothryum lentiginosum		**x**				
Dipsadidae						
Erythrolamprus aesculapii			**x**	AGR	NE	
Erythrolamprus typhlus		**x**		W	NE	
Helicops angulatus		**x**		W	NE	
Hydrodynastes bicinctus			**x**	W	NE	
Imantodes cenchoa		**x**		W	NE	
Leptodeira annulata		**x**	**x**	W	NE	
Pseudoboa neuwiedii		**x**				
Siphlophis compressus		**x**	**x**	W	LC	
Leptotyphlopidae						
Epictia tenella		**x**			NE	
Trilepida macrolepis			**x**	W	NE	
Viperidae						
Bothrops atrox			**x**	AGR	NE	
TESTUDINES (3 sp.)						
Chelidae						
Rhinoclemmys punctularia		**x**				
Testudinidae						
Chelonoidis carbonarius		**x**			NE	Appendix II
Chelonoidis denticulatus		**x**			NE	Appendix II

Appendix 3

Final bird list for the Upper Berbice biodiversity assessment survey, 21 September - 2 October 2014

Key

Sequence and nomenclature follow the American Ornithologists' Union South American Checklist Committee (version 22 April 2017).

UB = Upper Berbice River site; **WS** = White Sands site; **Doc** = documented on recordings at Macaulay Library.

List compiled by Brian J. O'Shea.

Species	English name	UB	WS	Doc
Tinamidae				
Tinamus major	Great Tinamou	X	X	X
Crypturellus erythropus	Red-legged Tinamou		X	
Crypturellus variegatus	Variegated Tinamou	X	X	X
Cracidae				
Penelope marail	Marail Guan	X	X	X
Ortalis motmot	Variable Chachalaca		X	X
Crax alector	Black Curassow	X	X	X
Odontophoridae				
Odontophorus gujanensis	Marbled Wood-Quail	X	X	X
Columbidae				
Patagioenas speciosa	Scaled Pigeon		X	X
Patagioenas plumbea	Plumbeous Pigeon	X	X	X
Patagioenas subvinacea	Ruddy Pigeon		X	X
Leptotila verreauxi	White-tipped Dove		X	
Leptotila rufaxilla	Grey-fronted Dove	X		
Claravis pretiosa	Blue Ground Dove		X	
Cuculidae				
Piaya cayana	Squirrel Cuckoo	X		
Piaya melanogaster	Black-bellied Cuckoo	X	X	X
Nyctibiidae				
Nyctibius grandis	Great Potoo	X		
Nyctibius aethereus	Long-tailed Potoo	X		X
Nyctibius griseus	Common Potoo	X	X	X
Nyctibius leucopterus	White-winged Potoo		X	X
Nyctibius bracteatus	Rufous Potoo	X		X
Caprimulgidae				
Lurocalis semitorquatus	Short-tailed Nighthawk	X	X	X
Nyctipolus nigrescens	Blackish Nightjar		X	X
Nyctidromus albicollis	Common Pauraque		X	
Antrostomus rufus	Rufous Nightjar		X	X

Species	English name	UB	WS	Doc
Apodidae				
Streptoprocne zonaris	White-collared Swift		X	
Chaetura spinicaudus	Band-rumped Swift	X	X	X
Chaetura chapmani	Chapman's Swift	X		
Chaetura brachyura	Short-tailed Swift		X	
Tachornis squamata	Fork-tailed Palm-Swift		X	
Panyptila cayennensis	Lesser Swallow-tailed Swift	X	X	
Trochilidae				
Topaza pella	Crimson Topaz		X	
Florisuga mellivora	White-necked Jacobin		X	
Phaethornis ruber	Reddish Hermit	X	X	X
Phaethornis bourcieri	Straight-billed Hermit	X	X	X
Phaethornis superciliosus	Long-tailed Hermit	X		X
Heliothrix auritus	Black-eared Fairy	X	X	
Discosura longicaudus	Racket-tailed Coquette		X	
Calliphlox amethystina	Amethyst Woodstar		X	
Chlorestes notata	Blue-chinned Sapphire		X	
Campylopterus largipennis	Grey-breasted Sabrewing	X	X	X
Thalurania furcata	Fork-tailed Woodnymph	X	X	
Hylocharis sapphirina	Rufous-throated Sapphire	X		
Hylocharis cyanus	White-chinned Sapphire	X	X	X
Psophiidae				
Psophia crepitans	Grey-winged Trumpeter	X		X
Scolopacidae				
Calidris minutilla	Least Sandpiper		X	
Actitis macularius	Spotted Sandpiper		X	
Tringa solitaria	Solitary Sandpiper		X	
Eurypygidae				
Eurypyga helias	Sunbittern	X		
Ardeidae				
Tigrisoma lineatum	Rufescent Tiger-Heron	X	X	
Agamia agami	Agami Heron	X		

Appendix 3

Final bird list for the Upper Berbice biodiversity assessment survey, 21 September - 2 October 2014 (*cont'd*)

Species	English Name	UB	WS	Doc
Threskiornithidae				
Mesembrinibis cayennensis	Green Ibis	X		
Cathartidae				
Cathartes melambrotus	Greater Yellow-headed Vulture	X	X	
Sarcoramphus papa	King Vulture	X		
Accipitridae				
Gampsonyx swainsonii	Pearl Kite		X	
Chondrohierax uncinatus	Hook-billed Kite	X		
Spizaetus tyrannus	Black Hawk-Eagle	X		
Spizaetus melanoleucus	Black-and-white Hawk-Eagle	X	X	
Spizaetus ornatus	Ornate Hawk-Eagle	X		
Accipiter superciliosus	Tiny Hawk		X	
Buteogallus urubitinga	Great Black Hawk	X	X	
Pseudastur albicollis	White Hawk	X	X	
Buteo nitidus	Grey-lined Hawk	X	X	
Strigidae				
Megascops watsonii	Tawny-bellied Screech-Owl	X	X	X
Lophostrix cristata	Crested Owl	X	X	X
Pulsatrix perspicillata	Spectacled Owl		X	X
Ciccaba virgata	Mottled Owl	X		X
Glaucidium hardyi	Amazonian Pygmy-Owl	X	X	X
Trogonidae				
Trogon melanurus	Black-tailed Trogon	X	X	X
Trogon viridis	Green-backed Trogon	X	X	X
Trogon violaceus	Guianan Trogon	X	X	X
Trogon rufus	Black-throated Trogon		X	
Trogon collaris	Collared Trogon	X		
Alcedinidae				
Chloroceryle inda	Green-and-rufous Kingfisher	X		
Momotidae				
Momotus momota	Amazonian Motmot	X	X	X

Species	English Name	UB	WS	Doc
Galbulidae				
Galbula albirostris	Yellow-billed Jacamar	X	X	X
Galbula leucogastra	Bronzy Jacamar		X	
Galbula dea	Paradise Jacamar	X	X	X
Jacamerops aureus	Great Jacamar	X	X	X
Bucconidae				
Notharchus macrorhynchos	Guianan Puffbird	X	X	X
Notharchus tectus	Pied Puffbird	X	X	
Bucco tamatia	Spotted Puffbird		X	X
Bucco capensis	Collared Puffbird	X	X	X
Malacoptila fusca	White-chested Puffbird	X		X
Nonnula rubecula	Rusty-breasted Nunlet		X	X
Monasa atra	Black Nunbird	X		
Chelidoptera tenebrosa	Swallow-winged Puffbird		X	
Capitonidae				
Capito niger	Black-spotted Barbet	X		X
Ramphastidae				
Ramphastos tucanus	White-throated Toucan	X	X	X
Ramphastos vitellinus	Channel-billed Toucan	X	X	X
Selenidera piperivora	Guianan Toucanet	X	X	
Pteroglossus viridis	Green Araçari	X		X
Pteroglossus aracari	Black-necked Araçari	X		X
Picidae				
Veniliornis cassini	Golden-collared Woodpecker	X	X	
Piculus flavigula	Yellow-throated Woodpecker	X	X	
Piculus chrysochloros	Golden-green Woodpecker		X	
Celeus torquatus	Ringed Woodpecker	X	X	X
Celeus undatus	Waved Woodpecker	X	X	X
Celeus flavus	Cream-colored Woodpecker	X		X
Celeus elegans	Chestnut Woodpecker	X		
Dryocopus lineatus	Lineated Woodpecker	X		X
Campephilus rubricollis	Red-necked Woodpecker	X	X	X

Appendix 3

Final bird list for the Upper Berbice biodiversity assessment survey, 21 September - 2 October 2014 (*cont'd*)

Species	English Name	UB	WS	Doc
Falconidae				
Micrastur ruficollis	Barred Forest-Falcon	X	X	X
Micrastur gilvicollis	Lined Forest-Falcon	X	X	X
Micrastur mirandollei	Slaty-backed Forest-Falcon	X	X	X
Micrastur semitorquatus	Collared Forest-Falcon	X	X	X
Ibycter americanus	Red-throated Caracara	X	X	X
Falco rufigularis	Bat Falcon		X	
Psittacidae				
Touit purpuratus	Sapphire-rumped Parrotlet		X	
Touit sp.	Parrotlet sp.		X	
Brotogeris chrysoptera	Golden-winged Parakeet	X	X	X
Pyrilia caica	Caica Parrot	X	X	X
Pionus fuscus	Dusky Parrot	X	X	X
Pionus menstruus	Blue-headed Parrot	X	X	X
Amazona ochrocephala	Yellow-crowned Parrot	X		X
Amazona dufresniana	Blue-cheeked Parrot		X	X
Amazona farinosa	Mealy Parrot	X	X	X
Amazona amazonica	Orange-winged Parrot	X	X	X
Pionites melanocephalus	Black-headed Parrot	X	X	
Deroptyus accipitrinus	Red-fan Parrot	X	X	X
Pyrrhura picta	Painted Parakeet	X		
Orthopsittaca manilatus	Red-bellied Macaw		X	
Ara ararauna	Blue-and-yellow Macaw	X	X	
Ara macao	Scarlet Macaw	X	X	X
Ara chloropterus	Red-and-green Macaw	X	X	X
Psittacara leucophthalmus	White-eyed Parakeet	X	X	X
Thamnophilidae				
Euchrepomis spodioptila	Ash-winged Antwren	X	X	
Cymbilaimus lineatus	Fasciated Antshrike	X	X	X
Thamnophilus murinus	Mouse-coloured Antshrike	X	X	X
Thamnophilus punctatus	Northern Slaty-Antshrike		X	X
Thamnomanes ardesiacus	Dusky-throated Antshrike	X	X	X
Thamnomanes caesius	Cinereous Antshrike	X	X	X
Isleria guttata	Rufous-bellied Antwren	X		
Epinecrophylla gutturalis	Brown-bellied Antwren	X	X	X
Myrmotherula brachyura	Pygmy Antwren	X	X	X
Myrmotherula axillaris	White-flanked Antwren	X		X
Myrmotherula longipennis	Long-winged Antwren	X	X	X

Species	English Name	UB	WS	Doc
Thamnophilidae (*cont'd*)				
Myrmotherula menetriesii	Grey Antwren	X	X	X
Herpsilochmus sticturus	Spot-tailed Antwren	X	X	X
Herpsilochmus stictocephalus	Todd's Antwren	X	X	X
Microrhopias quixensis	Dot-winged Antwren	X		
Formicivora grisea	White-fringed Antwren		X	X
Hypocnemis cantator	Guianan Warbling-Antbird	X	X	X
Cercomacroides tyrannina	Dusky Antbird	X	X	X
Cercomacra cinerascens	Grey Antbird	X	X	X
Percnostola rufifrons	Black-headed Antbird	X	X	X
Myrmelastes leucostigma	Spot-winged Antbird	X		
Myrmoderus ferrugineus	Ferruginous-backed Antbird	X	X	X
Myrmornis torquata	Wing-banded Antbird	X		
Pithys albifrons	White-plumed Antbird	X	X	X
Gymnopithys rufigula	Rufous-throated Antbird	X		
Hylophylax naevius	Spot-backed Antbird	X		
Willisornis poecilinotus	Common Scale-backed Antbird	X	X	X
Conopophagidae				
Conopophaga aurita	Chestnut-belted Gnateater	X		
Grallariidae				
Hylopezus macularius	Spotted Antpitta	X	X	X
Myrmothera campanisona	Thrush-like Antpitta	X	X	X
Formicariidae				
Formicarius colma	Rufous-capped Antthrush	X		X
Formicarius analis	Black-faced Antthrush	X		
Furnariidae				
Dendrocincla merula	White-chinned Woodcreeper	X		
Dendrocincla fuliginosa	Plain-brown Woodcreeper	X	X	X
Glyphorhynchus spirurus	Wedge-billed Woodcreeper	X	X	X
Dendrexetastes rufigula	Cinnamon-throated Woodcreeper	X		
Dendrocolaptes certhia	Amazonian Barred-Woodcreeper	X	X	X
Dendrocolaptes picumnus	Black-banded Woodcreeper	X	X	X
Hylexetastes perrotii	Red-billed Woodcreeper	X	X	X
Xiphorhynchus pardalotus	Chestnut-rumped Woodcreeper	X	X	X
Xiphorhynchus guttatus	Buff-throated Woodcreeper	X		X
Dendroplex picus	Straight-billed Woodcreeper		X	

Appendix 3

Final bird list for the Upper Berbice biodiversity assessment survey, 21 September - 2 October 2014 (*cont'd*)

Species	English name	UB	WS	Doc
Furnariidae (*cont'd*)				
Campylorhamphus procurvoides	Curve-billed Scythebill		X	
Lepidocolaptes albolineatus	Guianan Woodcreeper	X	X	X
Xenops minutus	Plain Xenops	X	X	
Microxenops milleri	Rufous-tailed Xenops	X	X	
Philydor erythrocercum	Rufous-rumped Foliage-gleaner	X		
Philydor pyrrhodes	Cinnamon-rumped Foliage-gleaner	X		X
Automolus ochrolaemus	Buff-throated Foliage-gleaner	X		X
Automolus infuscatus	Olive-backed Foliage-gleaner	X		
Tyrannidae				
Tyrannulus elatus	Yellow-crowned Tyrannulet		X	X
Myiopagis gaimardii	Forest Elaenia	X	X	X
Elaenia sp.	Elaenia sp.		X	
Ornithion inerme	White-lored Tyrannulet	X		X
Camptostoma obsoletum	Southern Beardless-Tyrannulet	X	X	X
Corythopis torquatus	Ringed Antpipit	X		X
Zimmerius acer	Guianan Tyrannulet	X	X	X
Phylloscartes virescens	Olive-green Tyrannulet	X	X	X
Myiornis ecaudatus	Short-tailed Pygmy-Tyrant	X	X	X
Lophotriccus vitiosus	Double-banded Pygmy-Tyrant	X	X	X
Lophotriccus galeatus	Helmeted Pygmy-Tyrant	X	X	X
Hemitriccus inornatus	Pelzeln's Tody-Tyrant		X	X
Todirostrum pictum	Painted Tody-Flycatcher	X	X	
Tolmomyias assimilis	Yellow-margined Flycatcher	X	X	X
Tolmomyias poliocephalus	Grey-crowned Flycatcher	X		X
Tolmomyias flaviventris	Yellow-breasted Flycatcher		X	
Neopipo cinnamomea	Cinnamon Manakin-Tyrant		X	
Platyrinchus saturatus	Cinnamon-crested Spadebill	X		X
Platyrinchus coronatus	Golden-crowned Spadebill		X	X
Platyrinchus platyrhynchos	White-crested Spadebill	X	X	X
Onychorhynchus coronatus	Royal Flycatcher	X		
Myiobius barbatus	Sulphur-rumped Flycatcher	X	X	
Terenotriccus erythrurus	Ruddy-tailed Flycatcher		X	X
Colonia colonus	Long-tailed Tyrant	X		
Conopias parvus	Yellow-throated Flycatcher	X	X	X
Tyrannopsis sulphurea	Sulphury Flycatcher		X	
Tyrannus melancholicus	Tropical Kingbird		X	X
Rhytipterna simplex	Greyish Mourner	X	X	X

Species	English name	UB	WS	Doc
Tyrannidae (*cont'd*)				
Myiarchus tuberculifer	Dusky-capped Flycatcher	X	X	X
Myiarchus swainsoni	Swainson's Flycatcher		X	
Ramphotrigon ruficauda	Rufous-tailed Flatbill	X	X	
Attila spadiceus	Bright-rumped Attila	X	X	X
Cotingidae				
Phoenicircus carnifex	Guianan Red-Cotinga	X		
Haematoderus militaris	Crimson Fruitcrow		X	
Querula purpurata	Purple-throated Fruitcrow	X		X
Perissocephalus tricolor	Capuchinbird		X	X
Cotinga cayana	Spangled Cotinga	X		
Lipaugus vociferans	Screaming Piha	X	X	X
Xipholena punicea	Pompadour Cotinga		X	
Pipridae				
Tyranneutes virescens	Tiny Tyrant-Manakin	X	X	X
Neopelma chrysocephalum	Saffron-crested Tyrant-Manakin		X	X
Corapipo gutturalis	White-throated Manakin	X	X	
Xenopipo atronitens	Black Manakin		X	X
Dixiphia pipra	White-crowned Manakin	X	X	X
Ceratopipra erythrocephala	Golden-headed Manakin	X	X	X
Tityridae				
Tityra cayana	Black-tailed Tityra	X	X	
Schiffornis olivacea	Olivaceous Schiffornis	X	X	
Iodopleura fusca	Dusky Purpletuft	X		
Pachyramphus marginatus	Black-capped Becard	X		X
Pachyramphus minor	Pink-throated Becard	X		X
Incertae Sedis				
Piprites chloris	Wing-barred Piprites	X	X	X
Vireonidae				
Vireolanius leucotis	Slaty-capped Shrike-Vireo	X	X	X
Hylophilus thoracicus	Lemon-chested Greenlet	X		X
Tunchiornis ochraceiceps	Tawny-crowned Greenlet	X	X	X
Pachysylvia muscicapina	Buff-cheeked Greenlet	X	X	X
Vireo olivaceus	Red-eyed Vireo		X	X

Appendix 3

Final bird list for the Upper Berbice biodiversity assessment survey, 21 September - 2 October 2014 (*cont'd*)

Species	English name	UB	WS	Doc
Corvidae				
Cyanocorax cayanus	Cayenne Jay		X	X
Hirundinidae				
Progne chalybea	Grey-breasted Martin		X	
Hirundo rustica	Barn Swallow		X	
Troglodytidae				
Troglodytes aedon	House Wren		X	
Pheugopedius coraya	Coraya Wren	X	X	
Cyphorhinus arada	Musician Wren	X	X	X
Polioptilidae				
Ramphocaenus melanurus	Long-billed Gnatwren	X		X
Turdidae				
Turdus albicollis	White-necked Thrush	X		X
Thraupidae				
Cyanicterus cyanicterus	Blue-backed Tanager	X	X	X
Chlorophanes spiza	Green Honeycreeper	X	X	
Hemithraupis guira	Guira Tanager	X		
Hemithraupis flavicollis	Yellow-backed Tanager	X	X	X
Tachyphonus cristatus	Flame-crested Tanager	X	X	X
Tachyphonus surinamus	Fulvous-crested Tanager	X	X	X
Tachyphonus phoeniceus	Red-shouldered Tanager		X	
Ramphocelus carbo	Silver-beaked Tanager		X	
Lanio fulvus	Fulvous Shrike-Tanager	X		X
Cyanerpes caeruleus	Purple Honeycreeper	X	X	
Cyanerpes cyaneus	Red-legged Honeycreeper		X	
Dacnis lineata	Black-faced Dacnis	X		
Dacnis cayana	Blue Dacnis	X	X	
Sporophila angolensis	Chestnut-bellied Seed-Finch		X	
Saltator grossus	Slate-coloured Grosbeak	X	X	X
Coereba flaveola	Bananaquit		X	X
Tangara gyrola	Bay-headed Tanager	X		X
Tangara mexicana	Turquoise Tanager	X		
Thraupis palmarum	Palm Tanager	X		
Ixothraupis punctata	Spotted Tanager	X		
Lamprospiza melanoleuca	Red-billed Pied Tanager	X		X

Species	English name	UB	WS	Doc
Emberizidae				
Arremon taciturnus	Pectoral Sparrow	X		
Cardinalidae				
Caryothraustes canadensis	Yellow-green Grosbeak	X	X	
Cyanoloxia cyanoides	Blue-black Grosbeak	X	X	X
Parulidae				
Setophaga pitiayumi	Tropical Parula	X		
Myiothlypis rivularis	Riverbank Warbler		X	
Icteridae				
Psarocolius viridis	Green Oropendola	X	X	X
Cacicus haemorrhous	Red-rumped Cacique	X		X
Fringillidae				
Euphonia plumbea	Plumbeous Euphonia		X	X
Euphonia chrysopasta	Golden-bellied Euphonia	X		
Euphonia minuta	White-vented Euphonia	X		
Euphonia cayennensis	Golden-sided Euphonia	X		X
		205	**196**	**157**

Appendix 4

Small mammals species list

SPECIES	
BATS	
Ametrida	*centurio*
Artibeus	*bogotensis*
Artibeus	*concolor*
Artibeus	*gnomus*
Artibeus	*lituratus*
Artibeus	*obscurus*
Artibeus	*planirostris*
Carollia	*perspicillata*
Chiroderma	*villosum*
Chrotopterus	*auritus*
Cynomops	*abrasus*
Desmodus	*rotundus*
Eumops	*hansae*
Glossophaga	*sorcina*
Lophostoma	*silvicolum*
Molossus	*molossus*
Molossus	*rufus*
Myotis	*nigricans*
Noctilio	*leporinus*
Phylloderma	*stenops*
Phylloderma	*hastatus*
Phyllostomus	*discolor*
Phyllostomus	*elongatus*
Pteronotus	*parnellii*
Rhinophylla	*pumilio*
Saccopteryx	*leptura*
Sturnira	*lilium*
Tonatia	*saurophila*
Tonatia	sp.
Trachops	*cirrhosus*
Uroderma	*bilobatum*
Vampyressa	*bidens*
RATS	
Nectomys	*rattus*
Proechimys	*guyannensis*

Appendix 5
Large to medium mammals- species list

Scientific Name	Common name
CARNIVORA	
Panthera onca	Jaguar
Puma concolor	Puma
Leopardus pardalis	Ocelot
Herpailurus yagouaroundi	Jaguarundi
Leopardus sp.	
UNGULATES	
Tapirus terrestris	Tapir
Mazama sp.	Brocket deer
Mazama americana	Red brocket deer
Mazama nemorivaga	Grey brocket deer
Pecari tajacu	Collared peccary
XENARTHRA	
Myrmecophaga tridactyla	Giant Anteater
Dasypus sp.	Armadillo
Priodontes maximus	Giant armadillo
RODENTIA	
Cuniculus paca	Labba
Dasyprocta leporina	Agouti
Myoprocta acouchy	Acouchi
PRIMATES	
Alouatta macconnelli	Red howler monkey
Ateles paniscus	Red-faced spider monkey
Sapajus apella	Brown capuchin
Pithecia pithecia	White-faced saki

Appendix 6

Fishes from sites in the Berbice and Corentyne River Basins

Key

Bold: Fishes from the Berbice and Corentyne River basin 2014 sites.

The list also includes species collected from previous expeditions to sites further downstream in the Berbice River basin; these have no numbers of specimens listed.

Order	Family	Genus	Species	Berbice River (# specimens)	Corentyne River (# specimens)
Beloniformes	**Belonidae**	***Potamorrhaphis***	***guianensis***	**3**	
Characiformes	Acestrorhynchidae	*Acestrorhynchus*	cf. *nasutus*		
Characiformes	Acestrorhynchidae	*Acestrorhynchus*	*falcatus*		
Characiformes	Acestrorhynchidae	*Acestrorhynchus*	*heterolepis*		
Characiformes	**Acestrorhynchidae**	***Acestrorhynchus***	***microlepis***	**9**	
Characiformes	Anostomidae	*Leporinus*	*arcus*		
Characiformes	Anostomidae	*Leporinus*	*fasciatus* group		
Characiformes	**Anostomidae**	***Leporinus***	***friderici* group**	**3**	
Characiformes	Anostomidae	*Leporinus*	*granti*		
Characiformes	Anostomidae	*Leporinus*	*nigrotaeniatus*		
Characiformes	**Anostomidae**	***Leporinus***	**sp.**	**14**	
Characiformes	**Anostomidae**	***Pseudanos***	***trimaculatus***	**4**	
Characiformes	Bryconidae	*Brycon*	*falcatus*		
Characiformes	**Characidae**	***Aphyocharax***	***erythrurus***	**9**	
Characiformes	**Characidae**	***Aphyocharax***	**sp.**	**6**	
Characiformes	**Characidae**	***Astyanax***	***bimaculatus***	**1**	
Characiformes	Characidae	*Charax*	*gibbosus*		
Characiformes	**Characidae**	***Cynopotamus***	***essequibensis***	**4**	
Characiformes	**Characidae**	***Gymnocorymbus***	***bondi***	**2**	
Characiformes	Characidae	*Hemigrammus*	*analis*		
Characiformes	**Characidae**	***Hemigrammus***	***bellottii***	**54**	
Characiformes	Characidae	*Hemigrammus*	sp.		
Characiformes	Characidae	*Hemigrammus*	*stictus*		
Characiformes	**Characidae**	***Hemigrammus***	***unilineatus***	**91**	
Characiformes	Characidae	*Hyphessobrycon*	*bentosi*		
Characiformes	**Characidae**	***Hyphessobrycon***	***minor***	**483**	
Characiformes	**Characidae**	***Hyphessobrycon***	**sp.**	**0**	**74**
Characiformes	**Characidae**	***Jupiaba***	***abramoides***	**0**	**10**
Characiformes	**Characidae**	***Jupiaba***	***polylepis***	**177**	**1**
Characiformes	**Characidae**	***Jupiaba***	**sp.**	**99**	
Characiformes	**Characidae**	***Microschemobrycon***	***casiquiare***	**47**	
Characiformes	Characidae	*Moenkhausia*	*collettii*		
Characiformes	**Characidae**	***Moenkhausia***	***copei***	**702**	

Order	Family	Genus	Species	Berbice River (# specimens)	Corentyne River (# specimens)
Characiformes	**Characidae**	***Moenkhausia***	***dichroura***	**7**	
Characiformes	Characidae	*Moenkhausia*	*jamesi*		
Characiformes	**Characidae**	***Moenkhausia***	***lepidura***	**53**	
Characiformes	**Characidae**	***Moenkhausia***	***oligolepis***	**74**	
Characiformes	**Characidae**	***Moenkhausia***	**sp.**	**90**	
Characiformes	**Characidae**	***Serrapinnus***	***gracilis***	**1**	
Characiformes	Characidae	*Parapristella*	*aubynei*		
Characiformes	**Characidae**	***Phenacogaster***	***microstictus***	**148**	
Characiformes	**Characidae**	***Poptella***	***compressa***	**16**	
Characiformes	Characidae	*Pristella*	*maxillaris*		
Characiformes	Characidae	*Roeboides*	*thurni*		
Characiformes	**Characidae**	***Tetragonopterus***	***argenteus***	**11**	
Characiformes	**Chilodontidae**	***Chilodus***	***punctatus***	**46**	
Characiformes	**Crenuchidae**	***Ammocryptocharax***	**sp.**		**8**
Characiformes	Crenuchidae	*Characidium*	*pellucidum*		
Characiformes	**Crenuchidae**	***Characidium***	***pteroides***	**22**	
Characiformes	Crenuchidae	*Crenuchus*	*spilurus*		
Characiformes	**Curimatidae**	***Curimatella***	**sp.**	**27**	
Characiformes	**Curimatidae**	***Cyphocharax***	***helleri***	**9**	
Characiformes	**Curimatidae**	***Cyphocharax***	***spilurus***	**39**	
Characiformes	Curimatidae	*Steindachnerina*	*guentheri*		
Characiformes	**Cynodontidae**	***Cynodon***	***gibbus***	**4**	
Characiformes	**Erythrinidae**	***Erythrinus***	***erythrinus***	**30**	
Characiformes	**Erythrinidae**	***Hoplias***	***aimara***	**18**	**1**
Characiformes	**Erythrinidae**	***Hoplias***	***malabaricus***	**7**	
Characiformes	**Gasteropelecidae**	***Carnegiella***	***strigata***	**103**	**1**
Characiformes	Hemiodontidae	*Hemiodus*	*microlepis*		
Characiformes	**Hemiodontidae**	***Hemiodus***	***unimaculatus***	**2**	
Characiformes	Iguanodectidae	*Bryconops*	*affinis*		
Characiformes	Iguanodectidae	*Bryconops*	*caudomaculatus*		
Characiformes	**Iguanodectidae**	***Bryconops***	***melanurus***	**30**	
Characiformes	**Iguanodectidae**	***Bryconops***	**sp.**	**28**	
Characiformes	**Iguanodectidae**	***Bryconops***	**sp. redtail**		**92**
Characiformes	**Iguanodectidae**	***Iguanodectes***	***spilurus***	**23**	
Characiformes	**Lebiasinidae**	***Nannostomus***	***marginatus***	**19**	**2**
Characiformes	**Lebiasinidae**	***Pyrrhulina***	***filamentosa***		**24**
Characiformes	**Lebiasinidae**	***Pyrrhulina***	***stoli***	**69**	

Appendix 6

Fishes from sites in the Berbice and Corentyne River Basins (*cont'd*)

Order	Family	Genus	Species	Berbice River (# specimens)	Corentyne River (# specimens)
Characiformes	**Prochilodontidae**	***Prochilodus***	***rubrotaeniatus***	**1**	
Characiformes	Serrasalmidae	*Metynnis*	*argenteus*		
Characiformes	Serrasalmidae	*Metynnis*	*hypsauchen*		
Characiformes	Serrasalmidae	*Myloplus*	*rhomboidalis*		
Characiformes	**Serrasalmidae**	***Myloplus***	***rubripinnis***	**13**	
Characiformes	**Serrasalmidae**	***Serrasalmus***	***eigenmanni***	**41**	
Characiformes	**Serrasalmidae**	***Serrasalmus***	***rhombeus***	**12**	
Characiformes	**Triportheidae**	***Triportheus***	***brachipomus***	**7**	
Cichliformes	Cichlidae	*Apistogramma*	sp.		
Cichliformes	**Cichlidae**	***Apistogramma***	***steindachneri***	**30**	**1**
Cichliformes	Cichlidae	*Biotodoma*	*cupido*		
Cichliformes	Cichlidae	*Cichla*	*ocellaris*		
Cichliformes	**Cichlidae**	***Crenicichla***	***alta***	**7**	**7**
Cichliformes	Cichlidae	*Crenicichla*	*johanna*		
Cichliformes	**Cichlidae**	***Crenicichla***	**sp.**	**2**	
Cichliformes	Cichlidae	*Crenicichla*	*wallacii*		
Cichliformes	**Cichlidae**	***Geophagus***	***crocatus***	**3**	
Cichliformes	**Cichlidae**	***Krobia***	***petitella***	**2**	**1**
Cichliformes	**Cichlidae**	***Mesonauta***	***guyanae***	**28**	
Cichliformes	**Cichlidae**	***Satanoperca***	***leucosticta***	**4**	
Clupeiformes	Engraulidae	*Anchovia*	*surinamensis*		
Clupeiformes	Engraulidae	*Anchoviella*	cf. *juruasanga*		
Clupeiformes	Engraulidae	*Anchoviella*	*guianensis*		
Clupeiformes	Engraulidae	*Anchoviella*	*manamensis*		
Clupeiformes	Engraulidae	*Lycengraulis*	sp.		
Cyprinodon-tiformes	**Rivulidae**	***Anablepsoides***	**sp.**	**3**	
Cyprinodontiformes	Rivulidae	*Laimosemion*	sp.		
Gymnotiformes	Apteronotidae	*Apteronotus*	*albifrons*		
Gymnotiformes	Gymnotidae	*Gymnotus*	*anguillaris*		
Gymnotiformes	**Gymnotidae**	***Gymnotus***	***carapo***	**32**	**2**
Gymnotiformes	Hypopomidae	*Brachyhypopomus*	*brevirostris*		
Gymnotiformes	Hypopomidae	*Hypopygus*	*lepturus*		
Gymnotiformes	**Hypopomidae**	***Hypopomus***	***artedi***	**24**	
Gymnotiformes	Hypopomidae	*Steatogenys*	*elegans*		

Order	Family	Genus	Species	Berbice River (# specimens)	Corentyne River (# specimens)
Gymnotiformes	Rhamphichthyidae	*Rhamphichthys*	*marmoratus*		
Gymnotiformes	**Sternopygidae**	***Eigenmannia***	***limbata***	**1**	
Gymnotiformes	**Sternopygidae**	***Eigenmannia***	**sp.**	**1**	
Gymnotiformes	**Sternopygidae**	***Sternopygus***	***macrurus***	**9**	
Myliobatiformes	Potamotrygonidae	*Potamotrygon*	*orbignyi*		
Perciformes	Sciaenidae	*Pachypops*	*fourcroi*		
Perciformes	Sciaenidae	*Plagioscion*	*squamosissimus*		
Siluriformes	**Aspredinidae**	***Bunocephalus***	***amaurus***	**3**	
Siluriformes	**Auchenipteridae**	***Ageneiosus***	***inermis***	**1**	
Siluriformes	Auchenipteridae	*Ageneiosus*	cf. *ucayalensis*		
Siluriformes	Auchenipteridae	*Auchenipterus*	*brevior*		
Siluriformes	**Auchenipteridae**	***Auchenipterus***	***nuchalis***	**14**	
Siluriformes	Auchenipteridae	*Tatia*	sp.		
Siluriformes	**Auchenipteridae**	***Trachelyopterus***	***galeatus***	**3**	
Siluriformes	**Callichthyidae**	***Callichthys***	***callichthys***	**7**	
Siluriformes	Callichthyidae	*Corydoras*	cf. *bondi*		
Siluriformes	**Callichthyidae**	***Corydoras***	***melanistius***	**94**	
Siluriformes	**Callichthyidae**	***Corydoras***	**sp. long nose**	**8**	
Siluriformes	**Callichthyidae**	***Megalechis***	**sp.**	**3**	
Siluriformes	**Cetopsidae**	***Helogenes***	***marmoratus***	**10**	**25**
Siluriformes	**Doradidae**	***Amblydoras***	**sp.**	**1**	
Siluriformes	Doradidae	*Doras*	*micropoeus*		
Siluriformes	Doradidae	*Leptodoras*	*linelli*		
Siluriformes	Doradidae	*Platydoras*	*hancockii*		
Siluriformes	Heptapteridae	*Brachyrhamdia*	cf. *beebei*		
Siluriformes	**Heptapteridae**	***Chasmocranus***	**sp.**	**3**	
Siluriformes	**Heptapteridae**	***Imparfinis***	**sp.**	**3**	
Siluriformes	**Heptapteridae**	***Pimelodella***	***cristata***	**6**	
Siluriformes	Heptapteridae	*Pimelodella*	sp.		
Siluriformes	**Heptapteridae**	***Rhamdia***	***quelen***	**7**	
Siluriformes	**Loricariidae**	***Ancistrus***	***leucostictus***	**15**	
Siluriformes	Loricariidae	*Ancistrus*	sp.		
Siluriformes	**Loricariidae**	***Hypoptopoma***	***guianense***	**36**	
Siluriformes	**Loricariidae**	***Hypostomus***	***hemiurus***	**1**	
Siluriformes	**Loricariidae**	***Hypostomus***	**sp.**	**1**	
Siluriformes	**Loricariidae**	***Hypostomus***	***taphorni***	**9**	

Appendix 6

Fishes from sites in the Berbice and Corentyne River Basins (*cont'd*)

Order	Family	Genus	Species	Berbice River (# specimens)	Corentyne River (# specimens)
Siluriformes	**Loricariidae**	***Loricaria***	***cataphracta***	**11**	
Siluriformes	**Loricariidae**	***Rineloricaria***	***fallax***	**19**	
Siluriformes	**Pimelodidae**	***Pimelodus***	***blochii* group**	**1**	
Siluriformes	Pimelodidae	*Pimelodus*	*ornatus*		
Siluriformes	Pimelodidae	*Pseudoplatystoma*	*fasciatum*		
Siluriformes	**Pseudopimelodidae**	***Batrochoglanis***	**sp.**	**4**	
Siluriformes	**Pseudopimelodidae**	***Microglanis***	***poecilus***	**2**	
Siluriformes	Pseudopimelodidae	*Pseudopimelodus*	sp.		
Siluriformes	**Trichomycteridae**	***Ituglanis***	**sp.**	**2**	
Siluriformes	**Trichomycteridae**	***Ochmacanthus***	***alternus***	**1**	
Siluriformes	Trichomycteridae	*Paracanthopoma*	*parva*		
Siluriformes	**Trichomycteridae**	***Trichomycterus***	**sp.**	**2**	
Siluriformes	Trichomycteridae	*Vandellia*	*plazai*		
Synbranchiformes	**Synbranchidae**	***Synbranchus***	***marmoratus***	**2**	
			Specimens:	**3073**	**249**

Appendix 7

List of aquatic beetles collected during the 2014 BAT survey of the Upper Berbice region of Guyana

Key

Taxa with asterisks are likely species new to science.

Taxon	Berbice River	White Sands
DRYOPIDAE		
Gen. nov. A sp. 1*	X	-
Gen. nov. A sp. 2*	X	-
Gen. nov. A sp. 3*	X	-
Gen. nov. A sp. 4*	X	-
DYTISCIDAE		
Amarodytes sp. A*	X	-
Amarodytes sp. C*	X	-
Anodocheilus silvestrii	X	X
Bidessodes charaxinus	X	X
Bidessodes evanidus	X	-
Bidessodes knischi	X	-
Bidessodes obscuripennis	X	-
Bidessonotus sp. G*	X	X
Bidessonotus tibialis	X	X
Bidessonotus truncatus	X	X
Celina sp. 1	X	-
Celina sp. 3	-	X
Celina sp. 2	-	X
Copelatus sp. 1	X	-
Copelatus sp. 10	X	-
Copelatus sp. 11	X	X
Copelatus sp. 12	X	X
Copelatus sp. 2	X	-
Copelatus sp. 3	X	-
Copelatus sp. 4	X	-
Copelatus sp. 5	-	X
Copelatus sp. 6	X	X
Copelatus sp. 7	X	X
Copelatus sp. 8	X	X
Copelatus sp. 9	X	-
Derovatellus lentus	X	X
Hydaticus subfasciatus	X	-
Hydrodessus angularis	-	X
Hydrodessus maculatus	X	-
Hydrodessus sp. A*	-	X
Hydrodessus sp. B*	-	X

Appendix 7

List of aquatic beetles collected during the 2014 BAT survey of the Upper Berbice region of Guyana (*cont'd*)

Taxon	Berbice River	White Sands
Hydrodessus sp. C	X	-
Hydrodessus sp. D	-	X
Hydrodytes inaciculatus	X	-
Hydrodytes opalinus	X	-
Laccodytes sp. 1	X	-
Laccodytes sp. 2	-	X
Laccomimus sp. 1	X	-
Laccomimus sp. 2	X	-
Laccophilus sp. 1	X	-
Laccophilus sp. 2	X	-
Laccophilus sp. 3	X	-
Laccophilus sp. 4	X	-
Laccophilus sp. 5	-	X
Laccophilus sp. 6	X	X
Laccophilus sp. 7	-	X
Laccophilus sp. 8	-	X
Megadytes sp. 1	-	X
Microdessus atomarius	-	X
Neobidessus surinamensis	-	X
Pachydrus sp. 1	-	X
Rhantus calidus	X	X
Thermonectus circumscriptus	-	X
Thermonectus leprieuri	X	-
Thermonectus nobilis	-	X
Thermonectus variegatus	X	-
Thernomectus succinctus	-	X
Vatellus amae	-	X
Vatellus grandis	X	-
ELMIDAE		
Austrolimnius sp.	X	-
Cylloepus sp. 1	X	X
Cylloepus sp. 2	X	X
Elachistelmis sp. 1	X	-
Elachistelmis sp. 2	-	X
Heterelmis sp. X	-	X
Hintonelmis sp. 1	X	X
Hintonelmis sp. 2	X	-

Taxon	Berbice River	White Sands
Microcylloepus sp. 1	X	-
Neoelmis spp. X	X	X
Stegoelmis stictoides	X	X
Stenhelmoides sp. 1	X	X
Stenhelmoides sp. 2	-	X
Stenhelmoides sp. 3	-	X
Stenhelmoides sp. 4	X	X
Xenelmis sp. 1	X	X
EPIMETOPIDAE		
Epimetopus sp. 1	X	-
Epimetopus sp. 2	X	-
Epimetopus sp. 3	X	-
GYRINIDAE		
Gyretes sp. A	X	-
Gyretes sp. C	X	-
Gyretes sp. D	X	X
Gyretes sp. E	X	-
Gyretes sp. F	X	X
Gyretes sp. G	-	X
HYDRAENIDAE		
Hydraena sp. X	X	X
HYDROCHIDAE		
Hydrochus sp. 1	X	-
Hydrochus sp. 2	X	-
HYDROPHILIDAE		
Berosus megaphallus	-	X
Cercyon sp. 7	X	-
Chasmogenus sp. B*	X	-
Chasmogenus sp. C*	-	X
Chasmogenus sp. X	X	X
Crenitulus sp.	X	X
Derallus intermedius	X	X
Derallus sp. 3	X	-
Derallus sp. 6	-	X
Derallus sp. 7	-	X
Derallus sp. 8	X	-
Enochrus sp. 1*	-	X
Enochrus sp. 2	X	X

Appendix 7
List of aquatic beetles collected during the 2014 BAT survey of the Upper Berbice region of Guyana (*cont'd*)

Taxon	Berbice River	White Sands
Enochrus sp. 3*	X	-
Enochrus sp. 4	X	X
Enochrus sp. 5	X	X
Enochrus sp. 6	-	X
Enochrus sp. 7	X	X
Enochrus sp. 8	X	-
Enochrus sp. 9	X	X
Globulosis sp. 1*	X	-
Helochares sp. 1	X	-
Helochares sp. 2	X	-
Helochares sp. 4	X	X
Helochares sp. 5	X	X
Helochares sp. 8	X	-
Helochares sp. 9	X	X
Helochares sp. 10	X	X
Hemiosus sp. 1*	-	X
Hydrobiomorpha sp. 1	X	-
Notionotus sp. B	X	-
Paracymus sp. 1	-	X
Paracymus sp. 2	-	X
Phaenonotum sp. 1	X	-
Phaenonotum sp. 2	-	X
Acidocerinae gen. nov. sp. 1*	X	-
Tropisternus chalybeus	X	X
Tropisternus laevis	X	X
Tropisternus setiger	-	X
Tropisternus sp. 1	X	-
LUTROCHIDAE		
Lutrochus sp. 1	X	-
NOTERIDAE		
Canthysellus sp. 1	X	X
Hydrocanthus socius	-	X
Liocanthydrus bicolor	X	X
Notomicrus cf. *traili*	X	X
Notomicrus sp. X	-	X

Appendix 8

Preliminary list of identified ant species from BAT3 sampling (B3) near the Upper Berbice River and BAT2 sampling (B2) near Kaieteur Falls and the Upper Potaro River

Key

The list represents mainly hand collections and baiting samples; at the time of publication the leaf litter ants had only been sorted to genus, with a few exceptions.

The Berbice species are marked according to sampling site (**S1-S3**).

Species are identified as introduced species (IS); putative new records for Guyana (NR); possible new species (NS); or collected only from leaf litter (LL).

Subfamily	Genus	Species	B2	B3	B3-S1	B3-S2	B3-S3	Notes
Dolichoderinae	*Dolichoderus*	*attelaboides*	x					
Dolichoderinae	*Dolichoderus*	*bidens*	x	x			x	
Dolichoderinae	*Dolichoderus*	*decollatus*		x	x			
Dolichoderinae	*Dolichoderus*	*diversus*	x					
Dolichoderinae	*Dolichoderus*	*epetreius*	x					NR
Dolichoderinae	*Dolichoderus*	*ferrugineus*	x					NR
Dolichoderinae	*Dolichoderus*	*imitator*	x					
Dolichoderinae	*Dolichoderus*	*septemspinosus*	x					
Dolichoderinae	*Dorymyrmex*	msp01	x	x		x		
Dorylinae	*Eciton*	*burchellii*	x	x	x			
Dorylinae	*Eciton*	*dulcium*		x	x			
Dorylinae	*Eciton*	*hamatum*	x					
Dorylinae	*Eciton*	*mexicanum*		x	x			
Dorylinae	*Eciton*	*vagans*	x	x	x			
Dorylinae	*Labidus*	*coecus*	x	x	x			
Dorylinae	*Labidus*	*praedator*	x	x	x			
Dorylinae	*Neivamyrmex*	*balzani*	x					NR
Dorylinae	*Neivamyrmex*	*bohlsi*		x	x			
Dorylinae	*Neivamyrmex*	*emersoni*	x					
Dorylinae	*Neivamyrmex*	*gibbatus*	x					
Dorylinae	*Neivamyrmex*	msp01		x	x			
Dorylinae	*Neivamyrmex*	*pilosus*	x					
Dorylinae	*Nomamyrmex*	*esenbeckii*	x					
Dorylinae	*Nomamyrmex*	*hartigii*		x	x			
Ectatomminae	*Ectatomma*	*brunneum*	x					
Ectatomminae	*Ectatomma*	*edentatum*	x					
Ectatomminae	*Ectatomma*	*lugens*	x					
Ectatomminae	*Ectatomma*	*tuberculatum*	x					
Ectatomminae	*Gnamptogenys*	*annulata*	x	x	x			
Ectatomminae	*Gnamptogenys*	*gracilis*	x					
Ectatomminae	*Gnamptogenys*	*horni*	x	x	x			

Appendix 8

Preliminary list of identified ant species from BAT3 sampling (B3) near the Upper Berbice River and BAT2 sampling (B2) near Kaieteur Falls and the Upper Potaro River (*cont'd*)

Subfamily	Genus	Species	B2	B3	B3-S1	B3-S2	B3-S3	Notes
Ectatomminae	*Gnamptogenys*	*pleurodon*		x	x			NR
Ectatomminae	*Gnamptogenys*	*strigata*	x					
Ectatomminae	*Gnamptogenys*	*tortuolosa*	x					
Formicinae	*Acropyga*	msp01		x		x		
Formicinae	*Brachymyrmex*	msp01	x	x		x		
Formicinae	*Brachymyrmex*	msp02	x					
Formicinae	*Camponotus*	msp01		x	x			
Formicinae	*Camponotus*	msp02	x	x	x			
Formicinae	*Camponotus*	msp03	x					
Formicinae	*Camponotus*	msp04	x					
Formicinae	*Camponotus*	msp05	x	x	x			
Formicinae	*Camponotus*	msp06	x					
Formicinae	*Camponotus*	msp07		x	x			
Formicinae	*Camponotus*	msp08	x					
Formicinae	*Camponotus*	msp09	x					
Formicinae	*Camponotus*	msp10	x					
Formicinae	*Camponotus*	msp11	x	x	x			
Formicinae	*Camponotus*	msp12	x	x			x	
Formicinae	*Camponotus*	msp13		x	x			
Formicinae	*Camponotus*	msp14	x					
Formicinae	*Camponotus*	msp15		x		x		
Formicinae	*Camponotus*	msp16	x					
Formicinae	*Camponotus*	msp17	x					
Formicinae	*Camponotus*	msp18	x					
Formicinae	*Camponotus*	msp19		x		x		
Formicinae	*Camponotus*	msp20	x					
Formicinae	*Camponotus*	msp21	x					
Formicinae	*Camponotus*	msp22	x					
Formicinae	*Camponotus*	msp23	x					
Formicinae	*Gigantiops*	*destructor*	x	x	x			
Formicinae	*Myrmelachista*	msp01	x					
Formicinae	*Nylanderia*	msp01	x	x	x			
Formicinae	*Nylanderia*	msp02	x					
Formicinae	*Paratrechina*	*longicornis*		x			x	IS
Myrmicinae	*Acromyrmex*	*coronatus*	x					
Myrmicinae	*Acromyrmex*	*hystrix*	x	x	x			
Myrmicinae	*Allomerus*	*octoarticulatus*	x					

Subfamily	Genus	Species	B2	B3	B3-S1	B3-S2	B3-S3	Notes
Myrmicinae	*Apterostigma*	msp01	x					
Myrmicinae	*Apterostigma*	msp02	x	x	x			
Myrmicinae	*Apterostigma*	msp03	x					
Myrmicinae	*Apterostigma*	msp04	x					
Myrmicinae	*Apterostigma*	msp05	x					
Myrmicinae	*Apterostigma*	msp06	x					
Myrmicinae	*Apterostigma*	msp07	x					
Myrmicinae	*Atta*	*laevigata*	x					
Myrmicinae	*Atta*	*sexdens*		x	x			
Myrmicinae	*Basiceros*	*militaris*	x					LL
Myrmicinae	*Basiceros*	*singularis*	x					
Myrmicinae	*Cardiocondyla*	*minutior*	x					IS, NR
Myrmicinae	*Cephalotes*	*atratus*	x	x	x			
Myrmicinae	*Cephalotes*	*minutus*	x					
Myrmicinae	*Cephalotes*	*opacus*		x	x			
Myrmicinae	*Cephalotes*	*persimilis*	x					
Myrmicinae	*Cephalotes*	*umbraculatus*	x					NR
Myrmicinae	*Crematogaster*	msp01	x					
Myrmicinae	*Crematogaster*	msp02	x					
Myrmicinae	*Crematogaster*	msp03		x	x			
Myrmicinae	*Crematogaster*	msp04	x	x	x	x		
Myrmicinae	*Crematogaster*	msp05		x		x		
Myrmicinae	*Crematogaster*	msp06	x					
Myrmicinae	*Crematogaster*	msp07		x		x		
Myrmicinae	*Crematogaster*	msp08	x					
Myrmicinae	*Crematogaster*	msp09	x					
Myrmicinae	*Crematogaster*	msp10		x	x			
Myrmicinae	*Crematogaster*	msp11	x					
Myrmicinae	*Crematogaster*	*tenuicula*	x					LL
Myrmicinae	*Cyphomyrmex*	*minutus*	x					
Myrmicinae	*Cyphomyrmex*	*rimosus*	x	x			x	
Myrmicinae	*Daceton*	*armigerum*	x					
Myrmicinae	*Hylomyrma*	*immanis*	x					LL
Myrmicinae	*Hylomyrma*	*reginae*	x					LL
Myrmicinae	*Megalomyrmex*	msp01	x					
Myrmicinae	*Megalomyrmex*	msp02	x					
Myrmicinae	*Megalomyrmex*	*wallacei*		x	x			
Myrmicinae	*Monomorium*	*floricola*	x					IS

Appendix 8

Preliminary list of identified ant species from BAT3 sampling (B3) near the Upper Berbice River and BAT2 sampling (B2) near Kaieteur Falls and the Upper Potaro River (*cont'd*)

Subfamily	Genus	Species	B2	B3	B3-S1	B3-S2	B3-S3	Notes
Myrmicinae	*Mycetophylax*	*bigibbosus*	x	x	x			
Myrmicinae	*Myrmicocrypta*	msp01	x					
Myrmicinae	*Myrmicocrypta*	msp02	x					
Myrmicinae	*Myrmicocrypta*	msp03		x	x			
Myrmicinae	*Myrmicocrypta*	msp04		x	x			
Myrmicinae	*Myrmicocrypta*	msp05	x					
Myrmicinae	*Ochetomyrmex*	*neopolitus*	x					
Myrmicinae	*Ochetomyrmex*	*semipolitus*	x					
Myrmicinae	*Octostruma*	*amrishi*	x					LL
Myrmicinae	*Octostruma*	*iheringi*	x					LL
Myrmicinae	*Pheidole*	*arachnion*	x					NR
Myrmicinae	*Pheidole*	*biconstricta*	x	x	x			
Myrmicinae	*Pheidole*	*carapuna*	x					
Myrmicinae	*Pheidole*	cf. *chocoensis*	x					NR
Myrmicinae	*Pheidole*	cf. *flavens*	x	x	x			NR
Myrmicinae	*Pheidole*	cf. *glomericeps*		x	x			NR
Myrmicinae	*Pheidole*	cf. *laevinota*	x					NR
Myrmicinae	*Pheidole*	cf. *laselva*	x					NR
Myrmicinae	*Pheidole*	cf. *securiger*	x					NR
Myrmicinae	*Pheidole*	cf. *triconstricta*	x	x	x			NR
Myrmicinae	*Pheidole*	cf. *triplex*	x					NR
Myrmicinae	*Pheidole*	cf. *zeteki*	x					NR
Myrmicinae	*Pheidole*	*cramptoni*	x					
Myrmicinae	*Pheidole*	*deima*	x					
Myrmicinae	*Pheidole*	*fimbriata*	x	x	x			
Myrmicinae	*Pheidole*	*gauthieri*	x					
Myrmicinae	*Pheidole*	*jelskii*		x			x	NR
Myrmicinae	*Pheidole*	*minutula*	x	x		x		
Myrmicinae	*Pheidole*	msp14	x					
Myrmicinae	*Pheidole*	msp16	x					
Myrmicinae	*Pheidole*	msp20		x	x			
Myrmicinae	*Pheidole*	msp21	x					
Myrmicinae	*Pheidole*	msp24	x					
Myrmicinae	*Pheidole*	msp28	x					
Myrmicinae	*Pheidole*	msp29	x					
Myrmicinae	*Pheidole*	msp32	x					
Myrmicinae	*Pheidole*	*pedana*	x					
Myrmicinae	*Pheidole*	*perpusilla*	x					
Myrmicinae	*Pheidole*	*pugnax*	x	x	x	x		NR

Subfamily	Genus	Species	B2	B3	B3-S1	B3-S2	B3-S3	Notes
Myrmicinae	*Pheidole*	*sensitiva*	x					
Myrmicinae	*Pheidole*	*susannae*	x					NR
Myrmicinae	*Pheidole*	*vafra*	x	x	x			NR
Myrmicinae	*Pheidole*	*vorax*	x	x	x			
Myrmicinae	*Procryptocerus*	msp01	x					
Myrmicinae	*Rhopalothrix*	jtl014	x					NS, LL
Myrmicinae	*Rhopalothrix*	jtl016	x					NS, LL
Myrmicinae	*Rogeria*	*blanda*	x	x	x			
Myrmicinae	*Rogeria*	*lirata*	x	x		x		
Myrmicinae	*Rogeria*	*subarmata*		x	x			
Myrmicinae	*Sericomyrmex*	*amabilis*	x					NR
Myrmicinae	*Sericomyrmex*	*bondari*	x					
Myrmicinae	*Solenopsis*	spp.	x	x	x	x	x	
Myrmicinae	*Strumigenys*	*alberti*		x	x			
Myrmicinae	*Strumigenys*	*precava*	x					
Myrmicinae	*Trachymyrmex*	msp01	x					
Myrmicinae	*Trachymyrmex*	msp02	x					
Myrmicinae	*Trachymyrmex*	msp03	x					
Myrmicinae	*Trachymyrmex*	msp04	x					
Myrmicinae	*Trachymyrmex*	msp05	x					
Myrmicinae	*Trachymyrmex*	msp06	x					
Myrmicinae	*Wasmannia*	*auropunctata*	x					
Myrmicinae	*Wasmannia*	*scrobifera*	x					
Paraponerinae	*Paraponera*	*clavata*	x	x	x			
Ponerinae	*Anochetus*	*mayri*		x		x		
Ponerinae	*Anochetus*	*micans*	x	x	x			NR
Ponerinae	*Anochetus*	msp01	x					
Ponerinae	*Cryptopone*	*guianensis*	x					
Ponerinae	*Cryptopone*	jtl001	x					NS, LL
Ponerinae	*Hypoponera*	msp01	x					
Ponerinae	*Hypoponera*	msp02		x	x			
Ponerinae	*Hypoponera*	msp03	x					
Ponerinae	*Hypoponera*	msp04	x					
Ponerinae	*Hypoponera*	msp05		x	x			
Ponerinae	*Hypoponera*	msp06	x					
Ponerinae	*Leptogenys*	msp01	x					

Appendix 8

Preliminary list of identified ant species from BAT3 sampling (B3) near the Upper Berbice River and BAT2 sampling (B2) near Kaieteur Falls and the Upper Potaro River (*cont'd*)

Subfamily	Genus	Species	B2	B3	B3-S1	B3-S2	B3-S3	Notes
Ponerinae	*Leptogenys*	*pubiceps*		x	x			NR
Ponerinae	*Leptogenys*	*unistimulosa*	x					NR
Ponerinae	*Mayaponera*	*constricta*	x	x	x			
Ponerinae	*Neoponera*	*apicalis*	x	x	x			
Ponerinae	*Neoponera*	*carinulata*	x					
Ponerinae	*Neoponera*	*commutata*	x	x	x			
Ponerinae	*Neoponera*	*crenata*		x	x			
Ponerinae	*Neoponera*	*laevigata*		x	x			
Ponerinae	*Neoponera*	*striatinodis*	x					NR
Ponerinae	*Neoponera*	*unidentata*	x					
Ponerinae	*Neoponera*	*verenae*	x	x	x			
Ponerinae	*Neoponera*	*villosa*	x	x	x			
Ponerinae	*Odontomachus*	*haematodus*	x	x	x			
Ponerinae	*Odontomachus*	*hastatus*	x					
Ponerinae	*Odontomachus*	*meinerti*	x					
Ponerinae	*Odontomachus*	msp01	x					
Ponerinae	*Odontomachus*	msp02	x					
Ponerinae	*Pachycondyla*	*crassinoda*	x	x	x			
Ponerinae	*Pachycondyla*	*harpax*	x					
Ponerinae	*Platythyrea*	*sinuata*	x	x	x			
Ponerinae	*Prionopelta*	msp01	x					
Ponerinae	*Pseudoponera*	*stigma*		x	x	x		
Ponerinae	*Rasopone*	*arhuaca*	x					
Pseudomyrmecinae	*Pseudomyrmex*	msp01	x					
Pseudomyrmecinae	*Pseudomyrmex*	msp02	x	x		x		
Pseudomyrmecinae	*Pseudomyrmex*	msp03		x		x		
Pseudomyrmecinae	*Pseudomyrmex*	msp04	x					
Pseudomyrmecinae	*Pseudomyrmex*	msp05	x					
Pseudomyrmecinae	*Pseudomyrmex*	msp06	x					
Pseudomyrmecinae	*Pseudomyrmex*	msp07	x					
		Potaro+ Berbice	**B2**	**B3**	**B3-S1**	**B3-S2**	**B3-S3**	
	Totals	210	174	78	61	15	5	

Appendix 9

Decapod crustacean species of the Upper Berbice region

Group	Family	Genus	Species
Crab	Pseudothelphusidae	*Microthelphusa*	sp.
Crab	Trichodactylidae	*Sylviocarcinus*	*pictus*
Crab	Trichodactylidae	*Valdivia*	*serrata*
Crab	Trichodactylidae	*Poppiana*	*dentata*
Shrimp	Euryrhynchidae	*Euryrhynchus*	*wrzesniowskii*
Shrimp	Palaemonidae	*Macrobrachium*	*brasiliense*
Shrimp	Palaemonidae	*Macrobrachium*	*amazonicum*
Shrimp	Palaemonidae	*Macrobrachium*	*olfersii*
Shrimp	Palaemonidae	*Palaemon*	*carteri*

Appendix 10

List of plants collected from the Upper Berbice biodiversity assessment study - 20 September to 2 October 2014

Collection Number	Family	Genus	Species
4906	Adiantaceae	*Lindsaea*	*schomburgkii* Klotzsch
4866	Amaranthaceae	*Chamissoa*	
4972	Anacardiaceae	*Tapirira*	*guianensis* Aubl.
4812	Annonaceae	*Anaxagorea*	
4824	Annonaceae	*Anaxagorea*	
4956	Annonaceae	*Annona*	*sericea* Dunal
4892	Annonaceae	*Duguetia*	*quitarensis* Benth
4843	Apocynaceae	*Aspidosperma*	*excelsum* Benth.
4776	Apocynaceae	*Tabernaemontana*	
4920	Apocynaceae	*Tabernaemontana*	
4896	Apocynaceae	*Tabernaemontana*	*undulata* (Vahl) A.DC.
4851	Apocynaceae	*Tabernaemontana*	*undulata* (Vahl.) A.DC.
4845	Araceae	*Philodendron*	
4883	Araceae	*Philodendron*	
4821	Araceae	*Pistia*	*stratiotes* L.
4803	Arecaceae	*Astrocaryum*	*gynacanthum* Mart.
4986	Arecaceae	*Attalea*	*microcarpa* Mart.
4794	Arecaceae	*Bactris*	*elegans* Barb. Rodr.
4786	Arecaceae	*Bactris*	*oligoclada* Burret
4987	Arecaceae	*Bactris*	*ptariana* Steyerm.
4787	Arecaceae	*Geonoma*	*baculifera* (Poit.) Kunth
4796	Arecaceae	*Oenocarpus*	*bataua* Mart.
4848	Arecaceae	*Socratea*	*exorrhiza* (Mart.) H. Wendl.
4860	Aspleniaceae	*Asplenium*	*serratum* L.
4811	Asteraceae	*Mikania*	
4910	Bignoniaceae	*Arrabidaea*	
4938	Bignoniaceae	*Tabebuia*	
4900	Bombacaceae	*Pachira*	*aquatica* Aubl.
4875	Boraginaceae	*Cordia*	*bicolor* A. DC.
4773	Bromeliaceae	*Tillandsia*	*bulbosa* Hook
4818	Burseraceae	*Protium*	
4914	Celastraceae	*Maytenus*	*kanukuensis* A.C. Sm.
4890	Celastraceae	*Maytenus*	*kanukuensis* A.C.Sm.
4831	Chrysobalanaceae	*Hirtella*	
4926	Chrysobalanaceae	*Hirtella*	

Collection Number	Family	Genus	Species
4842	Chrysobalanaceae	*Licania*	
4899	Chrysobalanaceae	*Licania*	*coriacea* Benth.
4853	Chrysobalanaceae	*Licania*	*densiflora* Kleinh.
4902	Clusiaceae	*Clusia*	
4905	Clusiaceae	*Clusia*	
4949	Connaraceae	*Connarus*	*coriaceus* Schellenb.
4871	Convolvulaceae	*Ipomoea*	
4785	Costaceae	*Costus*	
4826	Costaceae	*Costus*	
4829	Costaceae	*Costus*	
4876	Cucurbitaceae	*Cayaponia*	*racemosa* (Mill.) Cogn.
4933	Cucurbitaceae	*Psiguria*	*triphylla* (Miq.) C. Jeffrey
4953	Cyperaceae	*Becquerelia*	*cymosa* Brongn.
4959	Cyperaceae	*Calyptrocarya*	
4795	Cyperaceae	*Diplasia*	*karataefolia* L.C. Rich.
4955	Cyperaceae	*Eleocharis*	
4960	Cyperaceae	*Eleocharis*	*geniculata* (L.) Roem. & Schult.
4894	Cyperaceae	*Rhynchospora*	
4966	Cyperaceae	*Rhynchospora*	*holoschoenoides* (Rich.) Herter
4912	Cyperaceae	*Scleria*	
4779	Dennstaedtiaceae	*Lindsaea*	*stricta* (Sw.) Dryand.
4858	Dichapetalaceae	*Tapura*	*guianensis* Aubl.
4801	Dichapetalaceae	*Tapura*	*guianensis* Aubl
4862	Dioscoreaceae	*Dioscorea*	
4917	Dioscoreaceae	*Dioscorea*	
4800	Fabaceae	*Acacia*	*tenuifolia* (L) Wild.
4870	Fabaceae	*Calopogonium*	*mucunoides* Desv.
4976	Fabaceae	*Chamaecrista*	
4940	Fabaceae	*Dimorphandra*	
4887	Fabaceae	*Eperua*	*falcata* Aubl.
4814	Fabaceae	*Inga*	
4822	Fabaceae	*Inga*	
4977	Fabaceae	*Inga*	*heterophylla* Willd.
4872	Fabaceae	*Inga*	*nobilis* Willd.
4868	Fabaceae	*Mucuna*	*urens* (L.) Medik.
4833	Fabaceae	*Parkia*	

Appendix 10

List of plants collected from the Upper Berbice biodiversity assessment study - 20 September to 2 October 2014 (*cont'd*)

Collection Number	Family	Genus	Species
4913	Fabaceae	*Parkia*	*ulei* (Harms) Kuhlm. var. surinamensis
4804	Fabaceae	*Pithecellobium*	
4931	Fabaceae	*Pithecellobium*	*adiantifolium* (Kunth) Benth.
4859	Fabaceae	*Pterocarpus*	*santalinoides* L´Hér
4874	Fabaceae	*Senna*	*occidentalis* (L.) Roxb.
4907	Flacourtiaceae	*Casearia*	
4911	Flacourtiaceae	*Casearia*	
4981	Gentianaceae	*Irlbachia*	*alata* (Aubl.) Maas
4775	Heliconiaceae	*Heliconia*	
4863	Heliconiaceae	*Heliconia*	*chartacea* Lane ex Barreiros
4935	Heliconiaceae	*Heliconia*	*spathocircinata* Aristeg.
4784	Heliconiaceae	*Heliconia*	*stricta* Huber
4885	Hymenophyllaceae	*Trichomanes*	*martiusii* C. Presl.
4903	Hypericaceae	*Vismia*	*guianensis* (Aubl.) Choisy
4898	Lauraceae	*Ocotea*	*schomburgkiana* (Nees) Mez
4847	Lecythidaceae	*Eschweilera*	*grandiflora* (Aubl.) Sandwith
4961	Lentibulariaceae	*Utricularia*	*foliosa* L.
4921	Lycopodiacae	*Lycopodium*	
4881	Malpighiaceae	*Banisteriopsis*	
4944	Malpighiaceae	*Banisteriopsis*	
4882	Malpighiaceae	*Banisteriopsis*	*martiniana* (Juss.) Cuatr.
4889	Malpighiaceae	*Byrsonima*	
4971	Malpighiaceae	*Byrsonima*	
4878	Malpighiaceae	*Stigmaphyllon*	*sinuatum* (DC.) A. Juss.
4791	Marantaceae	*Calathea*	*legrelleana* (Linden) Regel
4799	Marantaceae	*Ischnosiphon*	*puberulus* Loes.
4893	Marantaceae	*Monotagma*	*spicatum* (Aubl.) J.F.Macbr.
4919	Marantaceae	*Ischnosiphon*	*gracilis* (Rudge) Körn.
4865	Marantaceae	*Stromanthe*	*tonckat* (Aubl.) Eichler.
4964	Mayacaceae	*Tonina*	*fluviatilis* Aubl.
4968	Melastomataceae	*Clidemia*	
4774	Melastomataceae	*Miconia*	
4936	Melastomataceae	*Miconia*	
4984	Melastomataceae	*Miconia*	
4879	Meliaceae	*Guarea*	*guidonia* (L.) Sleumer

Collection Number	Family	Genus	Species
4895	Metaxyaceae	*Metaxya*	*rostrata* (Humb. & Bonpl. ex Willd.) C. Presl
4979	Moraceae	*Ficus*	*broadwayi* Urb.
4945	Myrtaceae	*Myrcia*	
4816	Myrtaceae	*Psidium*	
4954	Nymphaeaceae	*Nymphaea*	*rudgeana* G. Mey
4837	Orchidaceae	*Maxilaria*	
4947	Orchidaceae	*Pleurothallis*	
4978	Orchidaceae	*Pleurothallis*	
4852	Orchidaceae	*Prosthechea*	*aemula* (Lindl.) W.E. Higgins
4854	Orchidaceae	*Vanilla*	
4844	Passifloraceae	*Passiflora*	
4934	Passifloraceae	*Passiflora*	
4904	Passifloraceae	*Passiflora*	*acuminata* DC.
4942	Pentaphylacaceae	*Ternstroemia*	
4967	Piperaceae	*Peperomia*	*macrostachya* (Vahl) A. Dietr.
4916	Piperaceae	*Piper*	
4869	Piperaceae	*Piper*	*aequale* Vahl
4941	Poaceae	*Andropogon*	
4877	Poaceae	*Lasiacis*	*ligulata* Hitchc. & Chase
4857	Poaceae	*Olyra*	
4780	Polypodiaceae	*Microgramma*	
4778	Polypodiaceae	*Microgramma*	*lycopodioides* (L.) Copel.
4783	Polypodiaceae	*Pecluma*	*plumula* (H&B ex Wild) Price
4828	Pteridaceae	*Ceratopteris*	*pteridoides* (Hook.) Hieron.
4927	Rapateaceae	*Spathanthus*	
4970	Rubiaceae	*Borreria*	*capitata* (Ruiz & Pav.) DC.
4798	Rubiaceae	*Genipa*	*spruceana* Steyerm.
4770	Rubiaceae	*Geophila*	*cordifolia* Miq.
4925	Rubiaceae	*Hamelia*	*patens* Jacq.
4805	Rubiaceae	*Notopleura*	
4943	Rubiaceae	*Pagamea*	
4891	Rubiaceae	*Posoqueria*	*latifolia* (Rudge) Roem.
4817	Rubiaceae	*Psychotria*	
4864	Rubiaceae	*Psychotria*	
4789	Rubiaceae	*Psychotria*	*astrellantha* Wernham

Appendix 10

List of plants collected from the Upper Berbice biodiversity assessment study - 20 September to 2 October 2014 (*cont'd*)

Collection Number	Family	Genus	Species
4965	Rubiaceae	*Sipanea*	*hispida* Benth. ex Wernham
4962	Sapindaceae	*Matayba*	*inelegans* Spruce ex Radlk.
4909	Sapotaceae	*Pradosia*	*schomburgkiana* (A. DC.) Cronquist
4777	Selaginellaceae	*Selaginella*	*parkeri* (Hook & Grev.) Spring
4819	Solanaceae	*Solanum*	
4982	Solanaceae	*Solanum*	*crinitum* Lam.
4974	Solanaceae	*Solanum*	*Monachophyllum* Dunal
4975	Solanaceae	*Solanum*	*subinerme* Jacq.
4880	Urticaceae	*Cecropia*	*angulata* I.W. Bailey
4873	Verbenaceae	*Aegiphila*	
4808	Vitaceae	*Cissus*	
4958	Xyridaceae	*Xyris*	*jupicai* L.C. Rich

BIODIVERSITY ASSESSMENT SURVEY OF THE UPPER BERBICE REGION, GUYANA

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