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Testing the use of specimen collection data and GIS in biodiversity exploration and conservation decision making in Guyana

V.A. FUNK[1,*], M. FERNANDA ZERMOGLIO[2] and NASEEM NASIR[2]
[1]*Department of Botany, MRC 166, Smithsonian Institution, Washington, D.C. 20560, USA;* [2]*Centre for the Study of Biological Diversity, University of Guyana, Turkeyen Campus, Georgetown, Guyana;*
**Author for correspondence (fax: 202 786 2563; e-mail: funkv@nmnh.si.edu)*

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Abstract. This paper presents the results of a study conducted at the request of the Government of Guyana by the Centre for the Study of Biological Diversity at the University of Guyana, and the Smithsonian Institution. The purpose of the study was to evaluate the utility of using systematic collections in identifying areas with a high priority for conservation. A biodiversity database and a gazetteer were assembled and interpreted primarily through the use of maps generated in ARC/INFO and ArcView. The data were examined to determine coverage and completeness, and while in general the results support a continued use of the methodology for making informed decisions in conservation related issues, several recommendations are offered in order to enhance the data. The primary use of the results of this study is in the identification of areas of interest for conservation and in the location of eleven areas covering most ecoregions in Guyana that are in need of additional study. The eleven areas have been chosen to avoid areas that are already allocated to logging and mining concessions or Amerindian lands. While it is true that this study would benefit from additional data and further analysis of those data, it is also true that decisions concerning areas for conservation in Guyana are being made in the near future, and if any data are to be used in this process, it will be those data presented in this paper.

Key words: biodiversity, biological collections, GIS, Guyana, protected areas

Introduction

Stork (1995) cites three reasons for which actions affecting biodiversity and conservation are based on inadequate information:

- The data necessary for informed decision-making are unavailable, incomplete, or unreliable.
- The data are not presented in a format that policy-makers and managers can use.
- The data are incorrectly interpreted.

The following is an attempt to address some of these concerns for Guyana by providing a biodiversity information base for use in the selection of areas that should be investigated in the course of designing a national system of protected areas.

Bordered on the west by Venezuela, the east by Surinam, the south and southwest by Brazil, and with the Atlantic ocean to the north, Guyana covers an area of 215 000 km^2 (80 000 mi^2) an area about the size of Idaho (USA) and slightly smaller than Great Britain. Guyana is endowed with a diverse array of habitats including: coastal mangroves, the vast Rupunini savannas in the southwest, smaller white sand savannas, swamps, marshes, dense tropical forests, deciduous forests, the famous Greenheart forests, and the legendary sandstone covered table top mountains with montane slope forests and summit tepui vegetation of the Pakaraima mountain range in the western region of the country including Mt. Ayanganna (2100 m) and Mt. Roraima (2800 m). Despite this wealth of natural habitats, a lack of infrastructure and the poor quality of the soils restricts the majority of Guyana's population (approximately 800 000) to residing on a narrow strip of coastal plain, primarily near the capital city of Georgetown. With the exception of the coastal regions and the Rupununi savannas, the country is relatively undisturbed and many areas are nearly pristine (Dinerstein et al. 1995; Funk 1997). Despite its vast expanses of relatively untouched lowland and montane forest, Guyana is often ignored by global priority setting initiatives in conservation (Olson and Dinerstein 1998; Mittermeier et al. 1998).

Although the forests in the interior have been protected by their isolation for many years, indeed they have been categorized as relatively stable by conservation initiatives (Dinerstein et al. 1995), they are now facing serious pressure from Asian timber companies, gold, diamond, and bauxite mining, wildlife traders, and the construction of new roads making the interior more readily accessible to larger numbers of people (Sizer 1996). In spite of these impending threats, Guyana only has one protected area, Kaieteur National Park (KNP), an 11 hectare area surrounding Kaieteur Falls. Recently, an expansion of KNP has been proposed by the Government of Guyana.

Strapped by a burgeoning international debt and the second lowest per capita income in the western hemisphere, the Government of Guyana is attempting to address the needs of the economy while at the same time setting aside areas for conservation. In so doing, the Government is acting on the recommendations made at the United Nation's Convention on Environment and Development to identify components of biodiversity important for conservation and sustainable use, and monitor, through sampling and other techniques, the components of biological diversity identified (also Articles 8, 9, and 10 of the Convention on Biological Diversity; Glowka et al. 1994).

Inventorying and monitoring of biodiversity in Guyana has been a long-standing interest for the Biological Diversity of the Guianas program (BDG) of the Smithsonian Institution (Boggan et al. 1992, 1997; Huber et al. 1995; Funk 1997). The collections made over the last 10–15 years by the BDG, combined with data taken from collections made over the last century by institutions world-wide, permit Guyanese and foreign scientists to investigate the country's biological composition. The benefits of these scientific endeavors for the sciences and society in general were discussed extensively by Stork (1995) and include the ability to verify field data with voucher specimens and the availability of specimens for checklist compilation. In light of the biosystematic crisis that Guyana now faces due to unrestrained development, international debts, and increasing environmental degradation, the BDG has placed a priority on continuing its efforts to help the Government address the practical needs for conservation initiatives and sustainable development in the country. In conjunction with biodiversity inventories, this effort provides part of the information that is required for informed decision-making. However, biological data cannot be the sole consideration in the establishment of protected areas. Indeed, researchers have shown again and again that the selection of areas for protection would be ineffectual without considering the needs and desires of the country's population (Diamond 1985; Painter 1988; Pimm and Gilpin 1989; Gadgil et al. 1993; Redford 1992; Sizer 1996). McNeely (1995) points out that losses of biodiversity stem from changes in attitudes toward nature, growth in human population and natural resource consumption, the impact of global trade, economic systems that fail to value the environment and its resources, and inequity in the ownership, management, and flow of benefits from the use and conservation of biological resources. Although they are not the focus of this paper, demographics, logging and mining concessions, and Amerindian lands were taken into consideration when designating areas of interest for further study.

The preliminary analysis presented below expands on the already existing BDG plant database of recent collections by incorporating a wealth of additional collection-based data from other museums and institutions. It constitutes the beginning of an information base about Guyana's biodiversity that will be used as a fundamental point of reference when selecting areas for conservation.

The data from the study were used to address the following questions:

1. What are the distributions of plants and animals in Guyana?
2. Where are the areas of greatest species richness and rarity?
3. How well do the data explain the biodiversity of Guyana?
4. What areas of Guyana are in most need of additional collecting efforts?
5. Can these data be used in conservation decision-making?

Methods

To determine the distribution of all plants and animals in Guyana would be an extensive task requiring a prolonged effort, as there are nearly 7000 known species of flowering plants alone in the country (Boggan et al. 1997). Consequently, in order to obtain a pattern representative of the current state of knowledge about the country's biodiversity within the time constraints of the project, the study focused on representative genera in 12 groups of organisms. These groups span a wide variety of organisms such as orchids, frogs, termites, and birds, and consisted of an average of three (2–18) representative genera within each group. The groups were selected based on three criteria. First, that a specialist in the group was available for consultation. This insures that the nomenclature for the collections surveyed had all been recently up-dated, thereby eliminating a majority of taxonomic errors and confusion. The necessity of accurate taxonomic treatment was eloquently expressed by May (1990b): “Without taxonomy to give shape to the bricks and systematists to tell us how to put them together, the house of biological science is a meaningless jumble.” Secondly, in order to obtain a maximum coverage of Guyana’s diverse ecological habitats, at least one genus selected in each group of organisms contained species with widespread distributions. For instance, the hummingbird group was selected for this purpose because it is a family of birds whose habitat varies from tropical forests to open savannas and alpine environments. Thirdly, to evaluate which species might be restricted in their distribution, another genus within each group was selected containing representatives with a high ecological fidelity (restricted distributions). This final criterion for genus selection is similar to that offered by proponents of the indicator species approach to biodiversity conservation (Brown 1991; National Research Council 1993; Stork 1995) which states that among other things, that an indicator species must have a narrow range of ecological specialization (restricted geographical distribution). Table 1 lists the groups and the number of genera and species chosen for this study. A complete species list (494 species), is available from the authors on request.

Table 1. Biological data.

Groups	No. of Genera	No. of Records	Institutions
Birds	18	1050	AMNH, BM, PA, US
Butterflies	7	306	Allyn, AMNH, BM, Booth, Castle, Ox
Frogs & Lizards	4	1256	AMNH, BM, ROM, US, UNMZ
Mammals	4	1426	AMNH, BM, ROM, US
Termites	3	341	AMNH, BM, US
Orchids	5	233	AMES, BRG, BM, FDG, K, MO, NY, SEL, U, US
Chrysobalanaceae	3	552	BDG, BM, K, NY, U, US
Ferns	4	735	BDG, BM, K, NY, U, US
Lecythidaceae	2	328	BDG, BM, K, NY, U, US
Legumes	2	601	BDG, BM, K, NY, U, US
Melastomes	3	300	BDG, BM, K, NY, U, US
Sedges	2	599	BDG, BM, K, NY, U, US
Total	57	7727	

* AMES (Ames Orchid Herbarium, Harvard), Allyn (Allyn Butterfly Museum, Sarasota, Florida), AMNH (American Museum of Natural History, New York), BDG (Biological Diversity of the Guianas Program data Base, Smithsonian), BM (British Museum, London), BRG (Guyana National Herbarium, University of Guyana), Booth (Booth Museum, Brighton, England), Castle (Castle Museum, Norwich, England), FDG (Forestry Commission, Guyana), K (Royal Botanic Gardens at Kew, England), NY (New York Botanical Garden, Bronx), Ox (Oxford Museum, England), PA (Philadelphia Academy, Pennsylvania), ROM (Royal Ontario Museum, Toronto, Canada), SEL (Selby Botanical Garden, Sarasota, Florida), U (University of Utrecht Herbarium, The Netherlands), UNMZ (University of Michigan, Zoology Museum, Ann Arbor), US (Smithsonian Institution, Washington, D.C.)

Efforts to conserve biological diversity require a knowledge of the biota. The most common approach to understanding biodiversity is species location data (McNeely et al. 1990; Coddington et al. 1991; WRI/IUCN/UNEP 1992). Distribution patterns for each selected group were determined by documenting the data from collections currently housed around the world at museums, herbaria, botanical gardens, and private collections (hereafter collectively referred to as museums). These collections provide a permanent historical record of the existence of each species at a specific locality and date, and are a vital and cost-efficient source of baseline data for inventorying and monitoring biological diversity (Stork 1995). Several comprehensive discussions on the benefits of using museum collections in biodiversity assessments have been published (Miller 1993; Goodman and Lanyon 1994; Spellerberg 1994; Cotterill 1995; Stork 1995). The majority of the information for the database for this study was taken from specimens and from existing databases located at the Royal Botanic Gardens at Kew, and The Natural History Museum, both in or near London; the Herbarium at the University of Utrecht; the Royal Ontario Museum in Toronto; the National Collections housed at the University of Guyana; and the American Museum of Natural History, the New York Botanical Gardens, and the Smithsonian Institution in the United States. In addition, the butterfly data contains information from specimens housed at a few important private museums (for a complete list see Table 1). To the best of our knowledge, these institutions maintain the principal holdings of biological specimens from Guyana.

The data were compiled in dBase IV, a program selected by virtue of its simple format, allowing a fairly simple conversion into other database programs such as Access, and because of its compatibility with the GIS software ARC/INFO. Several biodiversity database projects have provided a practical set of guidelines for the development of large databases (MacKinnon 1992; MacKinnon 1994; Filer 1994). However, the preliminary nature of this study and an anticipation of the future needs for the country required the design of a specific database structure (Table 2). For example, having a collection-based biodiversity survey required that the location of each particular specimen be designated, so several fields were incorporated into the database in order to facilitate this process, including the following: the Institution where the specimen is housed (Institut), the museum accession number for the specimen (Seriesnum), and the physical location, based on that institution's locator system, usually in the form of numbered rows and columns or alphabetical by family (Slide_loc). Some fields, such as the latitude and longitude, were used for all organisms, while other fields were not applicable to all groups. For example, the field Host (number 28) would remain empty for all organisms in this study except termites, whose description is contingent upon this information. Likewise, the field Sex (number 31) would not necessarily be occupied in the plant databases, though it is an essential descriptive characteristic for birds and mammals.

The database contains a total of 7727 records. During the time of data collection, an approximate count was taken of the total holdings for each group selected at all

Table 2. Database field structure.

No.	Field name	Field type	Field width
1	Instituts	character	16
2	collector	character	25
3	SeriesNum	character	10
4	Coll_Num	character	10
5	Family	character	20
6	Genus	character	26
7	species	character	32
8	Qual	character	5
9	Author	character	40
10	Det_date	character	55
11	Duplicates	character	3
12	Slide_Loc	character	10
13	Collteam	character	50
14	Colldate	character	26
15	Country	character	9
16	Province	character	50
17	Sorting	character	2
18	Locality	character	100
19	Elevm1	character	5
20	Elevm2	character	5
21	Lat_dgr	numeric	2
22	Lat_min	numeric	2
23	Lat_sec	numeric	2
24	Long_dgr	numeric	3
25	Long_min	numeric	2
26	Long_sec	numeric	2
27	Habitat	numeric	125
28	Host	numeric	35
29	Description	numeric	125
30	Notes	numeric	55
31	Sex	numeric	1
32	Type	logical	1
33	Supplement	memo	10
34	Barcode	character	8
35	Rec_no	numeric	3
36	Long_dd	float	11
37	Lat_dd	numeric	9
38	Rep	numeric	3
39	Up_date	character	10

institutions visited, both for those groups within Guyana and the groups in general. From these calculations, we estimate that the study sample consists of an average of 3% of the known species per selected group. This estimate determination includes an extreme range variation in values for certain groups of organisms, such as orchids with 50% and insects with less than 1% species coverage.

Because many historical collections have little or no information on the labels and do not cite latitude and longitude, a method for georeferencing these was established to allow their incorporation into ARC/INFO. First, a gazetteer of localities in Guyana was assembled using the BDG database, the available literature (Snyder 1966; Stevens and Traylor 1985; Gorts-Van Rijn 1990), and expert advice. Second, a latitude and longitude were assigned to localities based on recognized sites and supplemented by extensive map measurements. Finally, additional localities were identified through consultations with individuals having a pertinent knowledge of Guyana. These efforts notwithstanding, many records (31%) could not be georeferenced, particularly those within the bird and butterfly databases, and it is apparent that only the implementation of new methods for georeferencing sites will make these data useful to mapping endeavors. So that we could glean all available information from the data, the specimens that could not be georeferenced were included in the database and were examined by means of a table (see Discussion below) and were used to produce species lists.

Distribution patterns for each selected group were examined using ARC/View (2.0) in conjunction with layers consisting of the most current maps for vegetation and geology, political boundaries and divisions, major rivers and streams, towns and some types of land-use maps. A capability to manipulate and analyze the data in conjunction with these maps is essential for the expansion of our knowledge base of biogeographic patterns and the interrelationships between soils, geology, temperature, dispersal mechanisms, and other parameters. In addition, as discussed in the next section, these layers provide the physical data necessary for a comprehensive ecosystems approach in the evaluation and appraisal for conservation through the use of various environmental modeling software packages currently available, such as Bioclim, Domain, and BioRap (Busby 1991; Carpenter et al. 1993; Margules and Redhead 1995).

Results and discussion

Distribution of plants and animals

Species distribution maps (dot maps) were produced for each of the selected groups of organisms. Each dot represents a locality with at least one collection of one species. The example presented here is for five genera and ca. 60 species of frogs and lizards (Figure 1). The correlation between collection sites and major rivers is evident when examining the data sets. Another problem, demonstrated by Table 1 in conjunction with the frog and lizard dot map (Figure 1), is that although the total number of records for the 57 species of frogs and lizards surveyed is 1256, the actual number of collecting localities obtained is only 225. The dot maps are helpful in illustrating the regions where past inventories in Guyana have focused and in indicating areas having no known collections. However, their main weakness is that they do not give

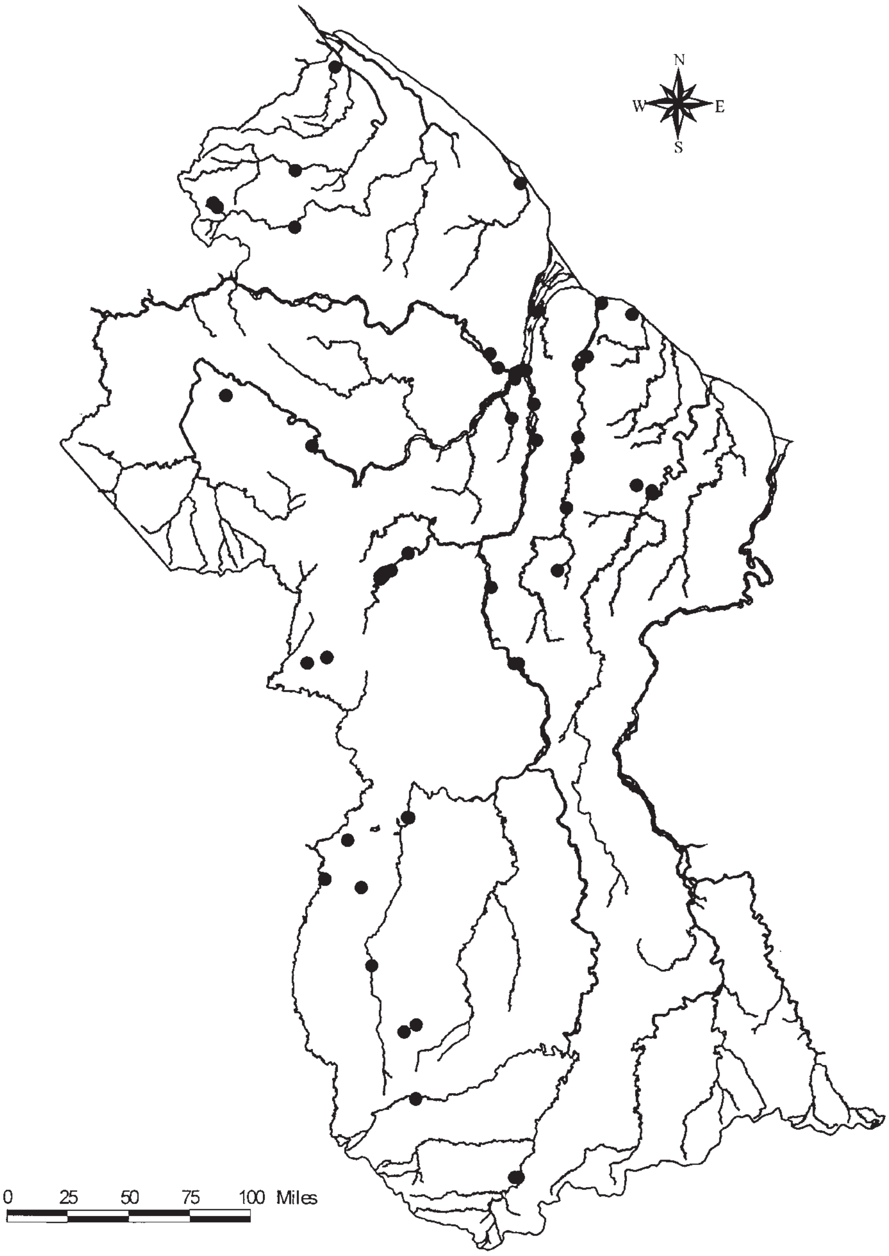

Figure 1. Map of Guyana, each dot represents at least one collection of at least one species of the representative genera of frogs and lizards selected for this study. Map produced by the Centre for the Study of Biological Diversity and the Smithsonian Institution.

any indication of collection density (i.e. how well an area has been collected). This problem was overcome by generating species richness maps (see below).

In order to gain a better understanding of ecosystem representation by the groups surveyed, species distribution maps were compared with a recently published vegetation map of Guyana that was drawn from satellite imagery (Huber et al. 1995). The objective of this analysis was to determine whether this project's current information was sufficient for making informed decisions about the distribution of species in similar habitats based on the presence of a well studied site within this habitat. The results, however, show that the vegetation map is not sufficiently detailed to assist in the analysis and that inferences cannot be drawn without additional data. One example of this problem is the riparian forests buffering virtually all major rivers in Guyana. In terms of the number of collections, the analysis showed that these tall, evergreen, flooded riparian forests comprise the best represented ecosystem type in this study with 20% of the 7727 records collected having been made in them. Without a doubt this is so because of the ready accessibility of these areas. However, a cursory inspection of the actual species composition within each major riparian zone of the various rivers shows that there are distinct differences between the forest types buffering each river. For example, the forests along the Essequibo, Demerara, and Cuyuni rivers tend to have many representatives of the Legume genus *Eperua*. *Eperua* species have very distinctive fruits and the genus has been commonly collected in Guyana. In contrast, only one of the five species of *Eperua* is found along the Barima and Corentyne rivers, even though they have also been visited by several expeditions. In addition, the few collections made in the riparian forests in the southern portion of the country indicate they have a dramatically different floristic composition.

The vegetation map (Huber et al. 1995) records four clearly distinct types of swamp forests in Guyana: Medium, evergreen/semi-deciduous gallery forest; two types of low, evergreen, seasonally flooded swamp forest; and Low/medium, evergreen, riparian and gallery forests. Representation profiles within the swamp forest types in this study differ dramatically, with the highest number of representatives varying between groups: plants (37 collections) are best represented in the medium, evergreen/semi-deciduous gallery forests, while animals, insects, and invertebrates (23 collections) have the highest representation in one class of low, evergreen, seasonally flooded swamp forest. This imbalance in representation demonstrates that there indeed exist clearly defined types of swamp forests in Guyana which differ in species composition and completeness of survey. Any inferences made on species composition between each forest type are thus not viable for predicting accurate representation patterns without more definitive data. These disparities in ecosystem representation illustrate the difficulties involved in drawing inferences from inadequate data.

Although the above conclusions are drawn from a relatively small portion of data, they do indicate that some floristic patterns on the vegetation map have not been clearly demarcated and are in need of revision. Such work will require the acquisition of additional data and manipulation of the data. Meanwhile, more inferences than the ones proposed here cannot be drawn from the existing information.

Species richness and rarity

Species richness and rarity have been the most commonly cited measures of biological density (Helliwell 1969; Margules and Usher 1981; Usher 1986; Prendergast et al. 1993; Willis et al. 1996; Borchsenius 1997). However, various definitions have been proposed for species richness (Spellerberg 1992). The term species richness is used here to indicate the total number of species in an area. Species Richness maps were produced by overlaying a grid on the country, and calculating the total number of species within each grid square. These were generated for each taxon individually, and then collectively for all groups surveyed. Figure 2 demonstrates that there are three areas in Guyana where over 50 species of our target taxa have been collected (red squares). These 'hotspots' are (1) Georgetown, the capital, located on the coast, (2) Kartabo-Bartica, located up the Essiquibo river at the confluence of three major rivers; it used to be the capital and it is a major point of entry into the interior, and, (3) Kaieteur Falls, a ca. 800 ft. single drop waterfall located at the edge of the Potaro plateau in the center of the country. All three of these areas have been the focal point of expeditions. For instance, William Beebe lived in Kartabo for many years and collected animals in the area (Beebe 1925, 1927) and the Smithsonian Institution has been conducting an inventory in the Kaieteur area for many years (Kelloff and Funk 1998). Another area with high numbers of species is the Rupununi Savanna and the Kanuku Mountains in the southwestern part of Guyana. The most species rich locality is Georgetown with 118 species, 1/5 of the total count for the species covered in this project. As in previous maps, Figure 2 substantiates the strong correlation between collecting localities and major landmarks such as old cattle trails, roads, rivers, and landing strips.

Any measure of the number of species that are rare, endemic, or have a restricted range is difficult to obtain with the existing data. Although some of the species in this study have a restricted range, without detailed knowledge of the entire distribution, we cannot comment on whether or not it is endemic. Moreover, there are many areas of Guyana that have not been properly surveyed, and this lack of information makes uncertain any designation of something as rare, endemic or restricted in range. Certainly literature searches and expert knowledge are useful for some of the taxa, however, the time constraints of this project make it impossible to incorporate this type of information and when groups are seriously under collected, even the literature and experts cannot help. The one group where we have some information on restricted range is the orchids where we have 50% of the species inventoried for all museums. These data indicate that the Kaieteur Falls area has many species of orchids found nowhere else in Guyana. However, one must view these numbers with some caution

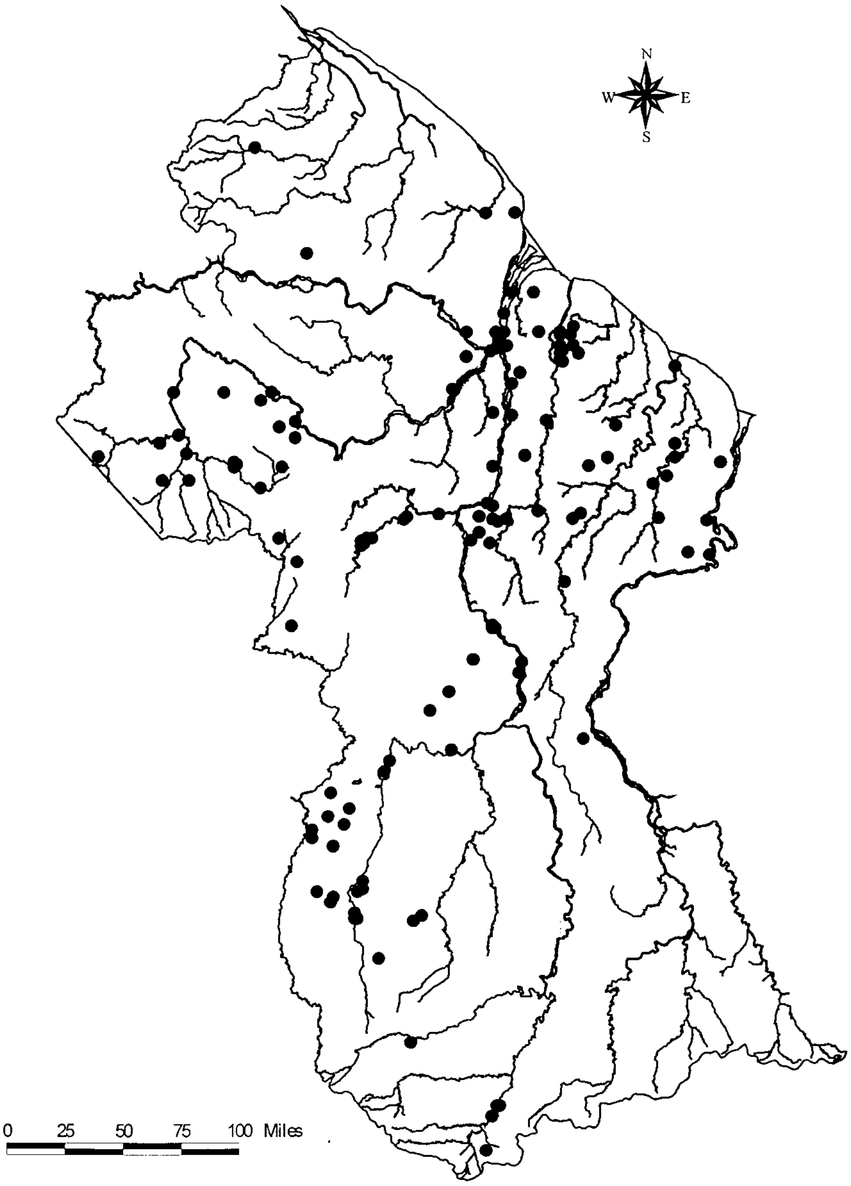

Figure 2. Map of Guyana, each dot represents at least one collection of at least one species of the representative genera of legumes selected for this study. Map produced by the Centre for the Study of Biological Diversity and the Smithsonian Institution.

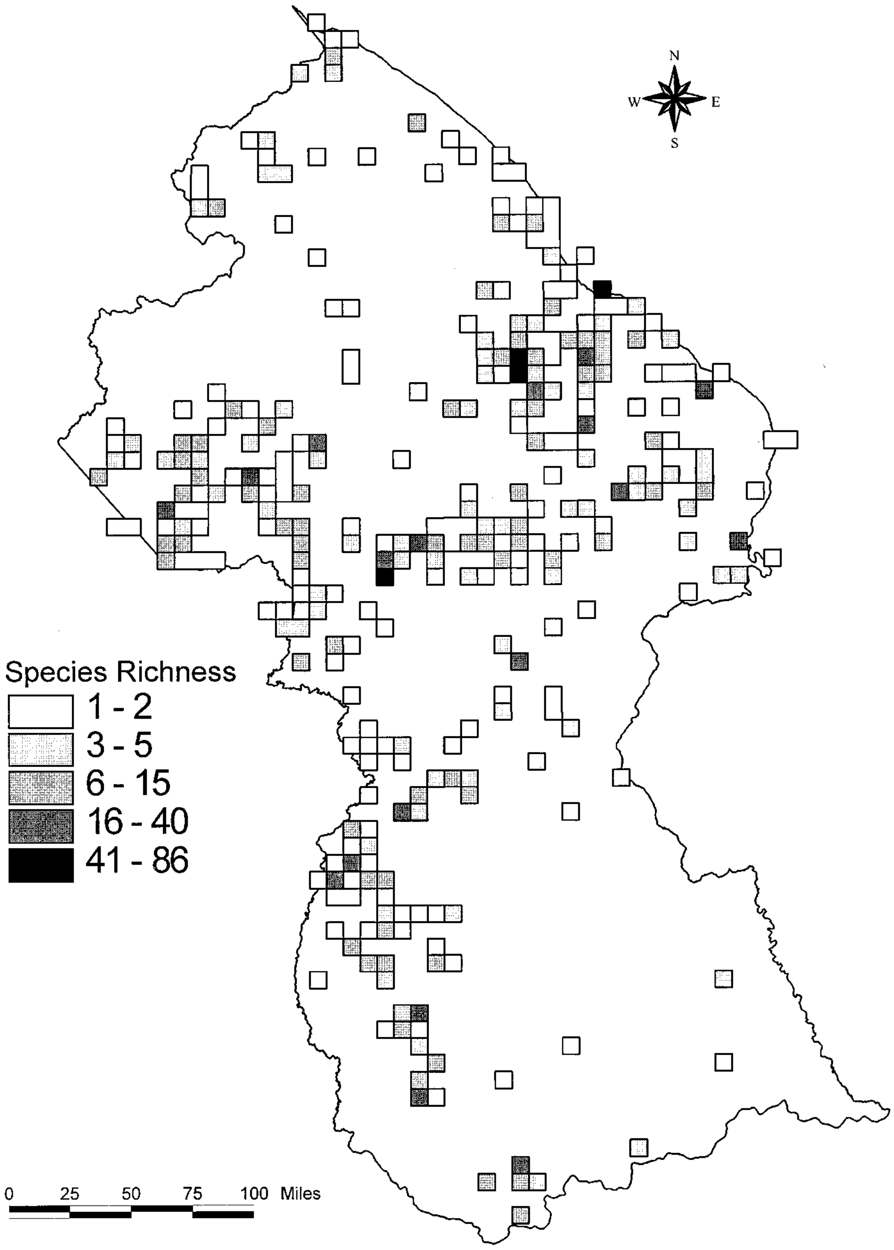

Figure 3. Map of Guyana with a grid showing the density of collecting for all ca. 500 species sampled. Map produced by the Centre for the study of Biological Diversity and the Smithsonian Institution.

because in 1996 a visit by an orchid specialist to the Kaieteur area doubled the number of species (from 100 to 200) known from the area close the waterfall.

Coverage and completeness of data

It is a common practice for management decisions to be based on the interpretation of incomplete data using GIS technology, and the efficacy of any conservation initiative is generally measured against the quality of the data and the reliability of the interpretation (Pressey et al. 1992; Neldner 1995; Olivieri 1995). So the question that is really important is: 'How well do the data represent the biodiversity of Guyana?' The adequacy of the data in this study was examined with respect to two criteria: coverage and completeness. To illustrate these analyses, we applied information from the only group for which comparative data are available, mammals. The mammalogists at the Royal Ontario Museum provided two sets of data. The first set contained all of the collection information for four genera, which together represent 1% of all the species of rats and bats found in Guyana. The second set had only the latitude and longitude for all Guyana mammals specimens housed in collections around the world. The disparities between data sets are evident on the 'Mammal Collection Sites' map (Figure 4). The black dots show the collection sites of the four genera used in this study and the gray dots are all the mammal collection sites for Guyana. In contrast to what other studies have shown (Smith et al. 1997) an inspection of the map demonstrates the inadequacies of using 1% of the data available for elucidating a comprehensive coverage of collection sites, and also illustrates that it is a necessity to boost the amount of data used for analysis. It is estimated that increasing the baseline biological data to 10–25% of species surveyed from collections would provide more accuracy to current distribution patterns for the selected taxa, and would render useful a remarkable wealth of information that has already been collected on the biological diversity of the country (Stork 1995). This recommendation relies heavily on the demonstration by others that tapping further into these sources has the potential of permitting further identification of gaps in the current knowledge base, as these historical collections provide the fundamental resources of biological diversity assessment (Lund and Thomas 1995). The costs for data improvement are minimal (Stork 1995), even while expanding the number of focus groups to include more plants and invertebrates.

To evaluate data completeness, at least some cursory knowledge of specific habitat requirements for each group of organisms is necessary since it is a reflection of how well they have been collected (Prance 1994). The database contains records of all known collections of the family Trochilideae (hummingbirds) from Guyana. Figure 5 shows how few sites actually have documented occurrences of hummingbirds. However, based on known habitat requirements and collections of hummingbirds made in Brazil and Venezuela, it is evident that hummingbirds are probably found over most of the country. With these few records the possibility of detecting

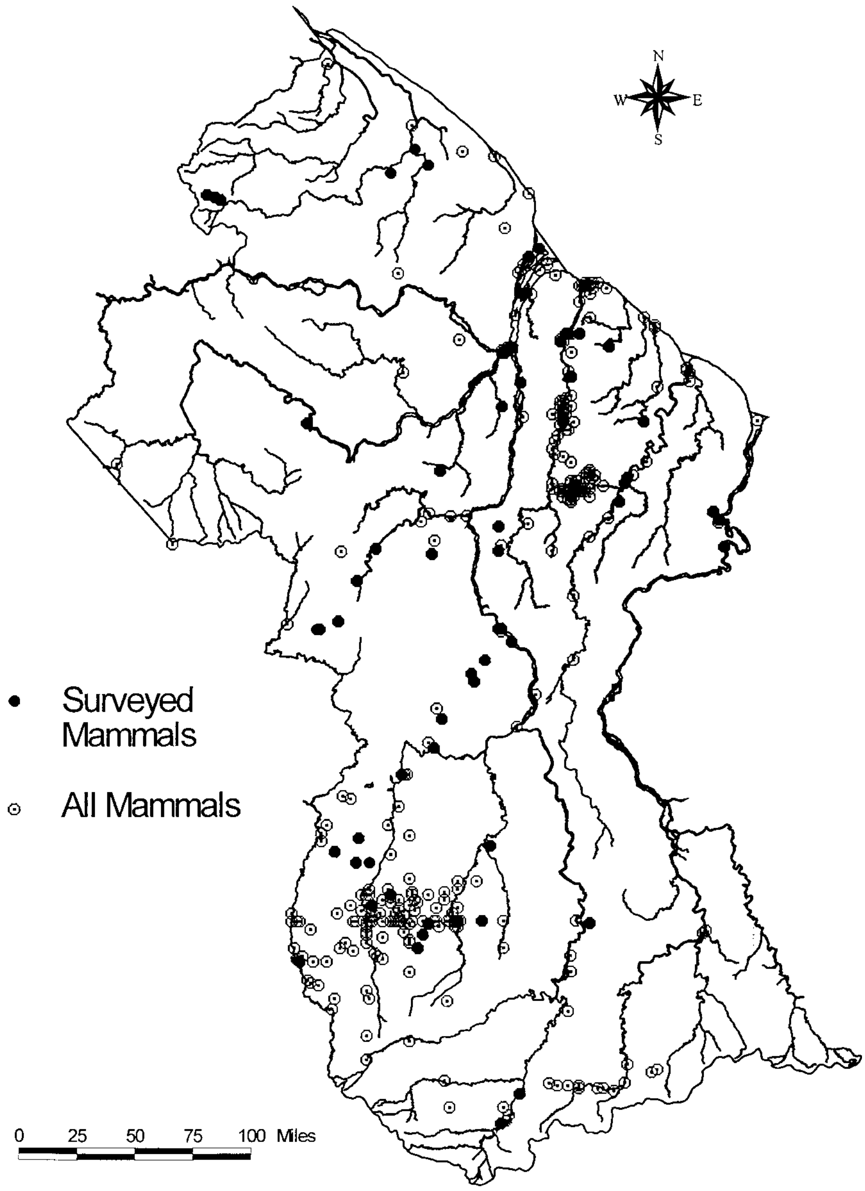

Figure 4. Map of Guyana, each dot represents at least one collection if at least one species of either the species surveyed (black), or all localities that have every been collected for mammals (circle with small dot). Map produced by the Centre for the Study of Biological Diversity and the Smithsonian Institution.

distributions, endemism, or richness of any species of hummingbird is impractical. Also, in the specific case of hummingbirds, because all of the available museum data have been gathered, new surveys will need to be conducted in order to aug-

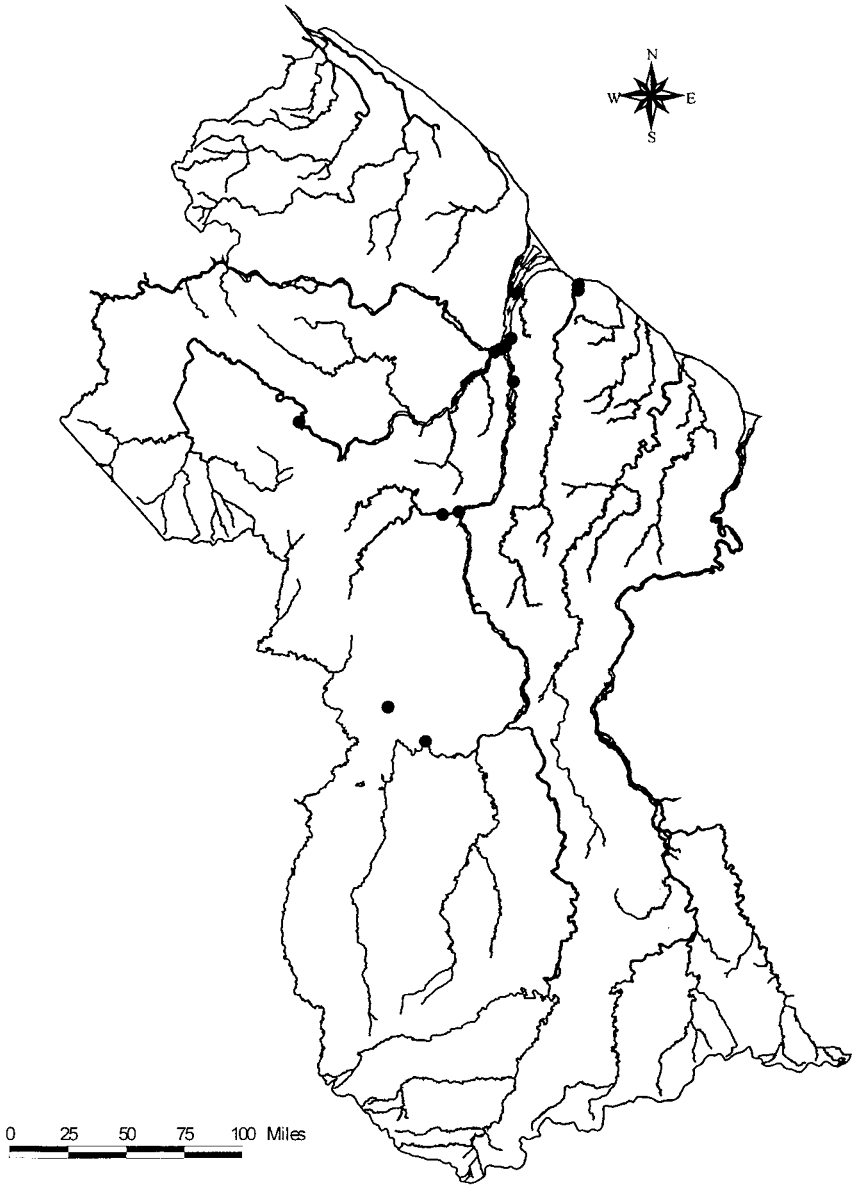

Figure 5. Map of Guyana, each dot represents at least one collection of at least one species of all genera of hummingbirds known from Guyana. Map produced by the Centre for the Study of Biological Diversity and the Smithsonian Institution.

ment the data. It seems that a more comprehensive analysis of the distributions for each group of organism will require that additional information be collected, both from museums and the field. While it is realistic that additional information will be collected in the next year or so, it is unrealistic to expect that all unexplored areas will be surveyed in the near future. Some manipulation of the data will no doubt have to be considered.

Though many questions require additional data, two conclusions are indisputable with respect to existing data: that there are many areas of Guyana for which we have little or no information and that for all but a few groups and areas the total collection numbers are not sufficient to give an accurate representation of collecting intensity. Both of these are illustrated in Table 3, which incorporates data containing collection and species numbers for each group of organisms collected, at a few selected general localities in Guyana. A tabular representation has at least one advantage over the species richness maps because the maps cannot incorporate non-georeferenced (vague) specimen data. For instance, a number of specimens were labeled ‘Kanuku Mountains’ but without a specific locality and so could not be georeferenced. In the table, however, we are able to include the total number of taxa collected for the mountains. The table shows Kartabo as the site with the largest number of collections in Guyana (696), in addition it illustrates that a large majority of the collections are frogs and lizards, or termites, while other groups such as plants and butterflies have been scarcely surveyed. The necessity for including the number of different species is noted in the same site, since the 696 collections of frogs and lizards represent only 64 different species. The implication from this is that many collections of the same species have been made in the area, and that areas should not be classified as ‘species rich’ based solely on total number of collections. An additional observation from the table is the high number of species (118) which have been collected in the greater Georgetown area. Obviously, it is likely that a large percentage of these species have disappeared due to housing and agricultural development in the vicinity. The lack of information available for regions like the Pakaraima and Kanuku mountains shown in

Table 3. Selected list of collecting areas (No. of collections/No. of species).

Organism	Georgetown	Kartabo	Ayangana	New River
Birds	70/22	63/10	0	0
Butterflies	35/14	0	0	0
Frogs & Lizards	222/15	397/27	0	0
Mammals	30/5	47/5	0	0
Termites	4/2	185/18	0	2/2
Orchids	14/10	0	0	0
Chrysobalanaceae	36/14	1/1	1/1	0
Ferns	33/9	1/1	0	0
Lecythidaceae	29/12	0	0	0
Legumes	12/5	0	0	0
Melastomes	14/5	2/2	1/1	0
Sedges	44/16	0	0	0
Total	543coll/131spp	696coll/64spp	2coll/2spp	2coll/2spp

this table also reflects the need for implementing new biodiversity inventory efforts in these regions.

The paucity of data available for insects and other invertebrates presents a problem considering their estimated diversity and their fundamental role in ecosystem health (Erwin 1982, 1983; May 1986, 1988, 1990a, 1990b; Wilson 1987; Stork 1988, 1995; Kim 1993; Miller 1993; Samways 1993; Colwell and Coddington 1994). A proper survey of insects is imperative in the assessment of biodiversity in Guyana. Nevertheless, this study included only about 60 species in total for both butterflies and termites, a value far less than 1%. Funding specialized insect and invertebrate field collectors as part of the data gathering efforts would strongly enhance these data.

Additional collecting efforts

In terms of further inventory, the most efficient approach for reconciling some of the gaps is to use the GIS data to identify areas in Guyana that demonstrate the greatest need for additional information. Currently there are about 7–10 expeditions a year into the interior of the country so, over a relatively short period, additional insight could be gained into many of these areas. Based on the results of the GIS studies, and complemented by discussions among the scientists involved and the staff at the Centre for the Study of Biological Diversity (University of Guyana), and the Guyana branch of Conservation International, the following 11 areas are here suggested as the most important for collecting (in alphabetical order). Most of these areas are accessible only via a complex trip requiring several days of travel by plane, boat, and on foot. Because we hope to help to prepare these areas for both rapid and long-term studies, we have selected those that are the most interesting biologically and that have the least amount of overlap with other land utilization practices such as logging, mining, and Amerindian lands (all are shown in Figure 6).

A. (1) Mt. Ayangana (2020 m) and (2) Mt. Wokomon (2000 m) are part of the Pakaraima Mts. and are the two highest peaks wholly in Guyana. Lowland rainforest surrounds their bases, their slopes are exposed rock or montane forests, and tepui vegetation crowns the exposed plateaus. Although each has been visited for a few days, they remain largely unknown. Mt. Ayangana has been proposed as a national park (Dalfelt 1978; Ramdass and Hanif 1990) and Mt. Wokomon as a Scientific Reserve (Ramdass and Hanif 1990).

B. The (upper) Berbice River is one of the three major rivers of Guyana. The upper basin of the Berbice River contains some areas of untouched forest (including Dubulay Ranch) and wet sand savannas and is home to important populations of giant otters, giant armadillos, and a wide variety of snakes. Down river, most areas are heavily disturbed. Parts of the Berbice River basin have been proposed as a biological reserve/wildlife sanctuary (Dalfelt 1978).

C. The (upper) Cuyuni River has a relatively unexplored headwaters area with many species from the Guiana Shield area. Recent expeditions give evidence of a

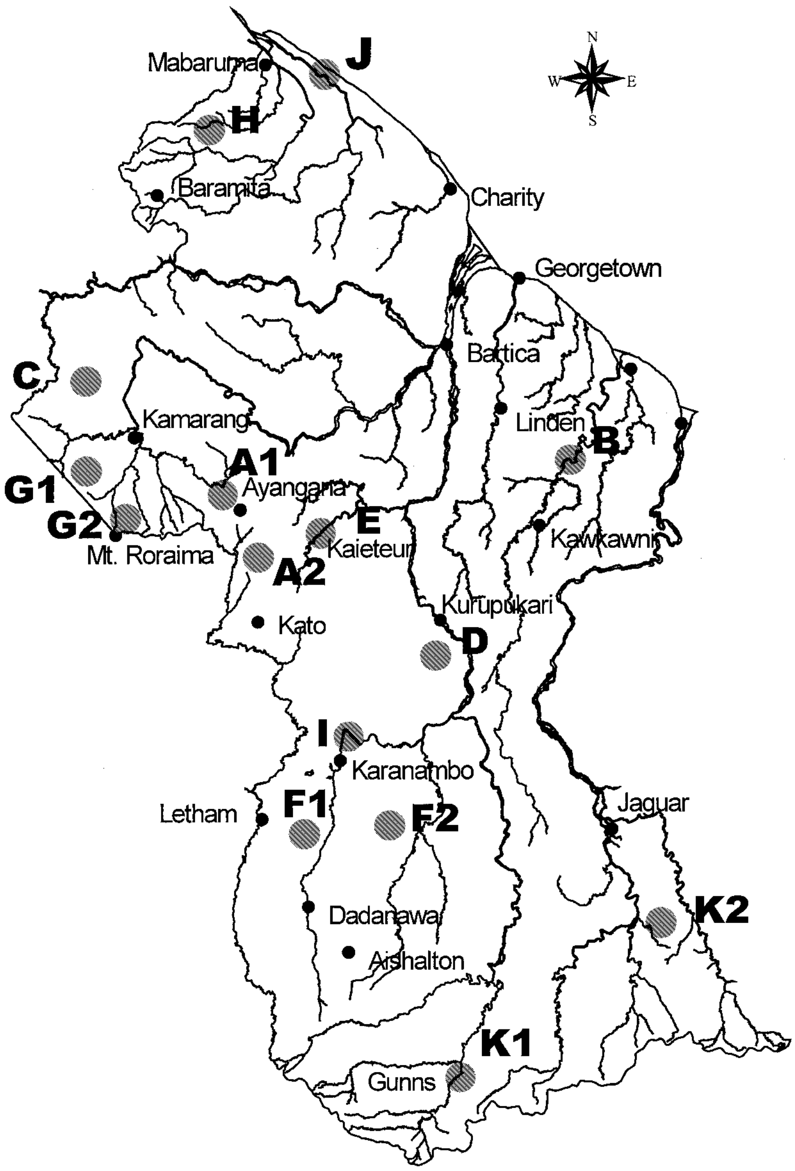

Figure 6. Map of Guyana showing the areas that are in need of additional collectng. Some or all of these areas may be recommended for conservation. Map produced by the Centre for the Study of Biological Diversity and the Smithsonian Institution.

unique flora that is very poorly studied and an unsampled fauna. In addition, the Cuyuni is a large river and important water source.

D. The (1) Essequibo River (upper) and the (2) River Islands above Krupukari are poorly studied while the lower river has some of the areas in Guyana that are best studied biologically. The river runs through the vital Greenheart forests, and the lower portion has been selectively logged for many years. Farther upriver, some of the Greenheart and riparian forests remain intact and large populations of turtles, otters, and birds are found. The area near Krupukari has been designated the Iwokrama International Centre for Rain Forest Conservation and Development (enacted in 1997). Under this legislation, at least half of the 360 000 ha site is designated as an area for sustainable utilization of natural resources and the other half has the potential for conservation. The plants of the Iwokrama area have been surveyed by the Smithsonian Institution and the animals by the Philadelphia Academy of Natural Sciences. However, the Iwokrama Mountains that lie within the designated area have not been well-studied and some major groups such as fungi and insects are not covered by the surveys. A part of the Iwokrama Conservation and Development area has been proposed as a Wildlife Reserve (Ramdass and Hanif 1990).

E. The proposed Kaieteur National Park (expanded) includes Kaieteur Falls, a ca. 750 ft waterfall that is one of the most dramatic places in South America and it is the number one tourist attraction in the interior of Guyana. The plants very near the waterfall are relatively well-known and a checklist of these plants has been completed (Kelloff and Funk 1998). However the animal groups have only recently begun to be investigated in an organized fashion. The area has been proposed as a park by several studies (Ramdass and Hanif 1990). A study recommending an expanded park of over 500 mi^2 was completed by World Wildlife Fund (Schuerholz 1992) and a reduced version of 224 mi^2 is being discussed within the government.

F. The (1) Kanuku Mountains (western) and (2) Kanuku Mountains (eastern)–Rewa River Area contain gallery, semi-deciduous, lowland, and montane evergreen forests. Conservation International has conducted a Rapid Assessment of Biological Diversity in the western mountains and found the area to be biologically diverse. The area along the Rewa River is seasonally flooded and supports unique ecosystems, and there is a distinctive type of vegetation on granite domes and steep cliffs. The area is rich in birds including Harpy Eagles and is known to have a diverse mammal fauna, especially in the more remote areas where there are populations of large vertebrates (Giant Otter, Giant River Turtle, Black Caiman, Arapaima) including 8 species of primates. Many collectors have visited the areas near the savannas but the areas more distant from the savannas are nearly unexplored. On the whole, the eastern mountains are less impacted by humans than the western Kanukus. The European Union financed a detailed study of the Kanuku Mountains area with the intention of assisting the Government of Guyana in establishing a national park in the region, however, no progress has been made to date. In addition, the area has been proposed as a national park by several studies (GAHEF 1991, 1992; Agriconsulting 1993; Parker et al. 1993), a Nature Conservation Reserve (Ramdass and Hanif 1990), and as a Multiple Use Forest Reserve (Dalfelt 1978).

G. The (1) Mazaruni River Headwaters and (2) Mt. Roraima contain many elements of the Guiana Shield flora and fauna that are found nowhere else in the world (tepui). Mt. Roraima (2800 m) is highest tepui in Guyana and is inaccessible from Guyana. These tepui mountains are poorly studied in Guyana but are known to be rich in unusual plants and animals on Venezuelan side. The Roraima area is located across the border from a large national park in Venezuela and the forests protect an important watershed that is vital to Guyana. Mt. Roraima contains several vegetation types from lowland rainforest to elfin woodlands. This area has been proposed as a World Heritage Site (Putney 1990; Ramdass and Hanif 1990; GAHEF 1991, 1992) and as a national park (Dalfelt 1978).

H. Most of the Northwestern Forest is heavily impacted by communities and both foreign and local logging concessions. However, some interesting and unexplored forest areas exist along the upper reaches of the Barama River and these should be investigated.

I. The Rupununi Savanna (north): The Rupununi Savannas are an extension of the Rio Branco Savannas of Brazil. The area contains both wet and dry savannas and some lowland forest. In general the plants and animals of the vast Rupununi Savanna have been burned and hunted to the point that the native flora and fauna are mostly gone. Although most of the area has been heavily disturbed, there are a few places that warrant further investigation and these should be extensively studied before they are completely devastated. This area is one of the few in Guyana where Giant River Otters and Black Caiman form sizable populations. The area has been proposed as a wildlife sanctuary (Dalfelt 1978; GAHEF 1991, 1992).

J. Shell Beach is located at the mouth of the Waini River. The beach is a vast bank of shells, approximately 10 km in length. The area helps protect against drastic changes in coastline. The area is one of most important nesting areas in the world for four species of sea turtles which are being actively studied. However, the rest of the flora and fauna have not been studied and it may very well be the only place left in Guyana with large intact mangrove communities. The area has been proposed as a wildlife sanctuary (Dalfelt 1978; GAHEF 1991, 1992).

K. The Southeastern Forest including (1) Gunn's and (2) the New River Triangle cover a vast area in southeastern Guyana on the border with Surinam and Brazil. The forest near Gunn's south to the Acari Mountains has been visited a few times by botanists and mammalogists and preliminary data indicate that this forest is very different from the other forests found in Guyana. The far eastern portion, the New River Triangle, has been visited briefly by two collectors, one for termites and ants, and the other for mammals. These preliminary data suggest a rich and unexplored flora and fauna with many possible new species records for Guyana as well as undescribed species. Both of these areas are believed to contain low elevation, high canopy rainforest and we rank them with the highest collecting priority. The entire south and southeastern part of the country including the New River Triangle has been proposed as a reserve (Ramdass and Hanif 1990) and an important area for conservation (GAHEF 1991, 1992). The New River Triangle area is claimed by Surinam and is a restricted area.

Conclusions and recommendations

The lack of biological information for most of the organisms in Guyana should be addressed before decisions on protected areas for the country are made. While the shortage can be solved by gathering additional data from museum collections and by sending collecting expeditions into poorly known areas, some decisions on protected areas will be made in the near future. One is faced with determining what can be done that would provide for the establishment of souond protected areas system and yet allow for time to continue to refine the recommendations as additional data are accumulated and analyzed. As a result of this study and financial constraints, it appears that the Government of Guyana will initially select only two areas as a prelude to the establishment of a complete protected area system. The results of this study have led us to recommend that the first area be a greatly expanded Kaieteur National park. This decision is based on the high species richness and the level of endemism in the Orchidaceae. In addition, this decision is supported by the Government of Guyana and by everyone who has visited or worked in the area. The choice of a second area is more problematic. Certainly any area containing Mt. Roraima, Mt. Ayanganna, and/or Mt. Wokoman would have many of the same characteristics and qualifications as the Kaieteur area. Likewise, the New River area would be a real asset to any protected area system. However, the Kanuku Mountains are also high in species richness and unique species. In addition, the Kanuku Mountains are in danger of being more heavily 'exploited' in the near future. With these considerations, the data from this study support the selection of the Kanuku Mountains, especially the eastern portion including the Rewa River, as the second protected area. Both of these areas have some data available that show high species richness and some indication that there are species of restricted range. For Kaieteur the data are primarily from plant collections while in the Kanuku Mountains most of the species with restricted ranges are animals.

Beginning with two areas and progressing to a full-scale protected areas system will allow time to more fully assess the biological diversity of Guyana before final decisions on protected areas are made. However, the action should be taken as soon as possible during this interim. To speed up the accumulation of data it seems likely that, in addition to increased collection of biological data, it will be necessary to use remote sensing tools to support land cover and habitat mapping for Guyana since they can provide large amounts of information on extensive regions for analyses in a relatively short time. Geospatial data such as vegetation, hydrography, and soils maps could also be combined into an analysis with the biological locality data to predict large-scale biogeographic patterns with greater accuracy and detail for locating possible nature reserves (Nix and Gillison 1985; Austin and Heylingers 1989, 1991; Busby 1991; Carpenter et al. 1993; Margules and Redhead 1995; Jones et al. 1997). The richest ecosystems on the planet are tropical forests, and despite our recognition of this fact, their rate of devastation continues to rise.

As a result of the country's historic isolation, Guyana's interior, which is endowed with a great variety of habitats, remains one of the most intact regions in tropical America. Yet the pressure from international logging and mining firms continues to endanger the integrity of the country's forests, savannas, and mountains. In light of these impending threats, the country's economic plight, and the shortage of time available for a complete biological assessment, one hopes that the data and recommendations presented here will assist the Government of Guyana in making informed decisions about the fate and future of the country's diverse natural habitats. Hopefully, the continued accumulation of new data and the application of rapidly developing data analysis methods will make even more information available for future designations of additional areas for conservation.

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