MEMORANDUM

2 April 2010

TO: Cristián Samper & Jonathon Coddington, NMNH

CC: Eva Pell, Scott Miller, Warren Wagner, Sue Fruchter, and Wendy Wiswall

FROM: V. Funk, Biological Diversity of the Guiana Shield Program (BDG)

RE: 2009 BDG Annual Report

The annual report for 2009 is attached. The report is based on our activities for the calendar year 2009; however, the budget figures are for FY09. You will receive a hard copy next week. Please take time to visit our website and see all the additions and changes that have taken place during the last year. (http://botany.si.edu/bdg/index.html)

As always, our thanks go to the OD at NMNH for the continued funding (and of course to Congress for the Global Change money years ago). Also, the Program could not run without the help of Carol Kelloff the Assistant Director of BDG, and our very capable part-time contractors, Sara Alexander, Eduardo Garcia Milagros, and John Dodge as well as our 300+ colleagues around the world and our friends in Guyana and across the Guiana Shield.

An electronic version of this report, without the budget information, will be sent to our many collaborators &to others in the administration of NMNH, and it will be posted on our website.
ANNUAL REPORT 2009
Biological Diversity of the Guiana Shield (BDG)
Activities 1 January to 31 December, 2009; Budget for FY2009
(http://botany.si.edu/bdg/index.html)

The goal of the Biological Diversity of the Guiana Shield Program (BDG) is to document, understand, and conserve the biological diversity of the Guiana Shield area. In line with that goal BDG continues to gather and study specimens from the Guiana Shield area of northeastern South America. We collect, sort, identify, mount, inventory, barcode, and file all plant specimens collected by the Program, and we assist scientists from other departments in NMNH (Zoology, Entomology, Anthropology) in their collecting and processing efforts. We interface with other bureaus at SI (STRI, NZP, NMNH, NASM, CRC), and we collaborate with over 300 scientists around the world. We publish scientific papers and books, as well as items for more general use, and we train and educate staff and students from the Shield area. Specific questions addressed in the publications vary greatly from the two basic questions of Systematics “What is it?” and “Where does it live/grow?” to more synthetic ones such as “What is it related to?”, “Are the species in a genus the result of an adaptive radiation across the shield?, “How much species turnover do we have along latitudinal gradients?”, “What is the estimated species diversity of the shield area?”, “Where should we collect to get the most new material?”, etc. All publications are available online along with many other items of interest.

In October of 2009 we developed a Google Earth video tour about the biodiversity of the Guiana Shield and about the BDG program. It was posted on the Google Earth Outreach Showcase and selected by GE Sightseer in its “Top Content” for October. But most important is that the tour has generated comments on the GE Blog which shows that it is being viewed and discussed by the public.

Google Earth Outreach program:
http://earth.google.com/outreach/showcase.html#kml=Biological_Diversity_of_the_Guiana_Shield_Program

Google Earth Sightseer (monthly newsletter) top content October 2009:
http://earth.google.com/newsletter/oct09/oct09.html

Google earth Blog (unofficial, but very influential):

HIGHLIGHTS
The Checklist Projects (http://botany.si.edu/bdg/whatsnew.html) continue to move forward. The Fishes of the Guiana Shield (Vari et al. 2009) was published in September 2009. It was designed to be a companion to the Checklist of the Terrestrial Vertebrates of the Guiana Shield (Hollowell & Reynolds 2005) and the Checklist of the Plants of the Guiana Shield (Funk et al. 2007). There is also A Field Checklist of the Birds of Guyana 2nd Edition that was published in 2007 (Braun et al.) and planned for the future is A Checklist of the
Butterflies of the Guiana Shield. In addition, interest has been expressed in a checklist of the ants.

The fish checklist represents 1173 species of freshwater fishes known from the Guiana Shield and is home of approximately 23% of the freshwater fish species from the vast expanse between southern South America and the southern border of Mexico (Reis et al. 2003). The checklist also accounts for over 4% of the 28,400 fish species recently estimated to be present in all marine and freshwater systems worldwide (Nelson, 2006). In addition, the Checklist has 16 pages of color photos with 6-8 photos per page so that the true diversity of the fish fauna of northeastern South America is illustrated. The monograph also has an overall discussion of the vertebrate diversity of the area as well as a detailed introduction to the fish fauna. This project has ‘spawned’ several other projects involving Dr. Richard Vari and ichthyologists living or working in Suriname and Guyana.

**WEBSITE**

The advances on our website during 2009 are the result of our efforts to make our information more available to colleagues and the public; we have made great progress. Most of the work is accomplished by a contractor, Eduardo Garcia-Milagros, and our part-time webmaster Sara Alexander with help from the Department of Botany IT Unit: Ellen Farr and Sylvia Orli. We also appreciate the assistance we have received from the NH-OIT office, especially from Denis Hasch, Dan Cole, and Tom Hollowell. As with all big data rich projects, getting everything organized and in an appropriate condition to go on line is a big job, it really “takes a village” and we have had encouragement and help from many sources.

All of the sites mentioned below can be found under our “What’s New” link [http://botany.si.edu/bdg/whatsnew.html](http://botany.si.edu/bdg/whatsnew.html).

**Georeferencing Plants of the Guiana Shield**

The 1st phase, *Georeferencing Plants of the Guiana Shield: US Types*, began in October of 2007 and was completed in July of 2008. It includes ca. 3400 TYPE collections from the Guiana Shield that are housed at the U.S. National Herbarium. Images were already done through the Botany Department but BDG updated the records by checking locality data and adding coordinates so these specimens could be mapped using Google Earth. In 2009 a paper was submitted on how Google Earth can be
used to improve georeferencing and why taking the time to do this is important to ecology and conservation biology. A copy of this manuscript is attached in Appendix A.

**Phase 2: Georeferencing Plants of the Guiana Shield: Mapping the BDG Expeditions**, focused on making the data from the BDG funded expeditions available on-line. During 2008-2009 all of our resident collectors were added (except Henkel who will be finished in April 2010). The final trip report is entitled ‘Miscellaneous collectors.’ This will be a compilation of reports from various small (less than 1000 numbers) expeditions conducted in the Guianas between 1985 and 2001. This volume will also include two BDG resident collectors who collected fewer than 2,000 numbers, William Hahn (1987 – 1989) and Patrice Mutchnick (1994 – 1995). With a little luck this will be completed by the end of 2010. Hard copy publication has occurred for three of the collectors and one is out for review. The others will follow the completion of the website. Originally, posting of the pdf of the hard copy publication was the only way the data were available. So this website is a huge improvement. This site allows the visitor to travel along with the collector, read their journal entries, view photos of the places and plants and animals they experienced; the user can see what a collecting expedition is really like.

**Phase 3: Georeferencing Plants of the Guiana Shield: Images**, is progressing with each collectors images being put on line after the expeditions are available.

**Phase 4: Georeferencing Plants of the Guiana Shield: Providing public access to the collecting information from the BDG Expeditions** went on line in December 2009 (except for Henkel and the “Miscellaneous Collectors” and Henkel is now finished). Most of the plants collected by the BDG program are now searchable by genus and species and have interactive maps using Google Maps API trace. This has proved to be very popular with our fellow scientists.

There is a **Phase 5** that is planned but so far unscheduled. In addition to the BDG collections mentioned above, we have data based over 100,000 specimens in the US National Herbarium (referred to as historical specimens) that we would also like to make available on line. However, the time and funds required to check all the locations and identifications, to georeference them, is not available at this time.

**Phase 6** is in the “dreaming” stage. It has the goal of scanning one representative specimen of each species to go on our website but we lack the funds. Expeditions during the last five years have had two new goals, take a photo of each collection and collect leaves in silica for each specimen. So, if we were to have the scan of the herbarium sheet we would also have thousands of photos to match up with the scan. The possibilities are many, the funds are few.

Dr. Karen M. Redden completed her SI postdoctoral fellowship with Dr. V.A. Funk in November of 2009, *Phylogeny and biogeography of six Caesalpinioideae legume genera concentrated on the Guiana Shield*. Additional markers are needed to fully resolve the cladograms and this work is underway using other funds. This project is investigating adaptive radiation across the Shield.

During 2009 BDG had a two month plant expedition in Guyana. Dr. Redden (former postdoc and now part-time faculty at UDC) along with Dr. Ken Wurdack, Curator-Botany, received funding from an NSF grant and the BDG program to collect plants in the upper Mazaruni and Kato River area near the border of Venezuela where very little collecting has been done (see below for additional information).
Dr. Christian Feuillet has published a paper titled: *Checklist of the Plants of the Guiana Shield. 1. An Update to the Angiosperms*. He found an astonishing 718 additions, corrections, and synonymies that had to be accounted for. There was a gain of 52 species and now the total for the Guiana Shield is 14,784. A total of 102 of the species were new to science. It won’t be long before we break 15,000!

Dr. Tom Hollowell published his dissertation in 2009. He studied the *Plant Community Structure, Fire Disturbance, and Recovery in Mangrove Swamps of the Waini Peninsula, Guyana*. Many people had been asking for these data and we are delighted to have made them available along with his analysis.

**Expeditions in 2009**

**Karen Redden** (SI Post-doc), (6378-6752) and **Ken Wurdack**, (4804 – 5168) traveled to Imbaimadai and the Kato River area, Guyana with K. Wurdack; C. Perry; D. Hunter; T. Hunter; V. Roland. Date: 3 – 23 May 2009. The botanical expedition was planned early in 2009 and was scheduled to climb Mt. Tulameng, a 5000+ foot high tepui in the Pakaraima mountain range near the Venezuela border. This tepui has never been botanically explored and the general region is represented by few collections. Unfortunately, due to low water levels, they were unable to navigate the creek leading to the base of the mountain. Instead they continue up the Kako River and climbed the mountain leading to the headwaters of the river. A total of 740 collections were made that included over 90 different plant families (see trip report in Appendix B) 24 day expedition to the Upper Mazaruni River region. This expedition and several others that we have planned will help fill in the missing data in our gap analysis model. Dr. Redden and Dr. Wurdack are planning another trip in 2010 to try and reach Mt. Tulameng. For a full trip report see Appendix B.

**Specimens returned to Host Countries:**
The University of Guyana has a backlog of specimens and has requested that BDG hold shipment until they are ready. Currently there are ca. 2,000 plant specimens ready to be shipped to Guyana.

**Other Activities**

1) Kelloff and Dodge continue to receive and process the mounted/unmounted ethnobotanical collections (B. Berlin) from the University of Georgia. Number of plants received in 2009 (excluding duplicates): ca 3,500. These specimens have been mounted and are filed by
family waiting until all have arrived. So far we have received a total of ca. 8,750 specimens for the US National Herbarium and ca. 5,000 for exchange.

2) Kelloff received the duplicate specimens from the T.F. Lucy collection that has been housed unprocessed and at BUF for over 100 years. Kelloff curated the original collection at Elmira in 1985-6. From notes within the duplicates labels will be made and specimens processed in 2010.

3) Funk and Kelloff attended the Botany 2009 meeting in Snowbird, Utah and presented talks and posters.

4) Kelloff and Funk are preparing the second addition to the Plants of Kaieteur National Park, Guyana, which should be completed by summer 2010.

5) The Checklist of the Freshwater Fishes of the Guiana Shield was published (see details above).

6) The third volume of the Contributions of the Centre for the Study of Biological Diversity was published. It is a study of plant community structure, fire disturbance and recovery in the mangrove swamps of the Waini Peninsula.

7) Funk, Kelloff, and Redden met with the members of the Iwokrama International Centre for Rainforest Conservation and Development, New Castle University UK and Duke University, NC to discuss the components of a climate change research program at Iwokrama, Guyana.

8) Kelloff was a judge for the Northern Virginia Regional Science Fair.

9) Kaslyn Holder, Botanical Scientific Officer at the Biodiversity Center helped with drying, processing, and verifying plant collections.

10) Student training: Erin Zimmerman, Graduate Student at the Botanic Garden, Montreal, Canada, participated in the Redden/Wurdack expedition. This was her first expedition so she needed a lot of training.

11) Four Amerindians received training and assisted with the Redden/Wurdack expedition: Claudius Perry a Para-taxonomist/ EPA counterpart (Aishalton), Delph Hunter (Imbimadai), Timothy Hunter (Imbimadai), Virgil Roland-Guide (Kako Village).

12) After her expedition Karen Redden taught a mini-class on using the BDG website at three locations: the Biodiversity Center (UG), Conservation International-Guyana, and the Office of Amerindian Affairs.

THE CENTRE FOR THE STUDY OF BIOLOGICAL DIVERSITY, GUYANA (CSBD)
The CSBD has had a busy year and is gradually gaining independence. The End of Year report is attached as Appendix C.

SPECIMEN WORK AND DATABASES

Plant Processing
Specimens determined: 987
Specimens sent as gifts/loans for determination: 281
Duplicates sent out as exchange: 811

Returned to the host country: GNH has a backlog of mounting and asked that we hold plant specimens until further notice – current holdings: ca. 2,000 collections
New collections: **739** single numbers, excluding duplicate sheets (new collections ca. **3,000** sheets)

Duplicate Labels prepared: ca. **4,843** (this includes Hoffman Suriname collections)

Sheets barcoded and inserted into the US National Herbarium: **1,521** (newly mounted)

Sheets that have been inventoried and barcoded: **1,387** (historical collections from US)

Brent Berlin collections processed and mounted: **3053**

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In 2006 the BDG sorting center began processing donated collections for various institutions. The University of Nebraska sent 10,000 mounted sheets of material collected in China and the Philippines (we kept 6,000 and sent the rest to herbaria in the countries where they were collected). In addition, we are now processing the priceless ethnobotanical collections of Dr. Brent Berlin (Chiapas, Mexico).

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**THE FUTURE**

During the next year we will complete the major e-projects that are underway on our website. We will begin discussions on how to handle the ca. 100,000 ‘historical’ collections from the US herbarium. These are data based but many are not geo-referenced and those that are need to be checked. Also, one representative of each species for both the BDG collections and the ‘historical’ collections need to be scanned.

BDG will participate in a short course run by University of Missouri, St Louis in Guyana in January 2010.
One short course from George Washington University will be taught in Guyana in June 2010; this has already been approved by GWU.

One six week plant collecting expedition will be sent to Mt. Tulameng. We will seek outside funding for this expedition. Collecting along with the botanists on this trip will be Dr. Jessica Ware from Rutgers University. She will be collecting Odenates and when she returns she will help Jerry Louton (Department of Entomology) set up a rigorous collecting program for this group of organisms on the Guiana Shield.

One three week ant collecting trip will be conducted by Ted Schultz and John LaPolla. They will travel to the CI concession in Guyana where Karen Redden has been working.

Matt Buffington and one other person from Entomology may go along on one of the trips as far as Rewa village. They will investigate the possibility of setting up a long term general entomology collecting program using pit fall traps, pan traps and malaise traps.

Wayne Mathis will do a short trip to SW Guyana to collect shore flies that he needs to complete a paper.

We predict the remaining four ‘collector’ volumes will be published within the next two years (FY2010-FY2011). Also to be completed is a volume for the remainder of the collectors, called “Miscellaneous Collectors.”

BDG has entered into discussions with Dr. Robert Anderson about modeling the BDG data and we have more or less decided to submit a grant proposal to NSF.

We are also in discussion with the Department of Entomology in how we can set up long term collecting stations in a variety of habitats across the Shield beginning with Guyana.

BDG is a natural fit with the new “Big Idea” now titled “Global Genome Initiative” and we hope to partner with them in future expeditions.

**Proposals submitted or worked on during 2009 and their fate:**
Redden, Funk & Herendeen submitted an NSF-REVSY Proposal: Biogeography, phylogenetics and taxonomic revision of the Neotropica genus Macrolobium (Leguminoseae, Caesalpinioideae) for $416,718 in July of 2009. [Reviewed well but was not funded, the reviewers asked for additional preliminary data we think this one has a good chance when we resubmit it in July]

A Smithsonian Women’s Committee proposal was submitted for $24,000 to pay for the shelving in the library at the Centre in Guyana. This proposal was considered but not funded in the final cut. However, we are seeking funds elsewhere.

Scholarly Studies/Endowment Proposal to investigate adaptive radiation across the Guiana Shield in two lineages one in the Compositae and one in the Leguminoseae: $40,000 would have
paid for field work and half time salary for a postdoc. This was declined and we have never received any comments on why.

Plants of the Guiana Shield: Inventorying using a comparative approach is a grant proposal to be submitted to NSF ($860, 115) for five years to establish a large plot in Guyana (in collaboration with the Brazilians) was nearing completion at the end of 2009. It will be submitted to BS&I in January 2010.

In 2009 we began work on a proposal to submit in early 2010 to National Geographic Society for field work in Guyana.

In 2009 we began discussions with Dr. Robert Anderson from City College of New York about submitting a proposal in 2010 to NSF for analyzing some of the BDG data.

**PREVIOUS ANNUAL REPORTS**

A pdf of the BDG Annual Reports from 2003-onwards can be found on our website: [http://botany.si.edu/bdg/program.html](http://botany.si.edu/bdg/program.html).

**PUBLICATIONS 2009**


**Publications not listed in previous reports:**


Appendix A:

Improving The Use of Information From Museum Specimens: Using Google Earth©
To Georeference Guiana Shield Specimens In The U.S. National Herbarium.

Eduardo Garcia-Milagros and V. A. Funk, U.S. National Herbarium, Department of Botany, National Museum of Natural History, Smithsonian Institution, Washington DC.
USA 20013-7012
Data found on labels of museum collections have been useful in a variety of biodiversity studies. However, the georeferenced data available are often hampered by poor interpretation of label information and as a result are not as accurate, and therefore useful, as they might be. We have used Google Earth© as a geographic information system to improve the georeferencing of the data. Its user interface allowed us to make use of all the label information and to represent the coordinates more accurately, thus producing a better quality and more reliable dataset to be used in our studies. The quality, defined as “fitness for use”, of the species-occurrence data generated, which is mostly affected by the values of accuracy and uncertainty associated to the coordinates, shows that uncertainly can be reduced. This method also allows us to show the power of examining georeferenced data from the stand point of ‘all collections from an expedition” rather than “all collections from a single area.” Type specimens housed at U.S. National Herbarium from the Guiana Shield were used in this work.

*Key words*: museum collections; georeferencing; data quality; Google Earth; type specimen.
The specimen collections housed in museums and herbaria are a permanent record of a species at a given location on a specific date. The locality of a collection is stored as text on a specimen label. Georeferencing is the process of converting these locality descriptions into latitude/longitude coordinates which can be easily analyzed with GIS applications. These species-occurrence data, together with environmental variables are often used in various modeling methods, i.e., to plot existing data and predict the geographic distribution of species (e.g., Elith & Graham et al. 2006). These predictive distribution models are becoming an important tool in analytical biology, with applications in conservation and reserve planning, ecology, evolution, epidemiology, invasive-species management and other fields (Phillips et al. 2005); however, they depend on accurate coordinates.

Studies show that the data stored in the collections are often geographically, temporally, and taxonomically biased (Funk et al. 1999, ter Steege et al. 2000, Funk & Richardson 2002). Although these studies suggest that collecting more data is necessary, the information behind these collections is of a high value. Gathering such data in databases and georeferencing them is a time-consuming and underappreciated task. However, once available they are used, for instance, in establishing priorities for future expeditionary research and thus filling gaps in the data (Funk et al. 2005) and in regional conservation planning (Ferrier 2002).

Recently there has been an increase in the availability of collections data (GBIF, TROPICOS, etc.) and an important consideration is how ‘good’ or reliable they are. Estimates of quality have been defined as “fitness for use” (Chrisman 1983) or “fitness for potential use” (English 1999) and Chapman (2005) describes how many factors may
affect the quality of the data. In terms of geographic position of location, precision and accuracy are of concern and geographic data always have an uncertainty value associated with them.

One goal of our research is to understand plant distributions across the Guiana Shield (Biological Diversity of the Guiana Shield Program, BDG). In order to do this we embarked on this project to apply the “principles of the best georeferencing practices” (Chapman & Wieczorek 2006) and investigate the use of Google Earth© as a GIS application for georeferencing and determine if its features could help improve the quality of the data. We also sought to determine the power of examining georeferenced data from the standpoint of “all collections from an expedition” rather than “all collections from a single area.” The full scope of the project involves checking the locations and uploading the data from all of the collections at U.S. National Herbarium (US) beginning with those made by the BDG (see progress at http://botany.si.edu/bdg/expeditions.html). However, the sample data used here are from the type collection of the US which are important but provide the biggest challenge because of the lack of information.

METHODS

All known species on earth have an official name. Typically that name consists of a genus, a specific epithet, and the name of the person(s) who described it. Usually each name is tied to a specimen that is housed in a recognized collection. These specimens are called ‘types’. All type specimens from the Guiana Shield that are housed at US (ca. 3400
specimens) were used in this work.

When the US type specimen database was downloaded, it became clear that locality information varied from just country information on the old collections to precise GPS latitude/longitude coordinates on the most recent. Over time some older records had coordinates added. An examination of these data showed that during the process of entering them into the database, accidental errors had occurred. For instance, mistakes in typing a locality name made that location inaccessible in Gazetteers and changing label formats resulted in the loss of information. To avoid these and other pitfalls, we studied the types individually and used all the information that we had at the time to georeference them. Access to the original label through U.S. Type Specimen Register Imaging Project (http://botany.si.edu/types/) has made this task easier.

The list below includes the fields that we found useful in the georeferencing process:

- **Locality names**: Towns, mountains, …
- **Elevation**.
- **Distances and heading**: 1 km N from…,
- **Habitats**: savanna, forest edge …
- **Expedition information**: base camp, intermediate camp …
- **Coordinates**.

We used Gazetteers (Guyana 1993, Suriname 1993, French Guiana 1993, and Venezuela 1993) as a first approximation of the localities or when available, coordinates on the label. The set of coordinates (transformed to decimal degrees) were uploaded to Google Earth using EarthPlot, (free software: http://www.earthplotsoftware.com/) which
allows easy plotting of large sets on Google Earth. In addition, we used maps of the Shield area, some published by different agencies and available through the BDG program map collection, and others from publications (i.e., Maguire 1945, 1948; Maguire & Reynolds 1955, Maguire & Wurdack 1959, Maguire 1981; Cowan 1952; Gleason 1931; Hitchcock et al. 1947, Huber 1995; Tate & Hitchcock 1930).

Below are three examples of how we have gathered and used the information to enhance the traditional georeferencing of collecting localities.

EXAMPLE 1 (Fig. 1)

The Type specimen of *Byrsonima rubrobracteata* Anderson (Malpighiaceae) was collected at Mount Ayanganna (Guyana). The Gazetteer’s coordinates for Mt. Ayanganna showed with the white placemark (Fig. 3A), did not take into account all of the information available on the label “on shoulder of E flank, (...) elev. 1418 m.” (Fig. 3B). As a result the location was moved to a new position, showed by the sunburst SI logo (Fig. 3A).

EXAMPLE 2 (Fig. 2)

Some Types had coordinates on their labels but often these seemed to be an approximation. For example, the Type specimen of *Rhamnus marahuacensis* Steyermark & Maguire (Rhamnaceae) had coordinates that in Google Earth fell at the SE base of Cerro Marahuaca (Fig. 2B). However, the label says that the specimen was collected at the ‘summit of Cerro Marahuaca, in the Fhuif section at 2450-2500 m’. That area was found using a combination of the Google Maps location of the summit and the elevation; the coordinates were changed to reflect the more accurate location (Fig. 2A).

EXAMPLE 3 (Fig. 3)
Some collections have references to such features as “base camp, intermediate camp…” Sometimes these expeditions were the first exploration of an area, and they produced a large number of types. This happened with expeditions conducted in the amazing table top mountains or tepuis found on the Guiana Shield. An example is the expedition conducted by Maguire to Tafelberg, Suriname, in 1944. Tafelberg is an isolated sandstone Table Mountain representing a remnant of a tepui. All of the types from this area had been georeferenced in the database with the same coordinates, the summit. However, Maguire had published a map with the routes and the names that he gave to some of his collection localities (Fig. 3B; Maguire 1948). Google Earth allows one to overlay images, such as the Maguire map, on the surface of Earth (Fig. 3C). The type specimen of Sagotia tafelbergii Croizat (Euphorbiaceae; Fig. 3E) has “North Ridge” as a locality description, and having Maguire’s map overlaid on the image from Google Earth allowed us to give more precise coordinates (Fig. 3D) for the ca. 70 types housed at US that were collected from this expedition.

In addition to these examples, many other situations were encountered and locations subsequently corrected. To keep track of these changes new fields were added to the database. For instance, Example 1 had coordinates on its label so the new fields added to the database were: 1) initial source: coordinates label, 2) final source: Google Earth interface, 3) reason 1: label description, 4) reason 2: elevation.

One might ask: How accurate are the imagery and elevation data that Google Earth displays? Google Earth uses WGS84 Datum as coordinate system and NASA Shuttle Radar Topography Mission data as Digital Elevation Model (although Google Earth may use different elevation data in some specific areas). We compared recent
locality information recorded by two BDG collectors (D.H. Clarke’s expedition to Mt. Ayanganna, Guyana, 2001 and K. M. Redden’s expedition to Yatua River, Venezuela, 2005) using GPS devices with Google Earth data; we found the average difference to be 50-100 m. The number of specimens and taxa studied and the coordinates provided are summarized in Table 1.

RESULTS

The direct results of this study are available as place marks powered by Google Maps and Google Earth that can be downloaded and consulted on the website: http://botany.si.edu/bdg/georeferencing.cfm

The results are provided as a single coordinate pair assigned to each location. That does not mean that the collections georeferenced show the exact locality. All coordinates, even those that were obtained using a GPS device, have an uncertainty value associated with them. In fact, uncertainty is an inherent attribute of geographic information (Goodchild 2001). Using the protocol described above, we think that we have improved the quality of the data by increasing the accuracy and thus reducing the uncertainty. The uncertainty value is important because it can determine if the data are suitable for a particular analysis. For example, a plant locality description saying “Banks of Potaro river”, might be useful for a research project on riparian vegetation, but not for a biodiversity survey of Kaieteur National Park or to predict distributions because, even though the Potaro River crosses the Park it is also outside of the Park and it crosses many vegetation types. Data from specimen labels have numerous sources of uncertainty:
precision of the locality, unknown ‘datum’ information on maps, imprecise distance measurements or directional information, generalized or incorrect coordinates, etc. It can be challenging to calculate the uncertainty value when combining uncertainties from different sources. Chapman and Wieczorek (2006) provide different examples of calculating uncertainty depending on the locality information and proposed the point-radius method (Wieczorek et al. 2004) to represent uncertainty. This method describes each locality as a circle where the radius represents the maximum distance error for that locality, storing the uncertainty value as the length of the radius. Using the Type of *Sagotia tafelbergii* (Example 2): if it is georeferenced using only the Gazetteer coordinates for Tafelberg its uncertainty is estimated as a circle with a 7.5 km radius which includes the whole mountain (Fig. 2F). Overlaying Maguire’s map (1945) on Google Earth allows the collection to be placed on the North Ridge thereby reducing the uncertainty to a circle with a 0.85 km radius (Fig. 2F). In addition, Guo et al. (2008) recently proposed a probabilistic method to represent a locality with a polygon rather than a circle which tends to overestimate uncertainty.

For our studies, we do not include coordinates for those records with, in our viewpoint, high uncertainty values. In Table 1, the lower percentage ratio of the three Guianas is explained because the number of ‘old’ (historic) collections where inadequate locality information is common. For example, there are ca. 300 types collected from 1835-1844 by Robert and Richard Schomburgk with “*British Guiana*” or “*Banks of Essequibo*” as the only locality information. Despite the extensive publication by van Dam (2002), it is still difficult to find a more precise locality and so they could not be mapped. Also excluded were collections with locality names that could not be found and
others with inconsistencies in their information; these may be added in the future.

**DISCUSSION**

The advent of new GIS techniques and their potential for analyzing and interpreting the large quantity of data stored in specimen collections creates a challenge for researchers. Google Earth has proven useful in improving the quality of our data and we recommend its use to others for their georeferencing projects. It has an interface that easily allows overlying maps, drawing paths, adding information marks, measuring distances, checking the elevation of a point and moving a collection from one place to another. Such techniques provide a method to release previously incorrect or ‘hidden’ data often from ecosystems that are no longer extant.

There is still a lack of ‘high resolution’ imagery in many areas. Such updates would increase the applications of the tool in, for instance, overlaying predicted distribution polygons over real satellite imagery and modifying them according to identified habitats help in the production of more accurate vegetation maps, documentation of changes of habitat or land uses, or for planning future expeditions.

Given the increased use of online databases it is critical that the data be checked and improved so that it helps give accurate answer questions rather than unreliable results.


WIECZOREK, J., Q. GUO AND R. HIJMANS. 2004. The point-radius method for
goreferencing locality descriptions and calculating associated uncertainty. Int. J.
Table 1. Results of specimens georeferenced a.

<table>
<thead>
<tr>
<th></th>
<th>Total Specimens</th>
<th>Total Taxa</th>
<th>Coordinates</th>
<th>No Coordinates</th>
<th>Georeferenced</th>
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a The data showed on this table were taken at the moment of presenting the work. The US National Herbarium database is being updated constantly and these numbers may vary at the present moment.
FIGURE 1. (A) Position of the GAZ coordinates (white placemark) and position after processing the label information. (B) Label of *Byronima rubrobracteata* Anderson with different information of the fields mentioned on the text.

FIGURE 2. (A) Position of the coordinates (white placemark) and position after processing the label information. (B) Label of *Rhamnus marahuacensis* showing coordinates.

FIGURE 3. (A) Tafelberg cut section at 450 m asl on Google Earth. (B) Tafelberg expedition map (Maguire 1948) (C) Expedition map overlaid on GE. (D) Type georeferenced. (E) Label of *Sagotia tafelbergii*. (F) Point radius uncertainty as calculated according to Wieczorek (2004). The radius of the circle represents the maximum distance error for that locality, this example uses the type specimen of *Sagotia tafelbergii* (Example 3). The larger circle is the uncertainty if the Gazetteer coordinates for Tafelberg are used. The smaller circle represents the uncertainly when using the method described here.
B) THE NEW YORK BOTANICAL GARDEN GUIANA EXPLORATIONS
PLANTS OF BRITISH GUIANA
UPPER MAZARUNI RIVER BASIN

No. 15128
Byronima rubrobracteata Anderson
et W.R. Anderson, 1979

Shrub to 5 m; lvs dark green above, light green
beneath, stiff, brittle, shiny; calyx green,
glans whitish-pink, corolla whitish-pink, shading
to red; fruiting calyx red, immature fruit
green; infrequent, low forest (6-10 m) on shoul-
der of E flank, about Thompson Camp; elev. 1110
m.
Mt. Apureanna

Stephan S. Tilki
Carolyn L. Tilki
Rufas Boyan
Aug. 11, 1998

Field work conducted with the cooperation of the Departments of Forestry and Interior, British Guiana.
Supported in part by funds provided by the National Science Foundation.
INSTITUTO NACIONAL DE PARQUES
DIRECCION DE INVESTIGACIONES BIOLOGICAS
HERBARIO NACIONAL DE VENEZUELA (VEN)
FLORA DE VENEZUELA

Nº 126049
Rhamnus marahuacensis Steyerm. & Magoon

Tree 1 m, leaves buff-brown below, fruit maroon-purple.

Territorio Federal Amazonas. Departamento Atalaia:
CERRO MARAHUACA - FULIPE. Cumbre, zona pantanosa no arbolada en la altiplanicie, río arrita, Alt. 2,400-2,500 metros, Lat. 3°35' N. Long. 63°20' O.

2 de febrero de 1982
Appendix B:

Preliminary Trip Report
Karen Redden / Kenneth Wurdack
Upper Mazaruni River Basin (Kako River)
April 28-May 31, 2009
Preliminary Trip Report
Karen Redden / Kenneth Wurdack
Upper Mazaruni River Basin (Kako River)
April 28-May 31, 2009

Team Members:
Karen Redden, PhD - Botanist
Kenneth Wurdack, PhD - Botanist
Erin Zimmerman, Student
Claudius Perry - Parataxonomist/ EPA counterpart
Delph Hunter - Boat Captain (Imbimadai)
Timothy Hunter - Captain (Imbimadai)
Virgil Roland - Kako Village Guide

Introduction
The botanical expedition was planned early in 2009 and was scheduled to climb Mt. Tulameng, a 5000+ foot high tepui in the Pakaraima mountain range and near the Venezuela border. This tepui has never been botanically explored and the general region is grossly under collected and represented by few collections. Unfortunately, due to low water levels we were unable to navigate the creek leading to the base of the mountain. Once we discovered we would not be able to ascend the mountain, we decided to continue up the Kako River and climb the mountain leading to the headwaters of the river. A total of 740 collections were made that included over 90 different plant families (see table below). Below is the account of our 24 day expedition to the Upper Mazaruni River region.

28-April – 1-May 2009 - K. Redden, K. Wurdack and E. Zimmerman arrive in Guyana at 7 am. Claudius Perry, parataxonomist from Dadanawa, arrived in Georgetown via the IntraServe bus. K. Redden and K. Wurdack processed the paperwork needed for permits for botanical collecting from EPA and the Ministry of Amerindian Affairs. The team met with UG staff. We purchased supplies needed for the 3 week expedition to the Upper Mazaruni region.

2-May 2009 - Left Ogle at 2:00 pm and arrived in Imbaimadai at 3:00 pm. We were hosted again by Compton Mendonca. This is the third time K. Redden has collected in the Imbaimadai region and Compton was an intricate part of helping with setting up the expedition, including supplying boats and motor, housing the team and gave very important advice concerning the area.

3-May 2009 - We collected savanna across from the Imbaimadai airstrip. The area is predominately white sands mixed with laterite rocks and pebbles. A fresh water creek at the edge of the savanna and bordered by gallery forest land, was also explored. The savanna vegetation is similar to that seen at
K. Redden & K. Wurdack Preliminary Trip Report 2009

Kaieteur including grasses, sedges, bromeliads, Eriocaulaceae, and sundews. Dominant trees included bloodwood (Vismia), wallaba (Dicymbe) and Dimorphandra. KMR 6378-6411; KJW 4804-4821

4-May-2009 - Left Imbaimadai ca 11 AM in 2 boats. We checked in with the Amerindian community of Jawalla and continued on until a suitable camp was located (Camp 1: N05 43’ 04.1” W 060 34’ 13.9”).

5-May-2009 - We continued on and headed up the Kako River and stopped at the Amerindian community of Kako. We set up camp further upstream (Camp 2, N 05 42’ 43.6”, W060 38’ 21.4”) and returned to Kako for a 4 pm community meeting about our expedition. Virgil Roland from Kako joined the team as our local guide. Purchased cassava bread, a paddle and returned to camp after dark.

6-May-2009 - In the morning we visited a savanna (N 05 42’ 52.3”, W 060 37’ 55.2”) lying between our camp at Kako and which was known to Roland. The savanna had a wet lower part, seepage slopes, scrub, a forest island in the middle, and parts that were recently burned. We collected the savanna and returned to camp for lunch. Ken stayed in camp to begin processing the morning’s collections, while the rest of the crew went upstream for river collecting. We pressed until dark. KMR 6412-6456; KJW 4828-4884

7-May-2009 - We continued pressing until ca 1 pm. In the afternoon we took a trail behind camp to another savanna. Similar but floristically depauperate compared with the prior savanna. The moist forest bordering the savanna was richer and thick with moss and epiphytes. KMR 6457-6467; KJW 4885-4905

8-May-2009 - Left camp 2 early, ca 7 AM and took ca 5 hrs. to reach Mayakopai (N 05 30’ 45.8”, W060 43’ 54.5”) and we continued on until a suitable camp was found (Camp 3: N05 33’ 33.6”, W060 47’ 04.0”). We hiked to the savanna behind camp with good views of the surrounding mountains. In the evening we celebrated Karen’s 43rd birthday

9-May-2009 - We packed up and left Camp 3 at ca 8:30 AM. We briefly headed up the creek leading to Mt. Tulameng and discovered that water was too low for boat passage. We continued up the Kako River until reaching impassable rapids and set up Camp 4 (N 05 30’ 06.7”, W060 50’ 44.6”). The rapids include a rocky island of well-worn pink sandstone rocks with small tussocks of vegetation including Cyperaceae and orchids. KMR 6468-6471; KJW 4906-4908

10-May-2009 - We hiked and collected the gorge of the Kako River toward the rock wall up from the camp. It rained heavy the in night. KMR 6472-6506; KJW 4909-4928

11-May-2009 - We cut line and collected up the mountain along an old cut line. A colony of army ants invaded our camp and kept us busy when we returned. We had to save the processing of the plants for the next morning. KMR 6507-6537; KJW 4929-4951
12-May-2009 - We collected along the Kako River. The forest is similar to that found at the top of the falls but with some different species. KMR 6538-6556; KJW 4953-4968

13-May-2009 - The team hiked up the mountain across from the camp to the headwater of the Kako River (N 05 30’ 12.4”, W060 51’ 29.1”; elevation 809 meters). The top of the falls provided a spectacular view of the gorge. The falls includes three separate drops and we observed swifts nesting under the falls. We collected along the falls and into the forest surrounding the falls. We decided that the flora warranted another day of collecting and we left the climbing spikes at the top of the falls. KMR 6557-6566; KJW 4969-4978

14-May-2009 - We hiked along the bank opposite our camp to try to reach the rock wall along the river (at the base of the falls). We were able to reach the rock and found a number of very interesting plants growing on the wall and rock ledges. Claudius Perry and Virgil Roland swam across the river to reach the cliff. We also collected along the edge of the lower falls. KMR 6567-6575; KJW 4979-4988

15-May-2009 - We hiked to back up to the falls and collected all day. KMR 6576-6606; KJW 4989-5007

16-May-2009 - Move camp back down river. We stopped at the savannah behind Camp 3 and did a more thorough botanical survey of the savannah. KMR 6607-6633; KJW 5007-5029

17-May-2009 - Collected along the Kako River upstream from Camp 5. KMR 6634-6649; KJW 5030-5048

18-May-2009 - Collected at the falls across from Camp 5. KMR 6650-6665; KJW 5049-5068

19-May-2009 - Collected in a swamp forest/savannah a short distance behind Camp 5. This swamp savannah included numerous different habitats including a muddy swamp, dry savannah, wet savannah and a burnt savannah. KMR 6666-6685; KJW 5069-5106

20-May-2009 - C. Perry, V. Roland, D. Hunter and T. Hunter cut line up Chinakuruk mountain. The rest of the team pressed the previous days plants and collected near camp. Some collections were made by the line cutting team and are so noted in the field books. KMR 6686-6697; KJW 5107-5112

21-May-2009 - We climbed the Chinakuruk Mountain. It took the team 5 hours to reach the rock ledge. We collected coming down the mountain. KMR 6696-6717; KJW 5113-5130

22-May-2009 - The team collected at the base of the waterfall nearest to Camp 5. This area was dominated by grasses, sedges, Orchids and Gesneraceae. KMR 6718-6733; KJW 5131-5143
23-May-2009 - We climbed back up to top of the mountain and continued collecting down the mountain to the base. KMR 6734-6752; KJW 5144-5157

24-May-2009 - Left Camp 5 and traveled to Jawalla. It was youth day and we watched the festivities. We overnighted in a guest house in the community.

25-May-2009 - Left Jawalla at 9 AM and arrived back in Imbaimadai at 1 pm. Made arrangements with Trans Guyana to travel back to Georgetown on the 26th. Again the team was hosted by Compton Mendonca at his compound. K. Wurdack collected in the savannah adjacent to the airstrip in the late afternoon.

26-May-2009 - The team packed up all gear and preserved plants and weight in at the Trans Guyana office in Imbaimadai. The total cargo weight was 916 lbs (@ $60 GUY/lbs) and the passage from Imbaimadai to Ogel was $10,000 GUY/ person (total bill of $94,960 GUY). We left Imbaimadai in two shifts in the early afternoon and arrived back in Georgetown at 3 pm. KJW 5158-5168

27-30-May-2009 - Obtained export permits through UG and EPA. Packed gear and processed plants for export.

31-May-2009 - K. Redden, K. Wurdack and E. Zimmerman travel back to the US. C. Perry returns via the IntraServe Bus to Lethum.

### Preliminary List of Families collected on 2009 Upper Mazaruni River Botanical Expedition

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Appendix C:

Report of Activities of the Centre for the Study of Biological Diversity, University of Guyana, Georgetown, Guyana – 2009

Center Report Not included; it is a very large file