Congo River Environment and Development Project (CREDP)

BIODIVERSITY SURVEY:
Systematics, Ecology, and Conservation Along the Congo River

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CONGO RIVER ENVIRONMENT AND DEVELOPMENT PROJECT (CREDP)

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TABLE OF CONTENTS

1. SUMMARY

The Congo River is the second most important site in the world for freshwater biodiversity, specifically fishes. Covering an estimated 1,500,000 miles^2, this river is the second largest river basin after the Amazon. Yet, unlike the Amazon, the Congo River is poorly known. Some areas have not been surveyed since Max Poll's expedition in 1953 (Poll, 1959); others, since the late 1970's (e.g., lower Congo rapids: Stewart and Roberts, 1976).

This rapid biodiversity survey was made at the request of Innovative Resources Management, the nongovernmental organization implementing the USAID-funded Congo River Environment and Development Project (CREDP). The following taxonomic groups were qualitatively sampled, to obtain an estimate of the number of species: fishes, birds, amphibians, reptiles, mammals, aquatic invertebrates, terrestrial and aquatic plants. In addition, ecological parameters of the river water were assessed at each site.

The survey was conducted by Dr. Caroly A. Shumway of the New England Aquarium, in collaboration with Dr. John Sullivan (Cornell University), Mr. Robert Schelly (American Museum of Natural History) and a team of researchers from the Kinshasa- based nongovernmental organization, Environmental Resources Management and Global Security, with the focal point coordinator being Dr. Dieudonné Musibono. Other team members included Dr. Séraphin Ifuta, Dr. Julien Punga, Dr. Jean-Claude Palata, and Mr. Victor Puema. Plants were brought back to the University to be identified by the Herbarium of the University. At each site, a local CREDP facilitator was present: either Germain Mankoto or Aimé Kamamba.

At each site, we actively involved local partners, including fishermen, in the work. Using a participatory approach, we showed our partners how and why we identified fish and other species, and how and why we were collecting water quality parameters. In Bas-Congo, the fishermen themselves conducted part of the water quality analyses. We also worked with the fishermen to create a field guide for fishes in the local languages, Lingala and Kikongo.

The survey was conducted in three provinces: Bandundu, Bas-Congo, and Equateur, with very different ecological characteristics. In Bandundu, the survey was conducted at several sites in Mushie, between Mushie and Bokoni, and around Bokoni. In Bas-Congo, the survey was conducted at 5 study sites in Inga: Inga #1 (aka Tank), Point 50, Nziya, Songa, and Fwomalo. In Equateur, the survey was conducted at Bodjia, Gombe, the confluence of the Ubangi and Congo Rivers, Irebu, midway between Gombe and Mbandaka, and Mbandaka.

For fish, nets used included cast nets, seine nets, gill nets, and dip nets. We also purchased samples directly from fishermen, both in their fishing grounds or at the market. For birds, a mist net was used. For amphibians, dip net sampling and tape recording of frog calls were used. For macroinvertebrates, dip net sampling, kick net, drop net (left in position) and Hester-Dendy sampling methods were used.

Overall, at least 140 species of fish were recorded: 93 species of fish in Bandundu; 55 in Bas-Congo, and 54 in Equateur. The numbers per province don't sum up to 140, because a number of species were found in all 3 sites. We collected fish from 23 families, representing 92% of the families <u>known</u> for the Congo basin. Two new species were found; additional new species may be present in the remaining undetermined material. A new species of Lamprologine cichlid was found in the rapids of Bas-Congo (Schelly and Stiassny, 2003, submitted). A new species of lampeye (family Poeciliidae; subfamily Aplocheilichthyinae) was also found (Schelly, personal communication).

We also identified 60 species of birds, 17 species of amphibians, 8 species of reptiles, 9 species of mammals, 38 species of aquatic invertebrates, and 39 species of plants. One-fourth of the plant species are invasive, while 1/3 have medicinal value. Almost all of the mammal species recorded were bushmeat, a worrisome fact for all provinces. We recorded one hippopotamus killed for bushmeat, and one alive, upstream from Bokoni on the Kasai River.

Important reference collection material of fish species were, under a federal permit, deposited with the American Museum of Natural History (AMNH), New York, U.S.A and Cornell University. A scientific reference collection of select preserved fish specimens is being made for the University of Kinshasa. The AMNH is pursuing a complete identification of species now.

2. TERMS OF REFERENCE

This biological field survey of the animals and plants living in and along the Congo River (including terrestrial and aquatic plants, fishes, birds, mammals, amphibians, reptiles, and macroinvertebrates) was conducted for IRM, by the New England Aquarium (NEAq) as External Technical Assistance Provider. IRM is the implementing agency for the USAID-funded CREDP project. The NEAq organized the survey, in collaboration with researchers from the Kinshasa-based nongovernmental organization, Environmental Resources Management and Global Security, with the focal point coordinator being Dr. Dieudonné Musibono. Other scientists with ERGS included Dr. Séraphin Ifuta, Dr. Julien Punga, Dr. Jean-Claude Palata, and Mr. Victor Puema. Additional members of the team were Dr. John Sullivan and Mr. Robert Schelly, two ichthyologists from Cornell University and the American Museum of Natural History, respectively.

The terms of reference were:

1. To conduct a rapid biodiversity survey of the animals and plants living in and along the Congo River, in three provinces. The aim of the survey was to establish baseline data on the living aquatic resources of the river, and along the river: on their systematics, ecology, their use, and their conservation. As wide an ecological range of aquatic habitats as possible would be visited, focusing in particular on sites heavily utilized by the local residents. Terrestrial ecological integrity would be assessed. In addition, ecological parameters of the river water would be assessed at each site.

2. The survey would be conducted during Sept. and Oct., 2002, with the agreement and support of local people, the Governors of the Provinces, local partners, and the relevant authorities.

3. The opportunity would be taken during the course of the study to train local partners, local residents, and, where possible, students in essential techniques of biodiversity surveying and water quality analysis, including the collection, sorting, scientific determination of species using published keys for identification, and preservation of said species; and the analysis of various water quality parameters.

4. The results of the survey would be used to provide recommendations for monitoring by the local partners and communities. Specifically, the NEAq will provide a list of possible options for communities to begin tracking abundance, resource use, and ecosystem integrity. Our local partners will determine which of these options works best for them.

5. Partial scientific sponsorship (in exchange for export of museum reference specimens) would be provided by The New England Aquarium, Cornell University, and the American Museum of Natural History.

6. Additional necessary equipment, laboratory consumables, and literature would be purchased for the project by the NEAq, and (with receipts provided), reimbursed by IRM. Unused items would be left with IRM or with one of the project's partners.

Dr. Caroly A. Shumway, New England Aquarium, Boston, MA

3. ACKNOWLEDGEMENTS

This work has been supported by the U.S. Agency for International Development, and we thank them for their assistance. Many thanks to Innovative Resources Management for requesting our involvement. We are grateful to the DRC government for granting the U.S. members of the team visas to allow us to travel to the DRC; and to the Governors of the Provinces of Bandundu (Prof. Kidinda Shandingo), Bas-Congo, and Equateur for permitting us to conduct fieldwork on the living aquatic resources of the Congo River and for their enthusiastic support of the CREDP project. At the conclusion of this survey, the Honorable Directeur Chef de Service, Kadekya Muandumusa in the Ministère des Affaires Foncières, Environnement et Tourisme, kindly granted us a permit to export samples of preserved specimens of the fishes from this survey for scientific purposes. Thanks to the Dean of the Science Faculty at the University of Kinshasa for facilitating the export permit. Thanks to our local partners on site, who assisted us with this survey. Bandundu: Thanks to the chief of Bokoni village (Mundele) and the chief of the fishers, Bino, and the two fishermen who worked with us, Lepetit, Abrahim and Zephyrin (driver). Bas-Congo: Dr. Ditseki di Mabiala (Inspecteur Provincial de l'Agriculture, Peche et Elevage), Mr. Gabriel Lazayadio (Administrator de Territoire, Mr. Kabuiku Cesar August, President (Comite National des Voluntaires Au Travail, CNVT), and Mr. Floribert Tshipele, Directeur, CNVT. Thanks to the Societé Nationale d'Electricité (SNEL) for granting us permission to survey the various sites at Inga. Thanks to the President and Vice-President of the Fishing Association, Manua Tsakala and Makumba Baku, respectively, and to all of the fishermen who worked with us: Kitoko Likoto, Elumba Gi, Frank Vwanga, Maneu Tza, Mundele Luwuata, and Entretien. Thanks to the missions, priests, and nuns for providing accomodations in Mushi and Mbandaka. Equateur: Thanks to the mayor of Gombe, Mboyo Bakobo, for graciously providing the use of his home and yard for accomodation and meetings. Thanks for Fulgence Ndombe, chief of pecheurs at Bodjia, and Mr. Dikanza, president of the Gombe Fishing Association for their support of our survey in their villages.

We are grateful to the local facilitators, Germain Mankoto and Aimé Kamamba for their assistance in the field, and to Eva Gilliam of MONUC and Evelyn Samu, CARPE focal point for DRC, for their assistance.

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Most importantly, many thanks to the citizens who patiently assisted us in our enquiries.

4. PARTICIPANTS' ADDRESSES

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5. ORGANIZATIONAL PROFILES

The American Museum of Natural History
The American Museum of Natural History was founded in 1869 in the heart of New York City, New York, USA, and has since become one of the world's foremost scientific and educational institutions. Today, in addition to educating the public via exhibits, the AMNH conducts research in areas spanning the fields of vertebrate and invertebrate zoology, systematics, anthropology, paleontology, and the physical sciences and publishes the magazine *Natural History.*

Cornell University
Founded in 1865, Cornell is a privately chartered Ivy League Institution that is also the land grant university for the state of New York, USA. Cornell's mission is to serve society not only by educating, but also by extending the frontiers of knowledge. Cornell has approximately 20,000 undergraduate and graduate students, and is home to 100 interdisciplinary centers, institutes, laboratories, and programs. The rich tradition of research at Cornell continues in fields as diverse as the environment, space research, international issues, and communications.

Environmental Resources Management and Global Security
Environmental Resources Management and Global Security (ERGS) is a university-based private initiative in Kinshasa, DRC, that promotes the rational management of environmental resources for global security. Founded by Professor Diedonné Musibono in 1998, ERGS' expertise comes from science, social science, and engineering. ERGS's services have been used in ecotoxicology, enviromental audits, environmental restoration/water quality management, biodiversity surveys, management and conservation.

Innovative Resources Management
Innovative Resources Management (IRM) is a non-governmental organization based in Washington, D.C., USA, committed to meeting the complex challenges of sustainable development with proven solutions that facilitate the building of effective teams and coalitions, promote effective natural resources management and economic development, and strengthen the technical and institutional capacity of all stakeholders. For the past 10 years, IRM staff has worked at the cutting edge of developing coalition-building methodologies to combat global desertification and tropical forest degradation, catalyzed the emergence or growth of national and local NGO coalitions involving successful partnerships across government institutions, research centers, donors, and resource user groups, and taken the lead in the development of methodologies that provide local resource users both the incentive and capacities to manage natural resources sustainably. Many of IRM's projects are in African nations.

New England Aquarium
The New England Aquarium (NEAq) is a non-governmental organization based in Boston, MA, USA, whose mission is to present, promote and protect the world of water. Conservationists at the NEAq (in the Department of Global Marine Programs) work to resolve aquatic conservation problems worldwide by creating and linking community efforts with science-based policy development and public education. The Aquatic Biodiversity Program, a division of the department, underscores the value of science in addressing pressing questions in aquatic

biodiversity, the interdependence of humans with other species and ecosystems, and the importance of changing human behavior. Our efforts span grassroots and community programs, scientific research, and public education in the U.S., Africa, and the South Pacific. Program objectives include 1) fostering aquatic stewardship by changing human behavior toward the natural world; and 2) providing practical, science-based advice to communities and NGOs dependent on their aquatic resources.

6. INTRODUCTION

6.1 The importance of the Congo River to biodiversity

The Congo River, the second largest river basin in the world, is one of the world's biological treasures. Its global importance is primarily due to the diversity of its freshwater fish. The river has a high species richness, high endemicity, is of evolutionary importance (being the site of origin for the evolution of 7 out of 10 Lake Tanganyikan families), and comprises a complexity of habitats, ranging from rapids, seasonal and permanent swamps, river, riverbanks, floodplains and flooded forest, and streams (www.wcmc.org). Teugels and Guegan consider that the climatic stability, environmental stability, and complexity of habitats have favored such high speciation. According to FishBase (www.fishbase.org), the Congo River contains at least 686 species of fish, from 25 families, 80% of which are endemic (cited in Teugels and Guegan, 1994, Muzigwa, 1992). In comparison, a similar sized temperate river, the Mississippi, contains only 250 species. The Congo river is a national symbol for the Congolese, provides needed animal protein (20% of daily requirements, as of 1991), and is the most important means of transport in the country.

6.2. Map of the three axes under study

We rapidly surveyed three project sites in three provinces (Bandundu, Bas-Congo, and Equateur) (see arrows on map below). These sites are included in the following ecoregions, denoted by WWF (Thieme et al., 2003, in press): Bandundu: *Kasai*; Bas-Congo: *Lower Congo Rapids*; and Equateur: *Sudanic Congo (Oubangi), Cuvette Centrale, Sangha*, and *Lake Tumba*.

Zoogeographically, our survey covered two ichthyofaunic zones: 1) Matadi to Malebo Pool (rapids); and 2) Central Basin (Malebo Pool to Kisangani falls) (Poll, cited by Lowe-McConnell, 1986). Hyrodographically, the project also covered two zones: Bas-Congo, being in the Lower Congo zone (Kinshasa to Matadi); the other two sites in the Kinshasa to Kisangani zone (Teugels and Guegan, 1994). Note that Lake Tumba and Mai-Ndombe are important evolutionary sites for African freshwater fish.

Map produced by the U.S. Central Intelligence Agency. Courtesy of The General Libraries, The University of Texas at Austin.

7. METHODS

7.1. Field personnel

The team was comprised of the following scientists:

Water team

1. Scientific coordinator/Ichthyologist – Dr. Caroly Shumway (NEAq, US)
2. Scientific coordinator/water quality expert - Dr. Dieudonné Musibono (ERGS, DRC)
3. Ichthyologist/Electric fish expert – Dr. John Sullivan (Cornell, US)
4. Ichthyologist/Cichlid expert – Robert Schelly (AMNH, US)
5. Ichthyologist - Mr. Victor Puemba. (ERGS, DRC)
6. Macroinvertebrate expert – Dr. Julien Punga (ERGS, DRC)

Land team

7. Bird expert – Dr. Séraphin Ifuta (ERGS, DRC)
8. Amphibian/Reptile/Mammal expert - Dr. Jean-Claude Palata (ERGS, DRC)
9. Plants were brought back to the University to be identified by the Herbarium of the University.

Community facilitator

10. CREDP team member – Germain Mankoto or Aimé Kamamba (IRM)

7.2. Participatory approach

At each site, we actively involved those interested local partners, including fishermen, in the work. Using a participatory approach at the different field stations, we showed our partners how and why we identified fish and other species. For those partners with us on pirogues, we showed how and why we were collecting water quality parameters. Where possible, we enlisted the help of the local fishermen to conduct water quality analyses, including depth measurements and chemical analyses. In Bas-Congo, the fishermen themselves routinely conducted much of the water quality analyses, while we recorded (and confirmed) their observations. For all provinces, we also worked with the fishermen to create a field guide for fishes in the local languages, Lingala and Kikongo.

7.3. Sampling stations

Raw data for each station was noted on two separate sheets, one for the water team and one for the land team (for example, see Appendix). This data has been summarized in tables for all of the stations within a given province. For each province, Tables 1-7a,b, or c summarize species information for all of the animal groups and plants studied; Table 8a, b, or c summarizes water quality data. For Bandundu and Bas-Congo only, an additional table (table 9) summarizes heavy metal analyses of the water. Following the tables, individual sampling station reports are provided. These are prepared in a standard format, indicating name of geographical locality, location, date of visit, procedures, and ecological notes. Photographic records were made at each station (Appendix).

7.4. Water quality analysis

Water quality was analyzed during this biodiversity survey, since the health and survival of aquatic biota depend on clean water. We were interested in two different categories in water quality analysis: 1) those elements that influence productivity; and 2) those elements which are potentially harmful to the fauna. We selected the measures below for a baseline determination, based on recommendations from AAAS (1983), EPA (1994), and Wooton (1992). For a general overview of water quality parameters in fish ecology, see Lowe-McConnell (1991).

AAAS (1983) recommends that the following always or often be tested: temperature, turbidity, dissolved gases, inorganic nutrients, organic nutrients, pH, conductivity, benthic organisms, and fish. These measures are useful for understanding impacts of mining, agriculture, forestry, sewage, fertilizer, and pesticides (Table 1). A study of 204 volunteer monitoring programs in the United States (EPA, 1994) found that the top 9 parameters measured were, in order: temperature, macroinvertebrates, pH, dissolved oxygen, debris cleanup, flow, habitat assessments, and nitrogen. The most common water quality concern for rivers is point sources of organic, oxygen-consuming waste. Dissolved oxygen, temperature, flow, and nitrogen are usually used in monitoring programs where these problems occur.

Note that seasonal variations in water quality affect the abundance and distribution of organisms.

Table 1. Recommendations for baseline studies for assessing impacts on water bodies. Reprinted with permission from F. Conant, P. Rogers, M. Baumgardner, C. McKell, R. Damann, and P. Reining, eds. (1983) Resource Inventory and Baseline Study Methods for Developing Countries. AAAS. Washington, D.C. 539 pp.

Components of Aquatic Ecosystems	Generic & Specific Project Actions																						
	Impoundments							Withdrawal/Return Water Uses						Dredging		Introduction of Chemicals				Biotic Resource Harvest			
	Irrigation	Hydroelectric	Flood control	Water supply	Industrial	Recreational	Fisheries	Agriculture/irrigation	Livestock	Municipal/domes	Industrial	Mining	Waste disposal treatment	Estuarine	Riverine	Fertilizer	Pesticides	Industrial emissions	Domestic emissions	Fish	Shellfish	Vegetation	Aquaculture
1. Physical properties																							
a. Climate		S	S	S																			
b. Precipitation	A	A	A	S	S	S	S	A	S	S	S	S	S			S	S	O	S	S	S	S	S
c. Surface water	A	A	A	A	A	A	A	A	O	O	O	O	O	S	S	A	A	A	A	A	A	O	A
d. Groundwater	S	O	O	O	O	O	O	A	S	O	O	A	A	S	S	A	A	A	O	S	S	S	S
e. Tides and wave action		S	S		S	S	O							A									
f. Currents and circulation	O	O	O	O	O	O	A	S	S	S	S	S	S	A	A	A	A	O	O	O	O	O	O
g. Temperature	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
h. Salinity	A	S	S	A	O	O	A	A	A	A	A	S	S	A		S	S	S	S	A	A	S	A
i. Density and stratification																O	O	O	O	O	O	O	O
j. Light and transparency	S	S	S	S	S	S	S	A	A	O	O	O	O	A	A	A	A	O	O	O	O	O	O
2. Chemical properties																							
a. Dissolved gases	O	O	O	O	O	O	O	A	A	A	A	A	A	O	O	A	A	O	O	A	A	A	A
b. Dissolved solids																							
1) Inorganics nutrients/others	O	O	O	O	O	O	O	A	A	O	O	O	A	A	A	A	O	O	O	A	A	O	A
2) Organics	S	S	S	S	S	S	S	O	A	O	S	S	A	O	O	A	A	O	O	O	O	O	O
c. Particulates																							
1) Inorganic	O	O	O	O	O	O	O	A	A	A	A	A	A	A	A	S	O	S	S	S	O	S	S
2) Organic	S	S	S	S	S	S	S	A	A	O	S	S	A	O	O	S	S	S	S	S	S	S	S
d. pH	O	O	O	O	O	O	O	A	A	A	A	A	A	O	O	A	O	A	A	O	O	O	O
e. Conductivity	A	A	A	A	A	A	A	A	A	A	A	A	A	O	O	A	O	A	A	A	A	O	A
3. Biotic properties																							
a. Benthos	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	O	O
b. Plankton																							
1) Zooplankton								A	A	O	O	O	O			A	A	A	A	A	S	S	O
2) Phytoplankton								A	A	A	A	A	A			A	A	A	A	A	O	O	O
c. Fish and fisheries	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	O	A	A
d. Littoral vegetation	O	O	O	O	O	O	O	O	O	O	O	O	O	A	A	A	O	O	O	A	O	A	O
e. Wetland vegetation	A	O	A			O	A	A	O	O	O	O	O	A	A	A	O			A	A	A	A
f. Periphyton	O	O	O	O	O	O	O	A	A	O	A	A	A	O	O	A	A	O	O	S	S	S	S
g. Microbiota, pathogens other	A	O	O	A	O	A	O	A	O	A	O	S	A	S	S	S	S	S	S	S	A	S	O
4. Functional properties																							
a. Nutrient cycling	A	A	A	A	A	A	A	A	A	O	O	O	A	A	A	A	S	O	O	A	A	A	A
b. Primary productivity	O	O	O	O	O	O	O	A	A	O	O	O	A	O	O	A	S	O	O	O	O	A	A
c. Secondary productivity	O	O	O	O	O	O	O	O	O	O	O	O	O	S	S	A	O	O	O	A	A	S	S
d. Eutrophication								A	A	O	O	O	A			A	S	S	O	O	O	O	S
e. Ecosystem indices	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	A	A	A	S	A	A		A
f. Water balance	A	A	O	O	S	S	S	A	S	S	S	S	S							S	S	O	S

Water quality was analysed on site for the following parameters, using a Hagen test kit: alkalinity, total hardness, phosphates, nitrates, and calcium. A digital pH meter (Orion) was used to determine pH. A conductivity meter was used to determine conductivity. Dissolved oxygen was measured with a YSI Dissolved Oxygen Meter. Saturation values were adjusted after returning to the U.S. and obtaining altitudinal data for each site (CRES, 2000). The correction factor to compute oxygen partial pressure at altitude was calculated with a saturation calculator found at http://www.internal.eawag.ch/~buehrer/O2 satur.html. Identical results were obtained from a regression line calculated from an altitude/dissolved oxygen table, available at the government of British Columbia website (http://wlapwww.gov.bc.ca/wat/wq/BCguidelines/do/do-01.html).Transparency and turbidity were assessed on site with a Secchi disk. True colour, turbidity, iron, manganese, cadmium, lead and copper were analysed in the laboratory by spectrophotometry, using the HACH DR/2000 (Hach, 1991). True color was determined by spectrophotometry, as described by Hach (1991) for DR/2000 analysis. Color was determined after filtration through Watman 0.45 µm paper.

Note that several water quality samples were collected for laboratory analysis of turbidity, true color, and heavy metals at a given site. Empty cells in the water quality tables indicate the columns of additional samples.

An explanation of the importance of these measures is provided below.

Clarity/turbidity. Measures of light transmission are useful in assessing the level of primary productivity in the river as well as the presence of dissolved organic matter. Secchi Disk readings can vary seasonally due to changes in primary productivity and amount of sediment entering the water during flooding. Turbidity is a measure of the cloudiness of the water. Light is extinguished by three factors: 1) absorption by the water itself; 2) absorption by dissolved or suspended particles in the water; and 3) scattering by particles in the water. Suspended materials decrease the productivity of the system. The most important inorganic particles that impact clarity are suspended clays and silt, which increase in amount with mining and forestry activity. Dissolved organics that impact clarity result from decomposition, secretions, fecal waste, and input from terrestrial sources.

Colour/true color. Water colour may differ greatly between waters with different chemical and biological properties. A brown or black tinge indicates a high level of humic substances which would render the water acidic, with low biological productivity.

Water temperature. Biotically, water temperature is an important measurement, because temperature affects the growth rate, development, metabolic rate, and distribution of aquatic species. Some species spawn more in warmer waters. Temperatures can also affect the spread of disease. Temperature affects the nutrient cycle, because increasing temperatures increase the rate of synthesis and decomposition of organic matter. Where water is slow-moving or stagnant, a change in water temperatures can influence the mixing of water layers. Thermal stratification is the most common means of creating density layers.

pH. This measure tells one about the concentration of hydrogen ions in the water. A pH less than 7 is acidic; that greater than 7 is basic. Being a logarithmic scale (pH is the log of the

reciprocal of the hydrogen ion concentration), a one-unit change in pH indicates a 10-fold change in hydrogen ion concentration.
Changes in pH can be the result of both physical inputs to the water as well as biological inputs.

Carbonate hardness (kH) – Carbonate hardness, also known as alkalinity, is a measure of the carbonate (CO_3) and bicarbonate (H_2CO_3) ion concentrations dissolved in water. The lower the carbonate hardness, the lower the buffering capacity of the water, and the more likely the water is to suffer pH swings.

General hardness (gH) – General Hardness is a measure of the concentration of Calcium and Magnesium ions. These salts are important in regulating the cellular functions of aquatic organisms, and in buffering the water.

Phosphate – Phosphorus is critical for metabolic processes involving the transfer of energy. Phosphate is generally the limiting nutrient in freshwater. A low concentration indicates that the water is not productive, and the animals in the water column must obtain their primary production from elsewhere. An overabundance would indicate eutrophication, which could lead to oxygen depletion. Note that tropical waters are typically nutrient-poor

Nitrate – Nitrogen's primary role in organisms is protein synthesis; plants also use nitrogen for photosynthesis.

Calcium – Calcium was measured as another nutrient needed for organisms. It is not limiting in most freshwaters.

Dissolved oxygen – Dissolved oxygen is critical for the survival of most aquatic life. This measure tells one how saturated the water is with oxygen. It is a measure of the metabolic activity in the water. The oxygen enters and leaves the water via the photosynthetic and respiratory activities of the biota, and by surface diffusion. The warmer the water temperature, the less oxygen it can hold. Most animals and plants grow fine when DO levels are higher than 5 mg/L. They become stressed between 3-5 mg/L. At 3 mg/L, the water is hypoxic, and mobile species will move elsewhere; nonmobile ones may die. In tropical waters, the reserve of oxygen above the critical minimum concentration (3 mg/l) is much less than that of temperate waters.

Conductivity – Conductivity provides information about the water's ability to conduct an electrical current. Conductivity is useful for estimating ionic content, and therefore, the fertility of the water. This parameter is critical for electric fish, one of the key groups of fishes in the Congo river, as the conductivity of the water is an important cue in their reproductive cycle.

Current flow – Current flow is important as a key determinant of habitat preferences, due to its influence on substrate, dissolved oxygen levels, and flora. Slower currents permit greater development of both planktonic and benthic flora and fauna. Unfortunately, due to cost constraints, we were only able to estimate current qualitatively.

Macroinvertebrates – Macroinvertebrates provide a simple method for monitoring the ecological integrity of a river. For example, 75% of the U.S. programs that monitor rivers monitor macroinvertebrates (EPA, 1994).

Heavy metals – Heavy metals give an indication of the level of pollution in the water from agriculture, mining or industry. Metals were analysed on samples from Bas-Congo (Inga) and Bandundu (Bokoni, on the Kasai River) trips because of upstream activities related to mining or industries. However samples from Gombe (Equateur) were also analysed for comparison. Attention was paid to lead (Pb), cadmium (Cd), copper (Cu), manganese (Mn), iron (Fe) and hexavalent chromium (CrVI) because of their effects on aquatic ecosystems (Musibono, 1999; Musibono, 1992; Dégrémont,1989).

7.5. Fish sampling and identification

For fish, we used cast nets (epervier), seine nets, experimental gill nets (with four panels varying in size), and dip nets. Net choice depended on the site. We also purchased samples directly from fishermen, both in their fishing grounds and at the market. We mainly sampled along river banks. We had hoped to sample in the middle of the river with a shrimp trawl, since the fish species would have been different in these areas, but could not do so given the small size of our research boats. We primarily used the 1994 Max Poll and Jean-Pierre Gosse book (General des poisson d'eaus douce de l'Afrique) as the reference guide. A copy of this book has been left with the University of Kinshasa and with the IRM field office in Kinshasa. We also had a list of the freshwater fishes of the DRC from FISHBASE (www.fishbase.org). Another useful general list is the Checklist of the freshwater fishes of Africa (CLOFFA 1,2,3,4 – Daget et al., 1984, 1986a, b, 1991).

7.6. Other vertebrate sampling and identification

For birds, a mist net was used. The net was checked every few hours. For amphibians, dip net sampling and tape recording of frog calls were used. Tape recordings of species serve as valid records of a species (Davies, 2002). Amphibian surveys were primarily conducted during the crepuscular period (dusk). Note that our amphibian counts in the dry season are less than would be found in the rainy season, as amphibians are much more active during the latter period. We used Borrow and Demey (2001) and Serle and Morel (1979) as reference guides.

7.7. Macroinvertebrate sampling and identification

For macroinvertebrates, dip net sampling, kick net, drop net (left in position for as many days as feasible) and Hester-Dendy sampling methods were used. We used Bland (1978); Dartevelle; Grisse (1972); Holthus (1951); and Tachet et al. (1996) as reference guides.

7.8. Museum specimens

In the field, numerous fish species, in particular, were identified only to genus. Collections of museum specimens (small representatives of the species) and tissue samples were transported back to the American Museum of Natural History to ensure accurate identification to the species level. After verification of species identification, a representative collection of fish specimens was sent back to the University of Kinshasa.

Tape recordings of bird and amphibian species will be deposited at the Macauley Library of Natural Sounds, Cornell University, Ithaca, NY, to be available for other researchers. Representative plant specimens were deposited at the University of Kinshasa herbarium. Representative invertebrate specimens were deposited at the University of Kinshasa.

7.9. Specimen preservation

All of the fish specimens collected were fixed in the field in 10% formalin solution. Large samples were slit on the ventral surface to allow the fix to enter internal organs. In Bandundu, the solution was made up in the field with H20, paraformaldehyde powder, and a handful of KOH pellets (4 pellets) used to get the paraformaldehyde into solution. A teaspoon of marble chips were used to buffer the solution. At the other two sites, formalin was used directly. Once fixed in formalin for one week, specimens were removed from the solution, provisionally identified, labeled, rinsed, damp-packed with H_20 in cheesecloth, triple sealed in heavy-duty polythene bags, and placed in approved liquipak drums for shipment to the American Museum of Natural History (AMNH). Those specimens registered at the AMNH were transferred to an alcohol preservative for long-term storage.

Tissue samples of select specimens were also prepared for molecular analysis to assist in species identification. Tissue samples (several mm) were obtained from a piece of muscle below the dorsal fin, and placed in 1.8 ml of ethanol in Eppendorf tubes. Some tissue samples were placed in a lysis buffer. A lighter was used to sterilize the forceps between specimens.

7.10. Taxonomic conventions

The following taxonomic conventions have been used throughout the report.
Order name is printed in upper case bold, e.g., **CRUSTACEA**
Family name printed in upper case, e.g., LIBELLULIDAE
Genus and species printed in italics, e.g., *Petrocephalus microphthalmus*
sp. = species undetermined

8. RESULTS

8.1 SUMMARY OF SPECIES REPRESENTED IN SURVEY

A summary of all species observed during this survey is presented in the following tables: Table 1a (Fish), 2a (birds), 3a (amphibians), 4a (reptiles), 5a (mammals), 6a (invertebrates), and 7a (plants).

Fish: 54% of the Congo's fishes (including characins, catfishes, electric (knife) fishes, carps and loaches) are part of the higher teleostean lineage named Otophysi (Ostariophysi in older literature). Graph 1 shows the percentage of species in each of the 11 orders that we recorded. The most abundant orders (with more than 5% of the species represented) are the same top 5 orders as reported by Teugals and Guegan for the Congo River (1994): Osteoglossiformes, Siluriformes, Characiformes, Perciformes, and Cypriniformes. Graph 2 shows the percentage of species among each of the 23 families recorded. These families represent 92% of the known families for the Congo River. This graph shows that the dominant family is the electric fish family, Mormyridae (order Osteoglossiformes), representing 23% of the species identified, and 27% of the mormyrids known for the Congo River. The next most dominant are the Cichlidae, at 11% of the sample, followed by the Characidae at 10%, the Distichodontidae at 9%, and two catfish families (Mochokidae and Bagridae, at 9% and 7%, respectively). The Cyprinidae constitute 7% of the sample. Graph 3 shows that Mormyridae significantly dominate in all provinces, representing over 20% of the sample. Other prominent families (representing over 5% of the sample) in all provinces include: Characidae, Mochokidae, Bagridae, Distichotidae, and Cichlidae. Cyprinidae are prominent in Bas-Congo (11%). Clariidae is among the dominant families only in Equateur (6%).

Table 1a shows the species found in the three provinces. Overall, at least 141 species of fish were recorded: 94 species of fish in Bandundu; 55 in Bas-Congo, and 54 in Equateur. None of the species are considered threatened or endangered by WCMC or Cites. The numbers per province don't sum up to 141, because a number of species were found in all 3 sites. Two new species were found; additional new species may be present in the remaining undetermined material. A new species of Lamprologine cichlid was found in the rapids of Bas-Congo (Schelly and Stiassny, 2003, submitted). A new species of lampeye (family Poeciliidae; subfamily Aplocheilichthyinae) was also found (Schelly, personal communication).

Three of the species observed are exotic: *Heterotis niloticus* (found in all 3 provinces), *Tilapia nilotica*, and *Lates niloticus*. Guy Teugels of the Africa Museum in Belgium estimates the following number of fish species for each ecoregion: *Kasai* (which includes Bandundu sites): 203, with an estimated 49 endemics: *Lower Congo Rapids* (which includes Bas-Congo sites): 59, with an estimated 17 endemics; and *Central Congo* (which includes some Equateur sites): 206, with an estimated 11 endemics.

To aid understanding, here is an overview of some fish families, listed by common name:

1. Lungfishes – Protopterus is an air-breathing fish. It can live in anoxic or hypoxic water.
2. Bichirs - Polypterus is characteristic of ancient fishes, with lobed fins and a hard coating on its scales.
3. Herrings – Odaxothrissa is a common freshwater species of a largely marine herring family (Clupeidae).

4. Elephant fishes – Mormyrids are weakly electric fish, with an electric organ in their tail, used for location and communication. They are primarily active at night.
5. Characins – Characids can be identified by their small dorsal adipose fin.
6. Killifishes (in the order Cyprinodontiformes). These top minnows are small insectivorous species that are an important prey item for other fish. They feed on insect larvae, such as mosquitoes, and may be important for disease control.
7. Cichlids are recognized by a single pair of nostrils.

Other groups: We also recorded 60 species of birds, 17 species of amphibians, 9 species of reptiles, 9 species of mammals, 38 species of aquatic invertebrates, and 35 species of plants. All of the mammal species recorded were bushmeat, a worrisome fact for all provinces. The largest mammal seen was one hippopotamus killed for bushmeat.

Birds. The DRC is known to have 929 bird species, of which 24 are endemic, and 26 threatened. With our rapid investigation, using only one mist net, we recorded 60 species of birds, belonging to 15 families. The most abundant order was the Passeriformes, followed by Coraciiformes and Ciconiiformes. We observed the following 5 threatened bird species (on the CITES list):*Treron calva* (African green pigeon; Bandundu), *Turtur afer* (Blue-spotted wood dove; Equateur), *Streptopelia semitorquata* (Bas-Congo and Equateur), *Corythaeola cristata* (Great blue turaco; Bandundu), and *Pycnonotus spp* (bulbuls; Bandundu and Equateur).

Plants. The DRC is known to have 11,007 higher plant species, of which 1,100 are endemic, and 69 are threatened. While our survey focused on animal groups, we identified the dominant plants in each habitat. We recorded 39 species of plants. Over 25% of these species are invasive.Thirty-three percent of the plants have medicinal value.

Abundant aquatic plants at our station sites included *Oryza barthii* (wild rice*), Echinocloa pyramidalis* (antelope grass), and *Echinochloa stagnina*. We also found *Hyparrhenia diplandra, Panicum maximum*, and the invasive *Imperata cylindrica (*cogon grass)*,* mainly at Gombe, Bokoni and Inga stations. Associated aquatic plants included *Cyperus sp*. and *Pistia stratiotes* (water lettuce), and the invasive species of *Panicum repens, Ipomea aquatica* (water spinach), *Eichornia crassipes* (water hyacinth), *Salvinia nymphellula,* and *Mimosa pigra* (sensitive plant). The littoral vegetation provides spawning and nursery grounds for both fish and macroinvertebrates, and a substrate for periphyton (a microscopic community of algae, protozoa, bacteria, snails, and insect larvae).

Secondary and degraded forest plants characterized were the shrub (*Alchornea cordifolia),Ficus spp*. (fig tree), *Chromolaena odorata* (an invasive shrub),and *Vossia cuspidata* (hippo grass).

Amphibians. The DRC is known to have 80 amphibian species, of which 53 are endemic (Earthtrends, 2001). We recorded 17 species in the families Bufonidae and Ranidae. None of these species are known to be threatened or endangered. Of these, 14 were Ranids, which represents 38% of all Ranids known for the DRC. Eighteen species are estimated for the Central Congo.

Reptiles. The DRC is known to have 377 reptile species, of which 35 are endemic, and 3 threatened. 77 reptile species are estimated for the Central Congo. We recorded 9 species, including the threatened dwarf crocodile, *Osteolaemus tetraspis*, on sale at the Mushi market.

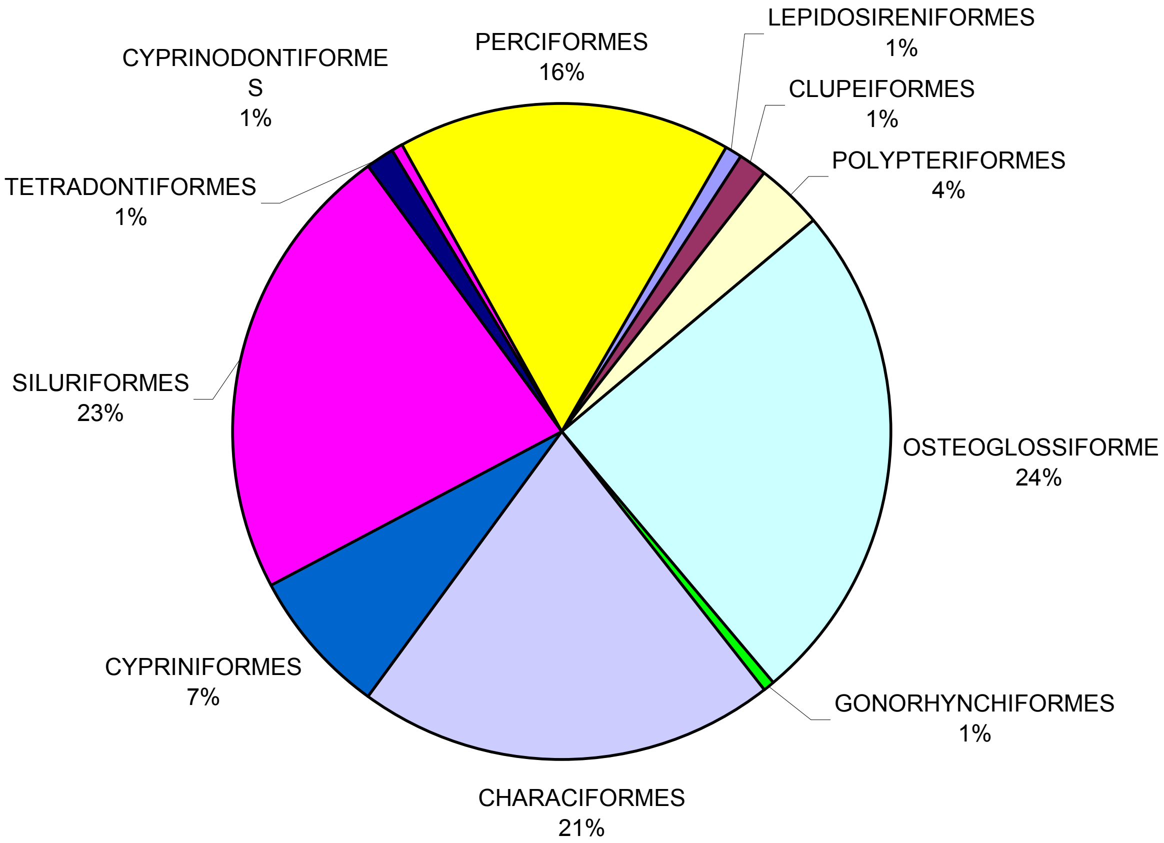
Mammals. The DRC is known to have 450 mammal species, of which 28 are endemic, and 38 threatened. 123 mammal species are estimated for the Central Congo. We recorded 9 species, of which The sitatunga (*Tragelaphus spekei*) is a truly aquatic mammal, found only in swamp grasses. Its hooves are specially adapted to walk on marshy soil.

Macroinvertebrates. The most dominant classes reported in the literature are Crustaceans and Insects, followed by Molluscs. These were also the 3 most dominant classes found in our survey. The Decapopa, Odonata, Caenogastropoda, and Hemiptera were the most abundant orders in our survey, with the Atyidae and Assimineidae the most abundant families represented.

Phylum	**Order**	**Species number**	**% represented**
Mollusca	Caenogastropoda	5	13
	Stylommatophora	1	2.7
	Sigmurethra	3	8
Arachnida	Araneae	1	2.7
	Labidognatha (suborder)	1	2.6
Crustacea	Decapoda	11	29
Insects	Odonata	6	16
	Hemiptera	6	16
	Coleoptera	2	5
	Heteroptera	2	5
Total	**10**	**38**	**100**

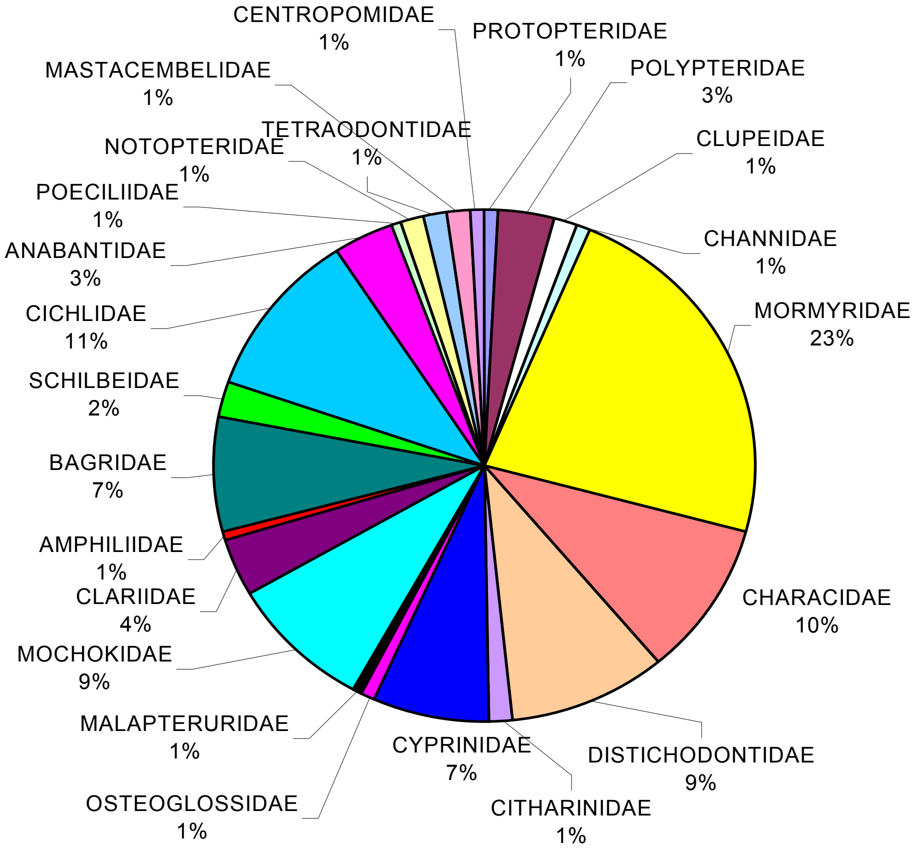
GRAPH 1. FISH ORDERS REPRESENTED

Percentages indicate the proportional representation of species in each order.



GRAPH 2. FISH FAMILIES REPRESENTED

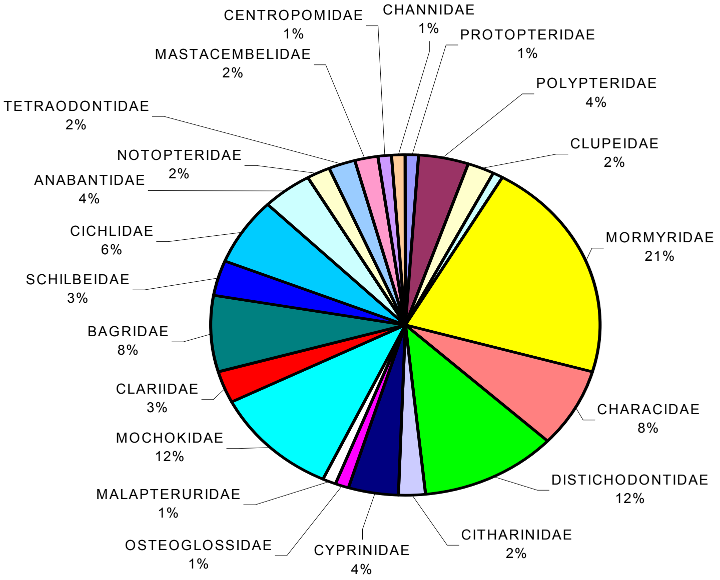
Percentages indicate the proportional representation of species in each family.



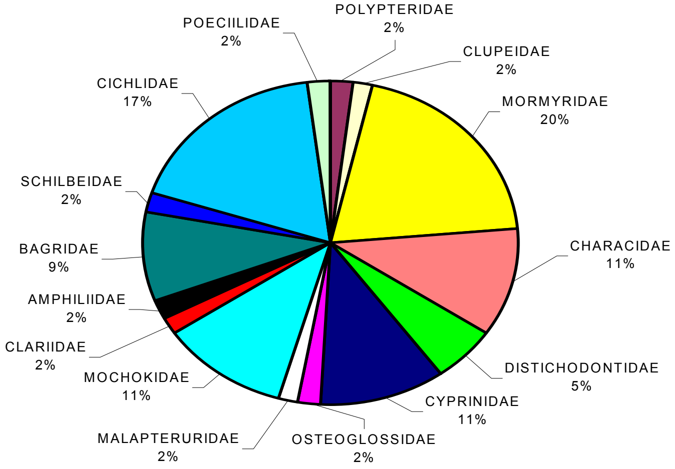
GRAPH 3. FISH FAMILIES REPRESENTED IN EACH PROVINCE.

Percentages indicate the proportional representation of species in each family.

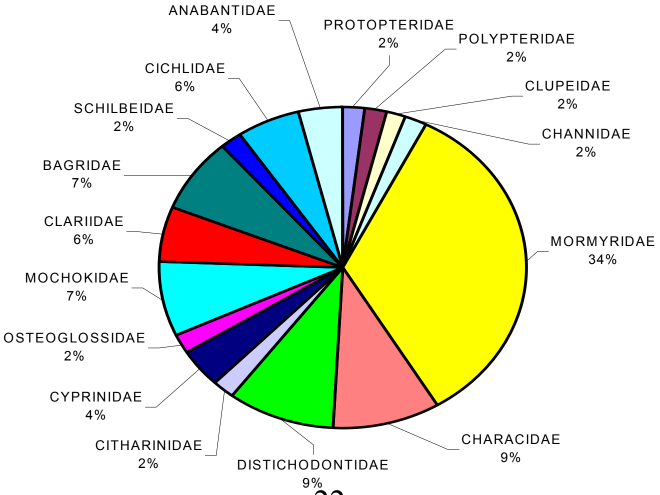
BANDUNDU



BAS-CONGO



EQUATEUR



8.2. Summary tables of species for all provinces.

TABLE 1A. SUMMARY OF FISH SPECIES RECORDED PER PROVINCE
+ = recorded ; sp. = unidentified, may not be the same across provinces.

ORDER	FAMILY (common name)	SPECIES	BANDUNDU	BAS-CONGO	EQUATEUR
LEPIDOSIRENIFORMES	PROTOPTERIDAE (lungfishes_	*1. Protopterus dolloi*	+		+
POLYPTERIFORMES	POLYPTERIDAE (bichir)	*2. Polypterus sp. 1 (black)*	+		
		3. Polypterus sp. 2 (banded)	+	+ sp.	
		4. Polypterus delhezi	+		
		5. Polypterus sp. 4i			+ sp.
		6. Polypterus ornatipinnus	+		
CLUPEIFORMES	CLUPEIDAE (herrings/sardines)	*7. Odaxothrissa spp.*	+		
		8. Clupeidae spp.	+	+ sp.	+ sp.
GONORHYNCHIFORMES	CHANNIDAE (snakeheads)	*9. Parachanna obscura*			+
OSTEOGLOSSIFORMES	MORMYRIDAE (elephantfishes)	*10. Petrocephalus sp. 1*		+ sp.	+
		11. Petrocephalus sp. 2			+
		12. Petrocephalus sauvagii	+		+
		13. Petrocephalus sp. (simus?)	+		
		14. Petrocephalus microphthalmus	+		
		15. Gnathonemus petersii	+		
		16. Gnathonemus sp.		+	+
		17. Genyomyrus donnyi	+		
		18. Hippopotamyrus discorhynchus	+	+	+
		19. Hippopotamyrus plagiostoma			+
		20. Hippopotamyrus pictus	+		
		21. Hippopotamyrus sp.			+
		22. Mormyrops anguilloides	+	+	+
		23. Mormyrops mariae	+		
		24. Mormyrops nigricans			+
		25. Marcusenius greshoffi	+		+
		26. Marcusenius sp. 1	+	+ sp.	+ sp.
		27. Marcusenius sp. 2	+		+ sp.
		28. Marcusenius sp. 3	+		
		29. Marcusenius monteiri		+	+
		30. Stomatorhinus sp. 1 (little, black)	+		
		31. Pollimyrus adspersus	+		
		32. Pollimyrus sp.	+		
		33. Mormyrus proboscirostris	+		+
		34. Mormyrus caballus bombanus	+	+	+
		35. Mormyrus ovis			+
		36. Campylomormyrus mivris		+	

		37. Campylomormyrus urirrostrus		+	
		38. Campylomormyrus tamandua	+		+
		39. Campylomormyrus elephas	+		
		40. Campylomormyrus sp. 1		+ sp.	+ sp.
		41. Campylomormyrus sp. 2		+ sp.	
	OSTEOGLOSSIDAE (bony tongues)	*42. Heterotis niloticus (Cuvier)*	+	+	+
	NOTOPTERIDAE (featherbacks)	*43. Xenomystus nigri (Gthr.)*	+		
		44. Papyrocranus afer (Gthr.)	+		
CHARACIFORMES	CHARACIDAE (characins)	*45. Bryconaethiops microstoma*	+		
		46. Brycinus sp.			
		47. Hydrocynus goliath	+	+	+
		48. Hydrocynus vittatus	+		
		49. Alestes sp.	+		+
		50. Brycinus sp. 1	+		+ sp.
		51. Brycinus sp. 2	+		
		52. Bryconaethiops sp.			+
		53. Micralestes sp.	+		
		54. Small characid sp. 1		+	+ sp.
		55. Small characid sp. 2		+	
		56. Small characid sp. 3		+	
		57. Small characid sp. 4		+	
		58. Small characid sp. 5	+ sp.	+	
	DISTICHODONTIDAE	*59. Ichthyborus ornatus*	+		
		60. Phago boulengeri	+	+	+
		61. Distichodus notospilus			+
		62. Distichodus fasciolatus	+		
		63. Distichodus atroventralis	+		+
		64. Distichodus antonii	+		+
		65. Distichodus maculatus	+		
		66. Distichodus affinis	+		
		67. Distichodus lusosso		+	+
		68. Distichodus sexfasciatus		+	
		69. Eugnathichthys sp.	+		
		70. Xenocharax spilurus	+		
		71. Nannocharax sp.	+		
	CITHARINIDAE	*72. Citharinus gibbosus (Blgr.)*	+		+
		73. Citharinus congicus	+		
CYPRINIFORMES	CYPRINIDAE (minnows/carps)	*74. Barbus sp.*	+		
		75. Labeo vellifer		+	
		76. Labeo coubie		+	
		77. Labeo lineatus	+	+ sp.	+ sp.
		78. Labeo weeksii	+		

		79. Labeo sp.cf. weeksii3	+		
		80. Labeo nasus		+	
		81. Labeo macrostoma		+	
		82. Labeo sorex		+	
		83. Leptocyprus sp.			+
TETRAODONTIFORMES	TETRAODONTIDAE (puffers)	*84. Tetraodon mbu (Blgr.)*	+		
		85. Tetraodon miurus (Blgr.)	+		
SILURIFORMES	MALAPTERURIDAE (electric catfishes)	*86. Malapterurus electricus*	+	+	
	MOCHOKIDAE (squeakers)	*87. Synodontis acanthomias*	+		+
		88. Synodontis sp. 1	+	+ sp.	+ sp.
		89. Synodontis sp. 2	+	+ sp.	+ sp.
		90. Synodontis sp. 3	+	+ sp.	+ sp.
		91. Synodontis sp. 4	+	+ sp.	
		92. Synodontis sp. 5	+		
		93. Synodontis sp. 6	+		
		94. Synodontis sp. 7	+		
		95. Synodontis sp. 8	+		
		96. Euchilichthys sp.		+	
		97. Mochokiella sp.	+		
		98. Microsynodontis		+	
	CLARIIDAE (airbreathers)	*99. Heterobranchus longifilis (Val.)*	+		+
		100. Channallabes apus (Gthr.)	+		
		101. Chariallobes sp.		+	
		102. Clarias sp. 1	+		+ sp.
		103. Clarias sp. 2			+ sp.
	AMPHILIIDAE (loach catfishes)	*104. Belonoglanis sp.*		+	
	BAGRIDAE (bagrids)	*105. Bagrus sp.*	+	+ sp.	
		106. Bagrus ubangensis			+
		107. Auchenoglanis occidentalis	+		+
		108. Parauchenoglanis spp.	+		
		109. Chrysichthys sp. 1	+	+ sp.	+ sp.
		110. Chrysichthys sp. 2	+	+ sp.	+ sp.
		111. Chrysichthys sp. 3	+	+ sp.	
		112. Chrysichthys sp. 4	+		
		113. Rheoglanis dendrophorus		+	
		114. Parailia congica	+		
	SCHILBEIDAE (schilbeids)	*115. Schilbe sp. 1*	+		
		116. Schilbe sp. 2	+		
		117. Schilbe mystis		+	+
PERCIFORMES	CICHLIDAE (cichlids)	*118. Tylochromis sp.*	+	+ sp.	+ sp.
		119. Tylochromis lateralis		+	

		*120. Lamprologus sp.**(new sp.)***	+	+ sp.	
		121. Lamprologus congoensis	+		
		122. Haplochromis demeusii		+	+
		123. Hemichromis elongatus	+	+ sp.	+ sp.
		124. Nannochromis sp.	+		
		125. Nanochromis consortus		+	
		126. Sarotherodon galileus boulengeri	+		
		127. Steatocranus casuarius		+	
		128. Steatocranus tinanti		+	
		129. Steatocranus glaber		+	
		130. Tilapia (Oreochromis) sp? = marichal	+		
		131. Tilapia sp.		+	
		132. Tilapia nilotica			+
	ANABANTIDAE (climbing gouramies)	*133. Ctenopoma acutirostre*	+		
		134.Ctenopoma pellegrini			+
		135. Ctenopoma kingsleyae	+		+
		136. Ctenopoma ocellata	+		
		137. Ctenopoma nebulosa	+		
	MASTACEMBELIDAE (spiny eels)	*138. Mastacembelus sp. 1*	+		
		139. Mastacembelus sp. 2	+		
	CENTROPOMIDAE (snooks)	*140. Lates niloticus (L.)*	+		
CYPRINODONTIFORMES	POECILIIDAE (poeciliids)	*141. Aplocheilichthyes sp. **(new sp.)***		+	
		TOTAL SPECIES/AXIS	**94**	**55**	**54**

TABLE 2a. SUMMARY OF BIRD SPECIES RECORDED PER PROVINCE

ORDER	FAMILY (common name)	SPECIES (common name, where available)	Bandundu	Bas-Congo	Equateur
CICONIIFORMES	ARDEIDAE (herons)	1.*Bubulcus ibis* (cattle egret)	+		+
		2.*Egretta alba* (Great white egret)	+		+
		3.*Egretta ardesiaca* (black heron)	+	+	+
		4.*Egretta garzella* (little egret)	+		
		5.*Egretta gularis* (Western reef heron)		+	
		6.*Ardea purpurea* (purple heron)	+		
	CICONIIDAE (storks)	7.*Ciconia episcopus* (woody-necked stork)	+ M		
CORACIIFORMES	MEROPIDAE (bee-eaters)	8.*Merops pusillus* (little bee-eater)	+	+	+
	BUCEROTIDAE (hornbills)	9. *Tockus sp*	+		
		10. *Tockus fasciatus* (African pied hornbill)			+
	ALCEDINIDAE (kingfishers)	11. *Alcedo cristata* (Malachite kingfisher)	+		
		12.*Ceryle rudis* (Pied kingfisher)	+	+	+
		13.*Halcyon senegalensis* (woodland kingfisher)	+		+
		14.*Halcyon leucocephala* (Gray-headed kinfisher)			+
		15.*Halcyon sp.*		+	
GRUIFORMES	RALLIDAE (rails)	16. *Porphyrio alleni* (Allen's gallinule)			+
PICIFORMES	CAPITONIDAE (barbets)	17. *Pogoniulus bilineatus* (yellow-rumped tinkerbird)	+	+	
		18. *Pogoniulus sp.*		+	
PELECANIFORMES	ANHINGIDAE (anhinga)	19. *Anhinga rufa* (African darter)	+		+
	PHALACROCORACIDAE (cormorants)	20.*Phalacrocorax africanus* (long-tailed cormorant)	+	+	
PSITTACIFORMES	PSITTACIDAE (parrots)	21. *Psittacus erythacus* (grey parrot)			+
FALCONIFORMES	ACCIPITRIDAE (hawks/eagles)	22. *Gypohierax angolensis* (palm-nut vulture)	+	+	+
		23.*Milvus migrans* (black kite)	+		+
GALLIFORMES	PHASIANIDAE (pheasants and partridges)	24. *Francolinus sp.*		+	
COLUMBIFORMES	COLUMBIDAE (pigeons and doves)	25. *Treron calva* (African green pigeon)	+ M		
		26. *Turtur afer* (blue-spotted wood dove)	+		+
		27. *Streptopelia semitorquata*		+	+
CHARADRIIFORMES	JACANIDAE (jacanas)	28. *Actophilornis africanus* (African jacana)	+		+

	CHADRIIDAE (plovers)	29. *Vanellus albiceps*	+		
	SCOLOPACIDAE (sandpipers and snipes)	30.*Tringa sp.*	+		
MUSOPHAGIFORMES	MUSOPHAGIDAE (turacos and allies)	31. *Corythaeola cristata*	+		
CUCULIFORMES	CUCULIDAE (cuckoos, coucals, and anis)	32. *Centropus senegalensis* (Senegal coucal)	+	+	+
CAPRIMULGIFORMES	CAPRIMULGIDAE (nightjars and allies)	33. *Macrodipteryx vexillarius* (Pennant-winged nightjar)			+
APODIFORMES	APODIDAE (swifts)	34. *Rhaphidura sabini* *(Sabine's spinetail)*			+
PASSERIFORMES	PASSERIDAE (Old-world sparrows)	35. *Passer griseus* (Gray-headed sparrow)	+	+	+
	PLOCEIDAE (weavers)	36. *Ploceus melanocephalus* (black-headed weaver)			+
		37. *Ploceus nigerrimus* (Veillot's black weaver)	+		
		38. *Ploceus pelzelni* (slender-billed weaver)			+
		39. *Ploceus aurantius* (orange weaver)	+		
		40. *Ploceus cucullatus* (village weaver)	+		+
		41.*Quelea quelea* (red-billed Quelea)			+
		42. *Brachycope anomala* (bob-tailed weaver)			+
	ESTRILDIDAE (waxbills)	43. *Estrilda sp.*			+
		44. *Lonchura cucullata* (bronze mannikin)	+	+	
		45. *Uraeginthus angolensis* (blue-breasted cordonblue)		+	
	PYCNONOTIDAE (bulbuls)	46. *Pycnonotus barbatus* (common bulbul)		+	+
		47. *Pycnonotus spp*	+		+
	CORVIDAE (crows, jays, and allies)	48. *Corvus albus* (pied crow)	+	+	+
	HIRUNDINIDAE (swallows and martins)	49. *Hirundo abyssinica* (lesser-striped swallow)		+	
		50. *Hirundo senegalensis* (mosque swallow)		+	
		51. *Hirundo rustica* (barn swallow)		+	
		52. *Delichon urbica* (house martin)		+	
	NECTARINIDAE (sunbirds and spiderhunters)	53. *Nectarinia sp.*	+		
		54. *Nectarinia chnloropygia*	+		
		55. *Anthrepes collaris* (collared sunbird)			+
	VIDUIDAE (Indigo birds)	56. *Vidua macruora* (pintailed whydah)	+		+
	MOTACILLIDAE (pipits and wagtails)	57. *Motacilla agwimp* (African pied wagtail)		+	

		58. *Motacilla flava* (yellow wagtail)	+		
	SYLVIIDAE (Old-world warblers)	59. *Cisticola natalensis* (croaking cisticola)		+	
	TURDIDAE (thrushes)	60. *Saxicola torquata* (South African stonechat)			+
	TOTAL SPECIES BY AXIS		**34**	**23**	**32**

Table 3a. SUMMARY OF AMPHIBIAN SPECIES RECORDED PER PROVINCE

FAMILY	**SPECIES**	**Bandundu**	**Bas-Congo**	**Equateur**
BUFONIDAE	1. *Bufo funereus*		+	+
	2. *Bufo maculatus*	+		
	3. *Bufo regularis*	+		+
RANIDAE	4. *Discroglossus occipitalis*			+
	5. *Hemisus marmoratum*	+		
	6. *Hymenochirus curteines*		+	
	7. *Rana mascariensis*	+	+	+
	8. *Phrynobatrachus natalensis*	+		
	9. *Phrynobatrachus sp.*	+		
	10. *Rana fuscigula angolensis*			+
	11. *Rana fuscigula nutti*			+
	12. *Rana fuscigula*	+	+	
	13.*Rana regularis*	+		
	14. *Rana sp.* 1			+
	15. *Rana sp. 2*		+	
	16. *Rana sp. 3*		+	
	17. *Rana sp. 4*	+		
	Many larvae		+	
	TOTAL SPECIES/AXIS	**9**	**6**	**7**

Table 4a. SUMMARY OF REPTILE SPECIES RECORDED PER PROVINCE

FAMILY	**SPECIES (common name)**	**Bandundu**	**Bas-Congo**	**Equateur**
TESTUDINIDAE	1. *Kinixys sp.* (a tortoise genus)	+		
COLUBRIDAE	2. *Colubridae sp.* (a snake genus)	+		
SCINCIDAE	3. *Mabuya maculilabris* (speckle-lipped skink)	+	+	
	4. *Mabuya sp.*			+
CROCODYLIDAE	5. *Osteolaemus tetraspis* (dwarf crocodile)	+		
AGAMIDAE	6. *Agama agama* (common agama)		+	
TRIONYCHIDAE	7. *Trionyx triunguis* (African soft-shelled turtle)			+
	8. *Cycloderma aubryi* (Aubrey’s flapshell turtle)			+
	TOTAL SPECIES /AXIS	**4**	**2**	**3**

Table 5a. SUMMARY OF MAMMAL SPECIES RECORDED PER PROVINCE

FAMILY	**SPECIES** (common name)	**Bandundu**	**Bas-Congo**	**Equateur**
PTEROPODIDAE	1. *Myonycteris torquata* (little collared fruit bat)		+	
	2. *Eidelon helvum* (straw-colored bat)		+	
CERCOPITHECIDAE	3. *Papio anubis* (anubis or olive baboon)			+
	4. *Cercopithecus ascanius* (red-tailed monkey)	+		+
	5. *Cercopithecus mitis* (blue monkey)			+
POTAMOGALIDAE	6. *Potamogale velox* (giant otter shrew)		+	
BOVIDAE	7. *Cephalophus monticola* (blue duiker)	+	+	
	8. *Tragelaphus spekei* (sitatunga)	+	+	
HIPPOPOTAMIDAE	9. *Hippopotamus amphibius* (hippopotamus)	+		
	TOTAL SPECIES/AXIS	**4**	**5**	**3**

Table 6a. SUMMARY OF MACRO-INVERTEBRATE SPECIES RECORDED PER PROVINCE

ORDER	**FAMILY** (common name)	**SPECIES**	**Bandundu**	**Bas-Congo**	**Equateur**
ARANAE	ARACHNIDAE (spiders)	1. *Unknown sp.*	+		+
LABIDOGNATHA (sub-order)	(spider)	2. *Unknown sp.*			
COLEOPTERA	DYSTICIDAE (predaceous diving beetles)	3. *Cybister tripunctatus*	+	+	+
		4. *Hydraticus dregei*	+		
DECAPODA	ATYIDAE (freshwater shrimp)	5. *Caridina africana*	+	+	+
		6. *Caridina sp. 1 (brown/black)*	+	+ sp.	
		7. *Caridina sp. 2 (green)*	+		
		8. *Caridina sp. 3 (yellow, long)*	+		
		9. *Caridina sp. 4*		+	+ sp.
		10. *Caridina sp. 5*		+	
	PALAEMONIDAE (freshwater shrimp)	11. *Palaemon dux congoensis*	+		
	POTAMONIDAE (freshwater crab)	12. *Potamonautes dybowkin*		+	
		13. *Potamonautes africanus*	+		
	ATEMNIDAE	14. Unknown species	+		
	THERIDIIDAE	15. *Theridiid sp.*			
HEMIPTERA	BELOSTOMATIDAE (giant water bugs)	16. *Belostoma niloticum*	+	+	+
		17. *Belostoma sp.*			+

	HYDROMETRIDAE (watermeasurers)	18. *Hydrometra sp.*	+		+
	NEPIDAE (water scorpions)	19. *Ranatra grandicollis*	+	+	+
		20. *Ranatrea fusca*	+		
	NOTONECTIDAE (back swimmers)	21. *Anisops varia*	+		+
HETEROPTERA	GERRIDAE (water striders)	22. *Gerris sp.*	+	+	+
		23. *Gerris sp.*		+	
CAENOGASTROPODA	ASSIMINEIDAE (small aquatic prosobranch snails)	24. *Assimi oreidae;*		+	
		25. *Pseudogibula duponti*		+	
		26. *Pseudogibula pallidior*		+	
	HYDROBIIDAE (small aquatic prosobranch snails)	27. *Hydrobia plena*		+	
	AMPULARIIDAE (apple snails)	28. *Aetheria elliptica*	+	+	+
STYLOMMATOPHORA	SIBULINIDAE	29. *Pseudoglossoria bessei*		+	
SIGMURETHRA	ACHATINIDAE (achatine snails)	30. *Achatina zebriolata*			+
		31. *Achatina schweintfurthi*			+
		32. *Achatina greyi*			+
ODONATA	COEANAGRIONIDAE (pond damselflies)	33. *Megaloprepus caerulatus*	+	+	+
	LIBELLULIDAE (skimmer dragonflies)	34. *Libellula quadrimaculata*	+	+	+
		35. *Palpopleura lucia*	+	+	+
	GRYLLIDAE	36. *Gryllid sp.*	+		
	AESHNIDAE (hawker dragonflies)	37. *Aeshnid sp.*		+	
	TRIGONIDIIDAE	38. *Trigonidiid sp.*			
	TOTAL SPECIES/AXIS		**22**	**20**	**19**

Table 7a. SUMMARY OF PLANT SPECIES RECORDED PER PROVINCE

FAMILY	**Species (common name, where available)**	**Bandundu**	**Bas-Congo**	**Equateur**	**Comments**
POACEAE	1.*Panicum repens L.* (Australia torpedo grass)	+	+	+	Invasive grass
	2.*Panicum maximum* (guinea grass; colonial grass)	+	+	+	Medicinal value
	3.*Oryza barthii* (species of wild rice)	+	+	+	Valuable for agricultural diversity
	4.*Echinochloa pyramidalis* (antelope grass)	+	+		Provides valuable dry-season grazing after coarse rainy-season growth has been burned off.
	5. *Echinochloa stagnina*				Aquatic perennial; good fodder
	6.*Imperata cylindrica* (cogon grass or speargrass)	+	+	+	Invasive, one of the ten worst weeds in the world
	7. *Hyparrhenia diplandra*		+	+	Dominant grass species of flooded wood savannah regions
	8. *Vossia cuspidata* (hippo grass)				Found in marshes
SALVINIEACEAE	9.*Salvinia molesta* (giant salvinia)	+			Invasive, free-floating water fern
	10. *Salvinia nymphellula*		+		Floating plant
ARACEAE	11. *Pistia stratiotes* (water lettuce)				
PONTEDERIACEAE	12. *Eichornia crassipes*	+	+	+	Invasive floating plant
CYPERACEAE	13.*Cyperus papyrus* (papyrus)	+			Grass
	14.*Cyperus sp.*		+		Grass
FABACEAE	15. *Mimosa pigra* (catclaw mimosa; aka giant sensitive plant)		+		Invasive, highly destructive; forms dense monocultures and suppresses other vegetation as well as impacts on fish life.
	16. *Mimosa pudica* (sensitive plant)	+			Invasive
SOLANACAE	17. *Physalis angulata L.* (Cape gooseberry; aka cutleaf ground cherry)	+			Considerable medicinal value; Bush
CONVOLVULACAE	18. *Ipomoea aquatica* Forsk (water spinach; aka swamp cabbage)	+	+		Invasive species; floating vine; Medicinal value
MORACEAE	19. *Ficus mucosa (fig tree)*		+	+	Medicinal value; documented to be used by chimps for same reason; timber species
	20. Ficus sp.			+	
RUBIACAE	21. *Nauclea latifolia* Smith (Pin cushion tree; aka African peach)	+	+		Small tree; medicinal value
EUPHORBIACAE	22. *Ricinodendron heudelotii* (Baill)	+			Tree
	23. *Bridelia ferruginea* Benth	+			Tree; medicinal value
	24..*Alchornea cordifolia L.*	+		+	Shrub; medicinal value
	25. *Hymenocardia acida*		+		Medicinal value
VERBENACAE	26. *Vitex doniana* Sw.	+			Tree found in flooded forests
IRVINGIACAE	27. *Irvingia smithii* Hook. F.	+	+		Tree in gallery forest

STERCULIACAE	28. *Melochia melissifolia* Benth	+			Invasive shrub
ASTERACEAE	29. *Chromolaena odorata*	+	+		Invasive perennial shrub
THELIPTERIDACAE	30. *Cyclosorus dentatus* (Forsk) (lynyolo)		+		Medicinal value
MYRTACAE	31. *Eugenia congolensis* DeWild and Th. Dur.		+		Tree found in flooded forests
PALMAE	32. *Elaeis guinensis* (African oil palm)			+	
ARECACEAE	33. Raphia sp. *(palm)*			+	
POLYGONACAE	34. *Polygonum acuminatum* H.B. and K. (knotweed)		+		Freshwater plant; medicinal value
ANACARDIACAE	35. *Lannea antiscorbutica* (Hiern) Engl.(pink lannea)		+		Found in riverine forests with sandy soil
CAESALPINIACAE	36.*Griffonia tessmannii* (De Wild) Compere			+	Shrub; medicinal value
BOMBACEAE	37. *Ceiba pentandra* *(kapok tree)*		+		Invasive tree
	38. *Andansonia digitata* *(African baobob)*		+		Native tree; medicinal value; pollinated by bats
FLACOURTIACAE	39.*Coloncoba glauca (P.Beauv.) Gilg.*			+	Tree; seeds used to destroy rats; oil used to treat leprosy
	TOTAL SPECIES/AXIS	**19**	**22**	**13**	

8.3. Water quality analysis. The following table shows the average concentration of heavy metals (µg/L) in the river in each province. These results show that the Bas-Congo site (Inga) is the most polluted site and the Equateur site (Gombe) the least polluted. However, all values might not be harmful to ecosystems due to the high percentage of organic material. The high percentage of organic material at Inga might be due to the death of water hyancinth *Eichornia crassipes* and algae. Data are still needed.

METAL	**BANDUNDU**	**BAS-CONGO**	**EQUATEUR**
Iron (Fe)	74	92	55
Cadmium (Cd)	4	18	1
Lead (Pb)	7	162	2
Manganese (Mn)	17	9	78
Copper (Cu)	7	47	2
Chromium (Cr VI)	0.6	4	0.2
% of organic material from suspended matter	8	31	13

TRIP # 1: BANDUNDU PROVINCE: MUSHIE TO BOKONI

8.4. OVERVIEW

8.4.1. Map of station sites in Bandundu

Stars mark the four sampling sites; bold numbers indicate water quality stations. All species and water quality were sampled at Mushi and Bokoni. Only fish were sampled at Bandundu.

8.4.2. Background

Our sampling sites are within the *Kasai ecoregion* (ecoregion # 21, Thieme et al., 2003, in press) in the Bandundu Province. WWF considers this region, particularly along the Fimi River to be among the highest priority areas for freshwater conservation, but notes that the region has been little studied ichthyologically. The region is thought to show high species richness for invertebrates. Sixty species of frogs are known for the ecoregion. The area is characterized by savannah-covered plateaus, cut by streams and rivers. The area has been little studied to date. Along the rivers, one finds 100 m to 10 km strips of tall seasonally and permanently inundated swamp forest and lowland (gallery) forest. The Kasai river starts on the Lunda Plateau of Angola. Major tributaries of the Kasai are the Kwango, Kwilu, Loange, Lulua, Sankuru and Wamba rivers. The peak of the rainy season is December and March. Flooding can raise the water level to 3 meters.

To the north of our sampling sites is Lake Mai-Ndombe. Its black waters are visible where the Fimi River converges with the Kisai. During high flooding, Lake Mai-Ndombe connects to Lake Tumba, making it one of the largest blocks of shallow blackwater and flooded forest in the Congo basin (Thaime et al., 2003, in press).

8.5. RESULTS

8.5.1. Summary

Aquatic habitats: Aquatic habitats included sand, papyrus swamps, grassy shores, islands (grass or sand), and lowland tree roots. Several invasive species were present. We sampled primarily near grass or sand islands. The islands and floating grasses provide important habitat for attached algae, invertebrates and fishes. They also store substantial amounts of nutrients, and are a source of dissolved organic compounds.

Terrestrial habitats: Terrestrial habitats included shrub savanna, flooded wood savannah, primary and secondary lowland gallery forest, and croplands. Invasive species were present.

Species: We found 94 fish species, comprising 21 families. Dominant families are Mormyridae (21% of the sample), Mochokidae and Distichodontidae, both at 12%, Characidae and Bagridae, both at 8%, and Cichlidae at 6%. While some of these species may possibly be new, this awaits confirmation from the AMNH. Some of the species are also valuable, or promising, for the aquarium trade (e.g., the beautifully colored *Synodontus* sp., *Polypterus ornatus*, *Nannochromis sp.*, *Campylomormyrus tamandua*, ‘hammerhead’ *Synodontus* (Appendix). A transparent shrimp (*Polyaemon dux congolese*) would also be a possibility for the pet trade. A particular species of Distichodus sells for as much as $50 in the pet trade (Sullivan, personal communication). With the help of an old experienced fisherman in Bokoni village, we made considerable progress on a field guide to fishes in the local languages, Lingala and Kikonga.

We found 34 bird species, 9 species of amphibians, 4 species of reptiles, and 4 species of mammals, the latter, all found as bushmeat. The lack of live mammals is of concern, particularly the lack of large mammals such as hippopotamus. In the past, hippopotami were abundant along the river banks (Thaime et al., 2003, in press, Mankoto, 2002). Hippopotami are critical for maintaining the integrity of riverine systems, and their disappearance affects the species composition of riverine plants and animals alike (Naiman and Rogers, 1997; for further details, see Discussion, section 6.6. and Conclusions, section 8). For example, they maintain the health of fish stocks by stirring up rich water sediments and increasing water fertility with their feces (Meine and Archibald, 1996). Hippos are the main animals responsible for modifying the physical environment in this part of Africa, creating pools in the water which serve as habitats for crocodiles and larger fish, and channels to/from the river as they migrate nightly to their land feeding grounds (Naiman and Rogers, 1997). The distribution of some floodplain tree species depends on animals such as hippos to eat the seeds, which enhances germination and aids dispersion (Feely, 1965).

We found 22 species of macroinvertebrates, primarily rheophilic. They were captured under the vegetation composed of the wild rice, *Oryza barthii*, and the invasive species water hyacinth, *Eichornia crassipes*. The most abundant macroinvertebrate group included larvae of skimmer dragonflies (in the family Libellulidae) and freshwater shrimp of the genus Caridina. These invertebrates likely are a key food item for vertebrate fauna, including fishes.

We identified 19 plant species. Several native species are noted for their medicinal value, especially the Cape gooseberry, *Physalis angulata*. Seven plant species are invasive; this is 37% of the plants observed.

8.5.2. Systematic account of all species for Bandundu province.

Table 1b. Provisional list of fishes recorded.

Note: Complete identification to species will take 6 months-1 year. * Station is unknown.

			STATION	
FAMILY	**SPECIES**	**Mushi**	**Bokoni**	**Bandundu**
PROTOPTERIDAE	*1. Protopterus dolloi*	+		+ M
POLYPTERIDAE	*2.Polypterus sp. 1 (black)*	+		
	3. Polypterus sp. 2 (banded)			+ sp. M
	4. Polypterus delhezi	+	+	Aqu.arium Trade
	5. Polypterus ornatipinnus		+	Aquarium Trade
CLUPEIDAE	*6.Odaxothrissa spp.*	+		
	7. Clupeidae spp.	+		
MORMYRIDAE	*8.Petrocephalus microphthalmus*	+ M		
	9.Petrocephalus sauvagii		+	
	10.Petrocephalus sp. (simus?)		+	
	11.Gnathonemus petersii		+	
	12.Genyomyrus donnyi		+	+ M
	13. Hippopotamyrus pictus	+		
	14. Hippopotamyrus discorhynchus	+	+	
	15.Mormyrops anguilloides	+	+	+ M
	16.Mormyrops mariae		+	
	17.Marcusenius greshoffii	+ M		
	18.Marcusenius sp. 1	+	+	
	19.Marcusenius sp. 2	+	+	
	20.Marcusenius sp. 3		+	
	21.Stomatorhinus sp. 1 (little, black)	+	+	
	22.Pollimyrus adspersus		+	
	23.Pollimyrus sp.	+M	+	
	24.Mormyrus proboscirostris		+	
	25.Mormyrus caballus bombanus			+ M
	26.Campylomormyrus tamandua		+	+
	27.Campylomormyrus elephas		+	
CHARACIDAE	*28.Bryconaethiops microstoma*	+		
	29.Hydrocynus goliath	+	+	+ M
	30.Hydrocynus vittatus	+	+	
	31.Alestes sp.	+		+ M
	32.Brycinus sp. 1	+	+	+ M
	33.Brycinus sp. 2	+	+	
	34.Micralestes sp.		+	
DISTICHODONTIDAE	*35.Ichthyborus ornatus*		+	+ spp. M
	36.Phago boulengeri	+	+	+ M
	37. Distichodus fasciolatus	+	+	
	38. Distichodus atroventralis		+	
	39. Distichodus antonii	+	+	Aquarium trade
	40. Distochodus maculatus	+		
	41. Distichodus affinis	+		
	42. Distichodus sexfasciatus			
	43.Eugnatichthys macroterolepis		+	
	44.Xenocharax spilurus		+	
	45.Nannocharax sp.		+	
CITHARINIDAE	*46.Citharinus gibbosus (Blgr.)*	+	+	+ M
	47. Citharinus congicus	+	+	
CYPRINIDAE	*48.Barbus sp.*	+	+	

	49.Labeo lineatus	+	+	+ spp. M
	50.Labeo weeksii	+	+	
	51.Labeo sp. cf. weeksii	+	+	Aquarium trade
BAGRIDAE	*52.Bagrus sp.*		+	
	53.Auchenoglanis occidentalis		+	+ M
	54. Parauchenoglanis spp.	+	+	
	55. Chrysichthys sp. 1		+	+ sp. M
	56.Chrysichthys sp. 2		+	
	57.Chrysichthys sp. 3		+	
	58.Chrysichthys sp. 4		+	+ M
CHANNIDAE	*59. Parachanna obscura*		+	+ M
SCHILBEIDAE	*60.Parailia congica*	+		
	61.Schilbe sp. 1	+	+	
	62.Schilbe sp. 2	+	+	
NOTOPTERIDAE	*63.Xenomystus nigri (Gthr.)*		+	
	64. Papyrocranus afer (Gthr.)		+	
ANABANTIDAE	*65. Ctenopoma acutirostre*	+	+	+M; Aquarium trade
	66. Ctenopoma kingsleyae		+	
	67. Ctenopoma ocellata	+	+	
	68. Ctenopoma nebulosa	+		
CENTROPOMIDAE	*69. Lates niloticus (L.)*	+	+	
OSTEOGLOSSIDAE	*70. Heterotis niloticus (Cuvier)*		+	+ M
TETRAODONTIDAE	*71. Tetraodon mbu (Blgr.)*		+	
	72. Tetraodon miurus (Blgr.)		+	
MASTACEMBELIDAE	*73. Mastacembelus sp. 1*	+		
	74. Mastacembelus sp. 2		+	
MALAPTERURIDAE	*75. Malapterurus electricus*			+ M
MOCHOKIDAE	*76. Synodontis acanthomias**			
	77. Synodontis sp. 1			+ sp.
	78. Synodontis sp. 2	+		
	79. Synodontis sp. 3	+		
	80. Synodontis sp. 4	+		
	81. Synodontis sp. 5	+		
	82. Synodontis sp. 6		+	
	83. Synodontis sp. 7		+	
	84. Synodontis sp. 8		+	
	85. Mochokiella sp.			Aquarium trade
CLARIIDAE	*86. Heterobranchus longifilis (Val.)*	+		
	87. Channallabes apus (Gthr.)			+ M
	88. Clarias spp.		+	+ M
CICHLIDAE	*89. Tylochromis*		+	
	90. Lamprologus congoensis		+	
	91. Hemichromis elongatus		+	
	92. Nannochromis sp.		+	+
	93.Sarotherodon galileus boulengeri		+	
	94. Tilapia (Oreochromis) sp? = marechal		+	+ M

Table 2b. Birds recorded. For common names, see Table 2a.

		STATION			
FAMILY	**SPECIES**	**Bandundu-Bokoni**	**Mushi**	**Mushi-Bokoni**	**Bokoni**
ACCIPITRIDAE	*1. Gypohierax angolensis*	+			+
	2. Milvus migrans	+	+	+	+
ALCEDINIDAE	*3. Alcedo cristata*				+
	4. Ceryle rudis			+	+
	5.Halcyon senegalensis			+	
ANHINGIDAE	*6. Anhinga rufa*	+		+	+
ARDEIDAE	*7. Ardea purpurea*			+	
	8. Bubulus ibis	+			
	9. Egretta alba	+	+	+	
	10. Egretta garzella	+		+	+
	11. Egretta ardesiaca		+		+
BUCEROTIDAE	*12. Tockus fasciatus*				+
CAPITONIDAE	*13. Pogoniulus bilineatus*				+
CHARADRIIDAE	*14. Tringa sp*			+	
	15.Vanillus albiceps			+	
CICONIIDAE	*16. Ciconia episcopus*		+ M		
COLUMBIDAE	*17. Treron calva*	+ M			
	18. Turtur afer				+
CORVIDAE	*19.Corvus albus*	+	+	+	+
CUCULIDAE	*20. Centropus sp*				+
ESTRILDIDAE	*21.Lonchura cucullata*		+		
JACANIDAE	*22. Actophilornis africanus*			+	
MEROPIDAE	*23. Merops pusillus*		+	+	+
MOTACILLIDAE	*24. Motacilla flava*		+		
MUSOPHAGIDAE	*25. Corythaeola cristata*				+
NECTARINIDAE	*26. Nectarinia chloropygia*				+
	27. Nectarinia sp.				+
PASSERIDAE	*28. Passer griseus*		+		
PHALACROCORACIDAE	*29.Phalacrocorax africanus*				+
PLOCEIDAE	*30. Ploceus cucullatus*				+
	31. Ploceus nigerrimus				+
	32. Ploceus aurantius				+
PYCNONOTIDAE	*33. Pycnonotus sp.*				+
VIDUIDAE	*34. Vidua macroura*				+

Table 3b. Amphibians.

		STATION	
FAMILY	**SPECIES**	Mushi	Bokoni
BUFONIDAE	*1. Bufo regularis*	+	
	2. Bufo maculatus	+	
RANIDAE	*3. Rana fuscigula*	+	+
	4. Rana regularis		+
	5. Rana mascareniensis	+	+
	6. Rana sp.		+
	7. Phrynobatrachus natalensis	+	
	8. Phrynobatrachus sp.	+	
	9. Hemisus marmoratum	+	

Table 4b. Reptiles.

		STATION	
FAMILY	**SPECIES**	**Mushi**	**Bokoni**
PELOMEDUSIDAE	*1. Kinixys sp.* *(a genus of tortoise)*	+	
CELUBRIDAE	*2. Celubridae sp.* *(a genus of snake)*	+	
SENCIDAE	*3. Mabuya maculilabris* *(speckle-lipped skink)*	+	+
CROCODYLIDAE	*4. Osteolaemus tetraspis* *(dwarf crocodile)*	+	

Table 5b. Mammals.

		STATION	
FAMILY	**SPECIES**	**Mushi**	**Bokoni**
HIPPOPOTAMIDAE	*1. Hippopotamus amphibius* (hippopotamus)	+	
CERCOPITHECIDAE	*2. Cercopithecus ascanius* (red-tailed monkey)	+	
BOVIDAE	*3. Cephalophus monticola* (blue duiker)	+	
	4. Tragelaphus spekei (sitatunga)		+

Note: all but *Cephalophus monticoloa* were found as bushmeat.

Table 6b. Macroinvertebrates.

			STATION	
ORDER	**FAMILY**	**SPECIES**	**Mushi**	**Bandundu**
DECAPODA	ATYIDAE	1. *Caridina africana*		+
		2. *Caridina sp. 1* (brown/black)	+	
		3. *Caridina sp. 2* (green)	+	
		4. *Caridina sp. 3* (yellow, long)	+	
	POTAMONIDAE	5. *Potamonautes africanus*	+	
	PALAEMONIDAE	6. *Palaemon dux congoensis*		+
	ATEMNIDAE	7. *Unknown sp.*		
COLEOPTERA	DYSTICIDAE	8. *Cybister tripunctatus*		+
		9. *Hydraticus dregei*		
	NOTONECTIDAE	10. *Anisops varia*		+
HETEROPTERA	GERRIDAE	11. *Gerris sp.*		
HEMIPTERA	NEPIDAE	12. *Ranatrea fusca*		+
		13. *Ranatrea grandicollis*		+
	BELOSTOMATIDAE	14. *Belostoma niloticum*		+
	HYDROMETRIDAE	15. *Hydrometra sp.*		+
ODONATA	COEANAGRIONIDAE	16. *Megalopropus caerulatus*		
	LIBELLULIDAE	17. *Palpopleura lucia*		+
		18. *Libellula quadrimaculata*		+
	GRILLIDAE	19. *Unknown sp.*		
	TRIGONIDIIDAE	20. *Unknown sp.*		
ARANAE	ARANEIDAE	21. *Unknown sp.*		+
MESOGASTROPODA	AMPULLARIDAE	22. *Aetheria elliptica*		+

Table 7b. Plants.

FAMILY	Species (common name, where available)	Comments
POACEAE	1.*Panicum repens L.* (Australia torpedo grass)	Invasive grass
	2.*Panicum maximum* (guinea grass; colonial grass)	Medicinal value
	3.*Oryza barthii* (species of wild rice)	Valuable for agricultural diversity
	4.*Echinochloa pyramidalis* (antelope grass)	Nutritious fodder for dry-season grazing
	5. *Imperata sp.*	Grass
SALVINIEACEAE	6.*Salvinia molesta* (giant salvinia)	Invasive, free-floating water fern
PONTEDERIACEAE	7. *Eichornia crassipes* (water hyacinth)	Invasive floating plant
CYPERACEAE	8. *Cyperus papyrus* (papyrus)	Grass
SOLANACAE	9.*Physalis angulata L.* (Cape gooseberry; aka cutleaf ground cherry)	Considerable medicinal value; bush
CONVOLVULACEAE	10. *Ipomoea aquatica* Forsk (water spinach; aka swamp cabbage)	Invasive species; floating vine; Medicinal value
FABACEAE	11. *Mimosa pudica* (sensitive plant)	Invasive; medicinal value
RUBIACAE	12.*Nauclea latifolia* Smith (Pin cushion tree; aka African peach)	Small tree; medicinal value
EUPHORBIACAE	13. *Ricinodendron heudelotii* (Baill)	Tree
	14. *Bridelia ferruginea* Benth	Tree; medicinal value
	15. *Alchornea cordifolia L.*	Shrub; medicinal value
VERBENACAE	16.*Vitex doniana* Sw.	Tree found in flooded forest
IRVINGIACAE	17. *Irvingia smithii* Hook. F.	Tree in gallery forest
STERCULIACAE	18. *Melochia melissifolia* Benth	Invasive shrub
ASTERACEAE	19. *Chromolaena odorata*	Invasive perennial shrub

8.5.3. Water quality analysis

Productivity, as measured by PO_4 and NO_3, was very low. This is typical for tropical rivers. Therefore, the beginning of the food chain in the river originates from the land: specifically, terrestrial plant matter and insects. Transparency was greatest by Bokoni, intermediate for the black water areas, and lowest when the water became muddy (samples M_F-M_H). For turbidity and true color, from Mushi to Bokoni, eight samples were taken (4 in Mushi; 4 between the two villages.) For these eight samples, the mean turbidity was 32.1 FTU and the true color was 178 (Pt-Co units). At Bokoni, 7 samples were taken, and the mean turbidity was 23.3 and true color was 53.6. The pH generally was acidic, particularly at the confluence of the Fimi River and the Kasai. Black waters, such as found in Mushi and en route to Bokoni, have low pH and reducing properties, and are vulnerable to deoxygenation, when newly drowned vegetation rots. The pH became slightly basic by the gallery forest (7.6; sample M_H). Conductivity generally ranged from 20-30 µS, with the exception of low conductivity of 10 µS by Mushi, on the Kwa river. Dissolved oxygen levels were lower adjacent to Mushi (79.5%, or roughly 6.1 mg/L), presumably indicating increased inputs of biological waste from the village. However, the dissolved oxygen is within a level that is not stressful for aquatic animals (see methods section for details). Heavy metal analysis of all sites indicates the water is within safe water drinking standards, as defined by the U.S. EPA (www.epa.gov/safewater).

Table 8b. Summary of water quality data for Bandundu province.

STATION NUMBER

	1	2	3	4	5	6	7	8	9	10
Sample	M_A	M_B	M_c	M_D	M_E	M_F	M_G	M_H	B_A	B_{B-G}
Site Description	Mushi Wetland by village	Mushi Wetland Opposite Village	Mushi Grassy Wetland	Mushi Center of river	Betwn Mushi/ Bokoni Center of channel, Fimi River	Betwn Mushi/ Bokoni	Betwn Mushi/ Bokoni, Where terrestrial landscape changed to trees	Betwn Mushi/ Bokoni,by lowland forest	Bokoni	Bokoni
GPS Location (lat/long, in degrees)	3°1.74 S 16° 5.37E	3°1.74 S 16° 5.37E	3°1.74 S 16° 5.37E	3°1.74 S 16° 5.37E	3 °1.0 S 16°56.68E	3 ° 0.51S 16°58.44E	3 ° 3.81S 17°4.01E	3 ° 5.34S 17°6.87E	3 ° 09.46S 17°09.73E	
Depth at measured site (feet)	-	4.3	43	57.7	23	23.3	13.7	9.9	4	
Water Temp. at Surface (C)	27.6	27.8	27.6	27.7	27.5	27.8	28.7	28.8	30.3	
Current (qualitative)		Still	-	Medium	Fast	Medium	Medium	Medium	Fast	
pH		7.0	6.8	6.0	6.0	7.0	6.6	7.6	6.75	
Conductivity (µS)	20	20	30	10	30	20	20	30	30	
Secchi Disk (cm)	-	40.34	42.7	42.0	65.15	17.35	14.25	18.23	-	
Turbidity (FTU)	31	25	25	43	41	32	30	30	10	X = 25.5
Color	Black	Black	Black	Black	Black	Muddy	Muddy	Muddy	-	
True Color (Pt-Co units)	218	136	135	222	214	172	163	164	28	
General Hardness (ppm)		-	-	53.7	53.7	53.7	35.8	35.8	35.8	
Carbonate Hardness (ppm)		-	-	53.7	53.7	35.8	35.8	35.8	35.8	
Dissolved Oxygen (%)		79.5%	86.8%		-	94.4%	93.2%	91.2%	89.2%	
Phosphate (PO_4) (mg/L)		0	.25	<.25	<.25	<.25	<.25	<<.25	<<.25	
Nitrate (NO_3) (mg/L)	3	-	5	5	<5	<5	<5	<5	<5	
Calcium (mg/L)	80	-	160	100	100	80	60	60	40	

Water quality: (- = no test; 0 = zero test value; empty cells indicate columns of additional samples for laboratory analysis).

Table 9b. Metals content in water samples from Bandundu
Values are in µg/L. Data analysed by ERGS.

Sites	Iron (Fe)	Cadmium (Cd)	Lead (Pb)	Manganese (Mn)	Copper (Cu)	Chromium (Cr VI)
Bandundu						
M_A	85	5	9	21	8	1
M_B	82	3	8	18	9	1
M_C	76	5	9	15	6	0.5
M_D	74	4	8	17	8	0.8
M_E	68	5	5	17	5	1
M_F	69	3	4	16	7	0.6
M_G	70	4	4	17	6	0.4
M_H	69	4	7	18	8	0.4
Bokoni	74	4	7	17	7	0.6
Average	**74.13**	**4.13**	**6.75**	**17.34**	**7.13**	**0.6**

8.5.4. Sampling Station Reports, Trip #1

Name: Bandundu to Mushi
Position: No position determined.

Date of visit: Sept. 15, 2002

Procedures: Ecological observations and testing of water conductivity were made en route.

Ecological notes: The river Kwilu is brown, roughly one-half the width of the main Congo River channel, with sparse *Cyperus papyrus* and the grass *Panicum repens* along the banks. Water conductivity abruptly changed from 20 to 30 µS at the convergence of the Kwilu and Fimi River.

Conservation/development notes: From Bokola to Mushi, the grass amounts decreased, as did the number of fishermen. This correlation indicates the importance of the grass habitats along the banks and islands to fish abundance.

Name: Mushi
Position: 3° 1.74 S; 16° 5.37 E

Date of visit: Sept. 15, 2002

Procedures: The land team surveyed vertebrates adjacent to the village, on the eastern side. Birds were caught with a mist net and released. Amphibians were recorded on tape. Plant samples were collected. Macroinvertebrates were caught primarily with a dip net. A drop net, Hester-Dendy sampler and kick net were also used. Fishes were collected by gill net in the wetland area on the riverbank opposite Mushi, and obtained directly from fishermen.

Ecological notes: On the village side of the river, the terrain of the terrestrial landscape was sloped. The village is directly on the bank of the river; few trees remain in the village along the banks. Adjacent to the village, the habitat was primarily shrub savanna, with patches of grassy wetland and sand. Aquatic plants in the wetland areas across the river from the village and in front of the village included abundant amounts of *Panicum repens,* the invasive water spinach (aka swamp cabbage), *Ipomoea aquatica,* the invasive water hyacinth, *Eichornia crassipes,* and the invasive giant salvinia, *Salvinia molesta*. Small larval fish of the family Eleotridae (*Kribia nana*) were observed in the wetlands. Adjacent to Mushi, the water was black. Very few insects were observed at the surface by plants; aquatic invertebrates were present, however. In the area sampled for macroinvertebrates, the river bottom ranged from sand to detritus. Fishes originating from the blackwaters of the Fimi River and the nearby Lake Mai-Ndombe have evolved darker coloration.

Water quality analyses were conducted at the following sites:
M_A: black water by the grassy wetland next to Mushi, on the Fimi River. Black water has a high concentration of dissolved organic carbon and humic compounds.
M_B: wetland across the river from Mushi village. The invasive floating *Eichornia crassipes* and *Salvinia molesta* fringed the wetland.
M_C: wetland, across the river from Mushi village west of site Mb, with floating *Eichornia*, *Panicum repens,* sand and mud bottom. This area had abundant amounts of dragonflies, and larval fish of the family Eleotridae (*Kribia nana*)
M_D: Middle of the Fimi River.
M_E: Black water, center of the channel of the Fimi River.

Conservation/development notes: Qualitatively, fish in the Mushi market were small to medium in size.

Name: Between Mushi and Bokoni (on pirogue)
Position: 3° 0.51 S, 16°56.68 E

Date of visit: Sept. 17, 2002

Procedures: Birds were noted en route. No other terrestrial animals were observed this time except for an aquatic snake. Water quality was tested at the confluence between the Fimi and Kasai River (sample $M_{F),}$ and by the bank where the biotope changed from grass to lowland (gallery) forest (sample M_G). At this site, there were many plants and a muddy bottom. Sample M_H was collected by a bank of lowland (gallery) forest.

Ecological notes: Several different habitats were observed during this one and a half-hour boat ride, including: sand, islands with Papyrus (*Cyperus papyrus*) and grasses along the banks (*Panicum repens*) (sand and grass were the predominant habitats), wetlands, patches of degraded lowland rainforest, and flooded wood savannah. These islands, along with floating littoral plants, provide key habitat for algae, invertebrates and fishes. Topographically, we encountered plains and sloping areas. Aquatic plants in grassy shore areas included abundant amounts of *Panicum repens* and *Alchornea cordifolia*. Soil was clay. Many insects were observed floating on the water surface.

Conservation/development notes: We observed fishermen fishing with cast nets.

Name: Bokoni
Position: 3° 09.46 S, 17° 09.73 E

Date of visit: Sept. 15, 2002

Procedures: Birds were caught with a mist net and released. Amphibians were recorded on tape. Fish were sampled at a wetland island (with 2 gill nets, a seine, and a cast net), at the fishing village of Lome (with seines and cast nets), and at Bokoni proper (with cast nets). Plant samples were collected.

Ecological notes: The forest around this small fishing village was sampled. Trees remain scattered throughout the village. The terrestrial landscape was a plain, with patches of field, secondary forest, and shrub savannah. The invasive Christmas bush (aka Siam weed), *Chromolaena odorata,* was present. Aquatic plants along the shore included abundant amounts of *Panicum repens* and *Imperata cylindrica*. *Hyparrhenia diplandra* and *Panicum maximum* were also present.

Conservation/development notes: At one site, we saw fishermen use an illegal 1-cm. gill net to catch medium-sized Distichotids, setting their gill nets parallel to the wetland. At another, we observed fishermen using legally sized gill nets of 3 cm.; also 6 cm. The fishermen creatively use local material to make parts of the net, using flip-flop material to make floats and cement for weights. We observed larvae in the wetlands; fishermen confirm that fish spawn in wetlands by the islands. These islands can be completely covered during the rainy season. They use fish traps in the flooded forest. By the Lome fishing village, they use 100-meter seines. Most fecund fish are thought to spawn twice a year.

While illegally sized nets are used, overfishing is not yet a serious threat, deduced from the fact that many fish caught in this region are a large size. Evidence of overfishing can often be indicated by a biomass flip, where one sees a shift in the populations of many species, and larger fish become scarce.

The number of fishing encampments increases in the summer, when the children get out of school. At the time we were there, school was in session; however, many children in this village did not go to school.

8.6. CONSERVATION AND MANAGEMENT

We rank this area as having moderate ecological integrity, given the number of invasive plants in the area, the extent of hunting, and the pressure of human populations. WWF (Thieme et al., 2003, in press) defines this category as follows: “Habitat is altered but potentially restorable. Human disturbance has extirpated many sensitive species, but some habitat remains suitable for most native species. Species composition and community structure are altered, but native species are likely to return with improved habitat and connections to source pools. Exotic species may potentially be managed. “

8.6.1. Threats and Development issues

- Bushmeat hunting: The lack of large mammals, particularly hippos is cause for concern. Burgis and

Symoens (1987, as cited in Thieme et al., 2003, in press) note that the area is habitat for hippo and forest elephant (*Loxodanta africana*). Hippopotami are critical for maintaining the integrity of riverine systems, and their disappearance affects the species composition of riverine plants and animals alike (Naiman and Rogers, 1997; for further details, see Discussion section). For example, they maintain the health of fish stocks by stirring up rich water sediments and increasing water fertility with their feces (Meine and Archibald, 1996). Hippos are the main animals responsible for modifying the physical environment in this part of Africa, creating pools in the water which serve as habitats for crocodiles and larger fish, and channels to/from the river as they migrate nightly to their land feeding grounds (Naiman and Rogers, 1997). One hippo can eat up to 60 kg. of grass every night. The distribution of some floodplain tree species depends on animals such as hippos to eat the seeds, which enhances germination and aids dispersion (Feely, 1965).

Crocodiles: The decline of crocodiles may also affect the ecosystem. Crocodiles feed heavily upon catfish, which prey upon mormyrids and cichlids.

Germain Mankoto notes the disappearance of hippos, crocodiles, turtles, and snakes for the region in his trip report (Mankoto, 2002). WWF (Thaime et al., 2003, in press) corroborates that hunting pressure is very high for at least the Mai-Ndombe region.

- Logging and habitat conversion: The forest is disappearing along parts of the Kwilu and the Kisai, due in part to logging and in part to agricultural changes. This was noted by Germain Mankoto in his trip report (Mankoto, 2002). WWF (Abell et al., 2002) reports that valid logging concessions are present in the region, but currently inactive. We saw a Belgian timber operation by Bokala. Even though they started just in July, 2002 (Mankoto, personal communication), considerable logging has already taken place.

- Overfishing. Fishermen fish in spawning areas and intensively fish during low water periods (Mankoto, 2002). Illegally-sized gill nets were observed on site at Bokoni, but the threat is a medium threat at this point.

- Mining: Diamond mining takes place much further downstream, in Tshikapa (Kasai Province). Mining increases the turbidity of the water, which can affect photosynthetic rates.

- Oil exploration and exploitation (future threat): The governor reported that oil is present underground, and he is pursuing exploitation of this resource.

- Malnutrition. The Governor reported a number of cases of malnutrition in Bokoni, primarily due to lack of vegetables.

8.6.2. Management

To maintain the entire ecosystem will require awareness of the importance of maintaining viable populations of key animals for the riverine ecosystem, specifically, hippos, and terrestrial plants. For fisheries, the best option here would be 1) a net exchange program, swapping illegal nets for legal ones, 2) mapping of key spawning areas and fishing grounds, and 3) beginning monitoring of fishing effort. At Bokoni, it would be helpful to support an agriculture effort to reduce the malnutrition present.

8.6.3. Potential partner options

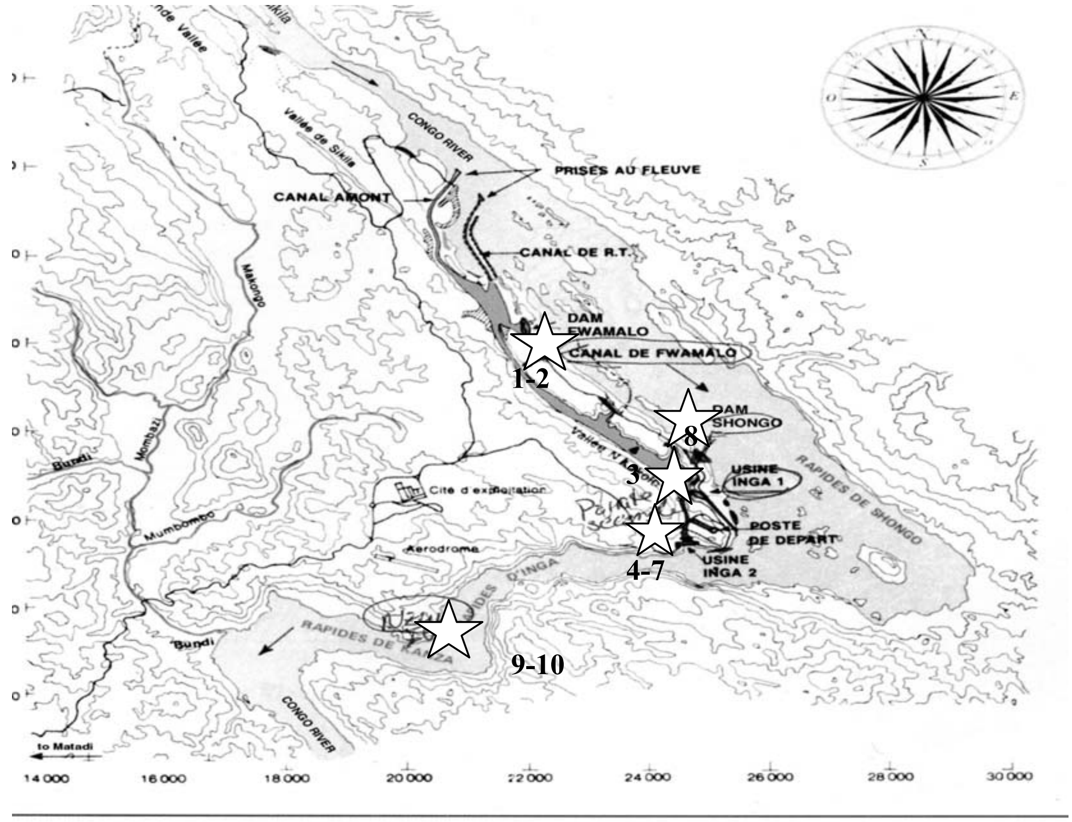
1) PERILAC (Bandundu) (President: Mr. Gryungo Nzambi Zenom). This NGO began two years ago. Its goal is to provide strategies for sustainable development.
2) SAQUA (Bandundu) This NGO is one year old. Its objective is to rejuvenate the pet trade and provide increased income for its members. However, the NGO currently has no connections for export, no representative in Kinshasa. Fish are caught with dip nets and a fine net made of clothes, catching fish at 1.5 meters.
3) COPADEM (Mushi) (President: Mr. Roger Iziza Pembe (aka Coco)). Newly formed NGO. Objective: sustainable development, including improved transportation for livestock and other goods.

TRIP # 2: BAS-CONGO PROVINCE: INGA

8.7. OVERVIEW

8.7.1. Map of station sites in Bas-Congo

Stars mark sampling sites; bold numbers indicate water quality stations. All species and water quality were sampled at all sites.



Map source: Société Nationale d'Electricité (2001)

8.7.2. Background

Our sampling sites are within the *Lower Congo Rapids* ecoregion (ecoregion # 60, Thieme et al., 2003, in press), in the Bas-Congo province. WWF considers this area of highest conservation importance. The rapids in this region are 300 km long. Currents are strong. The area by the rivers is wooded savannah, with pockets of gallery forest in parts. The rainy season here is Oct-Dec. and Jan. – April. According to Ifuta (personal communication), the region changed to savannah from tropical forest over the last century. Essentially, the savannah border moved further north. Pools abound. The last survey of the region was published in 1976 (Roberts and Stewart, 1976). These authors used the poison rotenone to sample the region. The region has exceptional species richness for fishes (129 species) and high endemism (34/129, or 26%), with many species specially adapted for life in the swift current — as evidenced by reduced eyes, coloration, and flattening of the body form. Other species fall into three other categories: 1) those poorly adapted (presence in rapids is atypical or accidental); 2) those moderately adapted (little or no morphological adaptation); and 3) those highly adapted to avoid rapids (e.g., hiding in caves and crevices, such as a blind lamprologine cichlid). Endemic fish species are found in the following families: Mormyridae, Characidae, Cyprinidae, Bagridae, Amphiliidae, Clariidae, Mochokidae, Cichlidae, and Mastacembelidae (Roberts and Stewart, 1976). Interestingly, the genera of these species are found widely throughout the Congo basin (Roberts and Stewart, 1976). The area is also thought to be important for molluscs, with at least 18 species (Bequaert and Clench: 1936, 1941).

8.8. RESULTS

8.8.1. Summary

Aquatic habitats: Aquatic habitats included rapids with strong currents, a reservoir, and the main river and a river channel with rocky boulders, sand, and wetlands. We sampled at 5 sites: Inga #1, aka Tank (the reservoir), Nziya (the main river with rocky boulders and sand along the banks), Shongho (rapids), Point 50 (rapids) and Fwamalo (a river channel, with sand, boulders, and a wetland). The difficulty in sampling the aquatic habitat, particularly the rapids, and the difficulty in reaching these sites hindered our collection of fish. The prior survey by Roberts and Stewart (1976) used the fish poison rotenone. As the CREDP project has an environmental focus, with an effort to improve the sustainability of fish capture, we did not want to set a bad example by using poison. Therefore, our collection of fish by the rapids came from fishermen.

Terrestrial habitats: Wooded savannah in parts; gallery forest in others.

Species:
We identified 55 species of fish, comprising 15 families. Two species were new. The first, a Lamprologine cichlid was found in the rapids at Nziya (Schelly and Stiassny, 2003, submitted). The second, a lampeye (genus Aplocheilichthyes), was found in the canal at Fwamalo (Schelly, personal communication). As the collection continues to be analyzed, additional species may be new, but this awaits confirmation from the AMNH. In the 1976 survey, Roberts and Stewart found 129 species from 17 families, the most speciose being Mormyridae and Cyprinidae, both at (15%); Cichlidae (13%); and Mochokidae (12%). Our results are similar. We found the most speciose family to be Mormyridae (20%), followed by Cichlidae (18%), and Cyprinidae, Mochokidae, and Characidae, all at 11%. It is important to note that sampling was very different between the two surveys: Roberts and Steward used rotenone, while we primarily obtained fish from fishermen, as well as with dip nets, cast nets and seines.

Two species in our sample are considered highly adapted to currents: the mormyrid, *Campylomormyrus muirus* and *Rheoglanus dendrophorus*. Campylomormyrus' adaptations include its long snout, used to eat insects within rock crevices, and small eyes. However, as almost all mormyrids have small eyes, Roberts and Stewart consider these fish to be 'preadapted' to a rapids habitat. For Rheoglanus, modifications include flattening of the body form, coloration, and small eyes. The following fish species found in our sample (in addition to potentially new species) were not reported by Roberts and Stewart during their extensive rotonene sampling: *Gnathonemus* sp.; *Campylomormyrus curvirostris*; *Phago* sp., *Ichthyoborus sp.*, *Labeo coubie*, *Ctenopoma* sp., *Heterotus niloticus*, *Chariallobes* sp., *Cyprinodintidae* sp., and *Belonoglanis* sp.

With the help of the Fishing Association, we made considerable progress on a field guide to fishes in the local languages, Lingala and Kikonga.

We identified 23 species of birds, 6 species of amphibians, 2 species of reptiles, and 5 species of mammals, the latter all found as bushmeat. The straw-colored bat (*Eidelon helvum*) is a fruit bat involved in the seed dispersal and germination of a threatened West African hardwood, *Melicia excelsa* (www.for.nau.edu/research/pb1). The giant otter shrew (*Potamogale velox;* technically not a shrew but a tenrec), is considered endangered by IUCN. Found in streams and swamps, habitat quality is critical to this animal. It is not found where waters are muddy from erosion caused by deforestation. The giant otter shrew eats fish, crabs, frogs and aquatic molluscs. The Cercopithecus monkey (*Cercopithecus ascanius*) found is in the Guenon family. Guenons pollinate flowers and disperse seeds.

We found 21 species of aquatic macroinvertebrates, including 7 species of molluscs. Two invertebrate groups in particular, are of importance to fish as prey items: a freshwater shrimp (*Caridina africana*) and larvae of Libellulidae (dragonflies): *Libellula quadrimaculata* and *Palpopleura lucia*.

We noted 22 species of plants, of which 6 (27 %) are invasive. The highly aggressive invasive plant, *Mimosa pigra*, was present.

8.8.2. Systematic account of species for Bas-Congo province.

Table 1c. Provisional list of fishes recorded. Note: precise identification to species will take 6 months-1 year.

+ = recorded; sp. = unidentified single species, may not be the same across sites; spp. = unidentified multiple species; M = fish for consumption, either collected from fishermen or observed at the market. * Station is unknown.

		STATION					
FAMILY	**SPECIES**	**Inga** ***(Tank)***	**Nziya**	**Shongho**	**Fwamalo**	**Point 50**	**Mar-ket**
POLYPTERIDAE	*1.Polypterus sp.*						+M
CLUPEIDAE	2.*Clupeidae sp.*	+					
MORMYRIDAE	*3.Petrocephalus sp.*	+					
	4.Gnathonemus sp.				+		
	5.Mormyrops anguilloides	+					+M
	6.Marcusenius monteiri		+				
	7.Marcusenius sp.				+		+M
	8.Mormyrus caballus bombanus		+				+M
	9.Hippopotamyrus discorhynchus		+				
	10. Campylomormyrus mivris		+				
	11. Campylomormyrus urirrostrus		+				
	12. Campylomormyrus sp. 1						+M
	13.Campylomormyrus sp.2						+M
CHARACIDAE	*14. Hydrocynus goliath*						+M
	15. Small characid sp. 1		+				
	16. Small characid sp. 2		+				
	17. Small characid sp. 3		+				
	18. Small characid sp. 4		+				
	19. Small characid sp. 5		+				
DISTICHODONTIDAE	*20.Ichthyoborus ornatus*				+		+M
	21.Distichodus sexfasciatus		+				+M
	*22. Distichodus lusosso**						
CYPRINIDAE	*23.Labeo velifer*		+		+		+M
	24.Labeo coubie		+			+	
	25.Labeo lineatus		+			+	
	26. Labeo nasus	+					
	27. Labeo macrostoma	+					
	28. Labeo sorex				+		
BAGRIDAE	*29.Chrysichthys sp. 1*		+				
	30.Chrysichthys sp. 2		+				
	31.Chrysichthys sp. 3		+				
	32.Bagrus sp.					+	
	33.Rheoglanis dendrophorus		+				+M
SCHILBEIDAE	*34.Schilbe mystis*						+M
OSTEOGLOSSIDAE	*35. Heterotus niloticus*		+				+M
MALAPTERURIDAE	*36. Malapterurus electricus*						+M
MOCHOKIDAE	*37. Synodontis sp. 1*		+				+M
	38. Synodontis sp. 2		+				
	39. Synodontis sp. 3		+				
	40. Synodontis sp. 4		+				
	41. Euchilichthys sp.	+					
	42. Microsynodontis		+				
CLARIIDAE	*43. Chariallabes sp.*						+M
CICHLIDAE	*44. Tylochromis sp.*		+	+			
	45. Tylochromis lateralis	+					
	46. Lamprologus sp. ***(new sp.)***		+				
	47. Haplochromis demeusii	+	+			+	
	48. Hemichromis elongatus	+			+		
	49. Nanochromis consortus		+				

	50. Tilapia sp.						+M
	51.Steatocranus casuarius	+		+			+M
	52.Steatocranus tinanti					+	+M
	53. Steatocranus glaber		+				
POECIILIDAE	*54. Aplocheilichthys sp.* ***(new sp.)***				+		
AMPHILIIDAE	*55. Belonoglanis sp.*				+		

Table 2c. Birds. For common names, see Table 2a.

		STATION				
FAMILY	**SPECIES**	**Inga (Tank)**	**Nziya**	**Shongho**	**Fwamalo**	**Pt. 50**
ACCIPITRIDAE	1.*Gypohierax angolensis*	+	+		+	
ALCEDINIDAE	2. *Halcyon senegalensis*	+				
ARDEIDAE	3. *Egretta alba*		+			+
	4. *Egretta ardesiaca*					
	5. *Egretta gularis*	+				
CAPITONIDAE	6.*Pogoniulus bilineatus*	+	+			
	7. *Pogoniulus sp*					+
COLUMBIDAE	8. *Streptopelia sp*					+
CORVIDAE	9. *Corvus albus*	+				
CUCULIDAE	10.*Centropus senegalensis*	+	+			
ESTRILDIDAE	11. *Lonchura cucullata*		+			+
	12.*Uraeginthus angolensis*		+			+
HIRUNDINIDAE	13.*Hirundo abyssinica*	+				
	14.*Hirundo rustica*				+	
	15.*Hirundo senegalensis*	+	+			+
	16.*Delichon ursica*				+	
MEROPIDAE	17. *Merops pusillus*					+
MOTACILLIDAE	18. *Motacilla agwimp*	+				
PASSERIDAE	19. *Passer griseus*					+
PHALACRO-CORACIDAE	20. *Phalacrocorax africanus*		+		+	+
PHASIANIDAE	21. *Francolinus sp.*	+				
PYCNONOTIDAE	22. *Pycnonotus barbatus*	+	+	+		
SYLVIIDAE	23. *Cisticola natalensis*				+	

Table 3c. Amphibians.

		STATION				
FAMILY	**SPECIES**	**Inga (Tank)**	**Nziya**	**Shongho**	**Fwamalo**	**Pt. 50**
BUFONIDAE	*1. Bufo funereus*	+	+			
RANIDAE	*2. Rana fuscigula*	+				+
	3. Rana sp. 1		+			
	4. Rana sp. 2					+
	5. Hymenochirus curteines					+
	6. Rana mascariensis	+				
	Many larvae				+	+

Table 4c. Reptiles.

		STATION				
FAMILY	**SPECIES**	Inga (Tank)	Nziya	Shongho	Fwamalo	Pt. 50
SCINCIDAE	1. *Mabuya maculilabris* (speckle-lipped skink)	+	+		+	+
AGAMIDAE	2. *Agama agama* (common agama)		+			+

Table 5c. Mammals.

		STATION				
FAMILY	**SPECIES**	Inga (Tank)	Nziya	Shongho	Fwamalo	Pt. 50
BOVIDAE	*1. Tragelaphus spekei* (Sitatunga)		+			
	2.*Cephalophus monticola* (Blue duiker)	M				
PTEROPODIDAE	*3. Eidelon helvum* (Straw-colored bat)	+ M				
	4. Myonycteris torquata (flying fox)				+	
POTAMOGALIDAE	*5.Potamogale velox* (Giant otter shrew)	Fisherman				

Note: All species except for Potamogale were found as bushmeat. We did not directly observe Potamogale; its presence was noted by a fisherman.

Table 6c. Macroinvertebrates.

			STATION				
ORDER	**FAMILY**	**SPECIES**	Inga (Tank)	Nziya	Shongho	Fwa-malo	Pt. 50
CRUSTACEA	ATYIDAE	1. *Caridina africana*	+			+	+
		2.*Caridina sp1*	+			+	
		3.*Caridina sp2*	+			+	
		4. *Caridina sp. 3*					
	POTAMONIDAE	5. *Potamonautes dybowkin*	+			+	+
COLEOPTERA	DYSTICIDAE	6. *Cybister tripunctatus*					

HETEROPTERA	GERRIDAE	7.*Gerris sp. 1*	+				
		8. *Gerris sp. 2*					
HEMIPTERA	NEPIDAE	9.*Ranatra grandicollis*	+				
	BELOSTOMATIDAE	10. *Belostoma niloticum*					
ODONOTA	COEANAGRIONIDAE	11. *Megaloprepus caerulatus*	+			+	
	LIBELLULIDAE	12.*Palpopleura lucia*					
		13. *Libellula quadrimaculata*	+				+
	AESHNIDAE	14. *Aeshnid sp.*					
MOLLUSCA	HYDROBIIDAE	15.*Hydrobia plena*				+	
	MELANIIDAE	16. *Melaniid sp.*					
	ASSIMINEIDAE	17. *Assimi oreidae*				+	
		18. *Pseudogibula duponti*					
		19. *Pseudogibula pallidior*					
	SIBULINIDAE	20. *Pseudoglossoria bessei*				+	
	AMPULLARIIDAE	21. *Aetheria elliptica*					

Table 7c. Plants.

FAMILY	**Species (common name, where available)**	**Comments**
POACEAE	1.*Panicum repens L.* (Australia torpedo grass)	Invasive grass
	2.*Panicum maximum (guinea grass; colonial grass)*	Medicinal value
	3.*Oryza barthii* (species of wild rice)	Valuable for agricultural diversity
	4.*Echinochloa pyramidalis* (antelope grass)	Nutritious fodder for dry-season grazing
	5. *Imperata sp.*	Grass
	6. *Hyparrhenia diplandra*	Dominant grass species of flooded wood savannah regions
CYPERACEAE	7. *Cyperus sp.*	Grass
CONVOLVULACAE	8. *Ipomoea aquatica* Forsk (water spinach; aka swamp cabbage)	Invasive species; floating vine; *Medicinal value*
SALVINIEACEAE	9. *Salvinia nymphellula*	Floating plant
PONTEDERIACEAE	10. *Eichornia crassipes* (water hyacinth)	Invasive floating plant
POLYGONACAE	11.*Polygonum acuminatum* H.B. and K. (knotweed)	Freshwater plant; medicinal value
MYRTACAE	12. *Eugenia congolensis*	Tree found in flooded forest
EUPHORBIACEAE	13. *Hymenocardia acida*	Medicinal value
IRVINGIACAE	14. *Irvingia smithii* Hook. F.	Tree in gallery forest
THELIPTERIDACAE	15.*Cyclosorus dentatus* (Forsk) (lynyolo)	Medicinal value
MORACEAE	16. *Ficus mucosa* (fig tree)	Medicinal value; documented to be used by chimps for same reason; timber species
RUBIACAE	17.*Nauclea latifolia* Smith (Pin cushion tree; aka African peach)	Small tree; medicinal value
ANACARDIACAE	18.*Lannea antiscorbutica* (Hiern) Engl. (pink lannea)	Found in riverine forests with sandy soil
BOMBACEAE	19. *Ceiba pentandra* (kapok tree)	Invasive tree
	20. *Andansonia digitata* (African baobob)	Native tree; medicinal value; pollinated by bats
FABACEAE	21. *Mimosa pigra* (catclaw mimosa; aka giant sensitive plant)	Invasive, highly destructive; forms dense monocultures. Suppresses other vegetation as well as impacts on fish life.
ASTERACEAE	22. *Chromolaena odorata*	Invasive perennial shrub

8.8.3. Water quality analysis

Inga was particularly poor in organics, compared to Bandundu (at Bokoni and Mushi sites). Productivity, as measured by PO4 and NO3 was extremely low. This means that the aquatic food chain depends upon food sources from the land: specifically, terrestrial plant matter and insects.

The water was consistently clear and brown-tinged, with the coloring humic substances orginating from the Cuvette Centrale (Roberts and Stewart, 1976). Transparency, as measured by the Secchi disk, was consistent throughout the sampling sites (48-50 cm); Robert and Stewart reported transparency levels of less than 100 cm. Mean total turbidity was 32 (FTU); mean true color was 172.4 (Pt-Co units). The pH was close to neutral, ranging from 6.5 to 7. Roberts and Stewart reported pH values between 7-7.5. Conductivity was constant throughout the sampling sites (33 –36 µS). Carbonate hardness (aka alkalinity) was particularly low at the rapids of Point 50 and the stiller waters of Nziya. Roberts and Stewart noted the very low alkalinity levels for the rapids. By the rapids of Shongho and Point 50, dissolved oxygen levels were super-saturated, as previously reported by Roberts and Stewart (1976). The faster the current (and the mixing), the greater the level of dissolved oxygen. Water temperatures were more than four degree higher than those reported by Roberts and Stewart for August, 1973. They reported water temperatures of 24.7-34.8 ^{o}C for their two Inga sampling sites, with air temperatures of 23.3-30^{o} C; we found water temperatures from 28-30^{o} C, with air temperatures ranging from 28-32.6^{o}C; mean: 29.97^{o}C) for this September, 2002 survey.

Results of chemical analysis for metals showed that the Inga sites are significantly polluted in heavy metals, especially in lead (Pb), and Cadmium (Cd). The heavy metal pollution poses a danger for human health, if the water is used for drinking, may pose a problem for the consumption of certain fish, particularly benthic feeders such as catfish (see paragraph below), and may pose a threat to the health of other species. Relatively high levels are also found for iron (Fe) and copper (Cu), but they do not pose a health hazard. The mean lead level of 163.82 µg/L is a real concern if the water is used as drinking water. The EPA considers a lead level of 40 µg/L "imminent and substantial endangerment, based on toxicological studies on young children," (www.epa.gov/safewater), and *the lead level found is 4 times greater than this.* Health effects for infants and children include "delays in physical or mental development, slight deficits in attention span, and learning abilities." For adults, high lead levels cause kidney problems, liver and thyroid function, and high blood pressure. Lead is also cancer-causing. Lead primarily enters water via corrosion of plumbing systems and erosion of natural deposits, but industrial processes could also play a role.

According to Eisler, 1988, "lead has been shown to have adverse effects in amphibians, including loss of sodium, reduced learning capability, and developmental problems (Horne and Dunson 1995; Freda 1991). Fish exposed to high levels of lead exhibit a wide-range of effects including muscular and neurological degeneration and destruction, growth inhibition, mortality, reproductive problems, and paralysis (Eisler 1988b; EPA 1976). At elevated levels lead can cause reduced growth, photosynthesis, mitosis, and water absorption (Eisler 1988b). Birds and mammals suffer effects from lead poisoning such as damage to the nervous system, kidneys, liver, sterility, growth inhibition, developmental retardation, and detrimental effects in blood (Eisler 1988b; Amdur et al. 1991). Lead partitions primarily to sediments, but becomes more bioavailable under low pH, hardness and organic matter content (among other factors). *Lead* *bioaccumulates in algae, macrophytes and benthic organisms*, but the inorganic forms do not biomagnify. Lead poisoning in higher organisms has been associated with lead shot and organolead compounds, but not with food chain exposure to inorganic lead (other than lead shot, sinkers or paint). There are complex interactions with other contaminants and diet. *Lead adversely affects algal growth, invertebrate reproduction and fish survival.* ... The main potential ecological impacts…result from direct exposure of algae, benthic invertebrates, and embryos and fingerlings of freshwater fish and amphibians to lead. Potential endpoints include growth reductions and impaired survival."

The samples were also more than three times higher than the safe level for cadmium (5 μg/L). High levels of cadmium cause kidney damage. Cadmium enters the water system through corrosion of galvanized pipes, discharge from metal refineries, runoff from waste batteries and paints, and erosion of natural deposits. Further investigation of both water quality and bioaccumulation of heavy metals in ecosystems will allow us to identify mitigative measures that should reduce the threats to people and other species.

Table 8c. Summary of water quality data for Bas-Congo province.

STATION NUMBER

	1	2	3	4	5	6	7	11	8	9	10
Site Description	Fwamalo H1	Fwamalo H2	Inga Center H1	Point 50 Bank	Point 50 Center A1	Point 50 Center A2	Point 50 Center A3	Point 50 Center A4	Shongho A1	Nziya 1	Nziya H2
GPS Location (lat/long, in degrees)	5°28.13S 13°35.01E	5°28.13S 13°35.01E	5°31.01S 13°37.17E	5°31.69S 13°36.47E	5°31.69S 13°36.47E	5°31.69S 13°36.47E	5°31.69S 13°36.47E	5°31.69S 13°36.47E	5°31.43S 13°37.76E	5°32.25S 13°33.61`E	
Depth at measured site (feet)	Center: 67		Center: 69	-					24.7	Center: 22.3	
Water Temp. at Surface (C)	27.9			29.2					30.0	30.1	
Current (qualitative)	Medium			Fast					Fast	Slow	
pH	6.73		6.8	6.6					6.99	6.54	
Conductivity (µS)	34.3		35.5	36.1					33.5	33.4	
Secchi Disk (cm)	50			48					50	50	
Turbidity (FTU)	32	32	31	33	33	34	31	32	31	32	32
Color	Clear, Brown-tinged			Clear, Brown-tinged					Clear, Brown-tinged	Clear, Brown-tinged	
True Color (Pt-Co units)	160	178	169	180	173	180	175	179	178	179	162
General Hardness (ppm)	53.7		35.8	35.8					35.8	53.7	
Carbonate Hardness (ppm)	53.7		35.8	17.9					35.8	17.9	
Dissolved Oxygen (%)	93.8%			105.1%					104.2%	-	
Phosphate (PO4) (mg/L)	<<0.25		<<0.25	0					0	0	
Nitrate (NO3) (mg/L)	-			-					-	<<5	
Calcium (mg/L)	20			60					20	20	

Water quality: (- = no test; 0 = zero test value; empty cells indicate columns of additional samples for laboratory analysis).

Table 9c. Metals content in water samples.
Values are in µg/L. Data analysed by ERGS.

Sites	Iron (Fe)	Cadmium (Cd)	Lead (Pb)	Manganese (Mn)	Copper (Cu)	Chromium (Cr VI)
Inga, H1 Center	94	17	169	11	45	3
Nziya H_1	91	18	159	8	39	4
Nziya H_2	89	18	160	8	52	5
Shongo A_1	99	19	177	7	48	5
Fwamelo H_1	97	18	159	8	45	4
Fwamelo H2	95	14	132	13	48	3
Point 50	89	23	165	8	53	3
Point 50, A_2, Center	88	18	166	8	45	4
Point 50,A_2,Center	93	17	169	8	44	5
Point 50, Center II	94	16	177	9	53	5
DG, Center	90	19	169	7	46	4
Average	**92.64**	**17.91**	**163.82**	**8.73**	**47.09**	**4.09**

8.8.4. Sampling Station Reports, Trip #2

Name: Inga #1 (Tank)
Position: 5° 31.01 S, 13 ° 37.17 E

Date of visit: Sept. 24, 2002
Returned the evening Sept. 25, 2002 to record the fishermen's catch.

Procedures: Birds and amphibians were observed and tape-recorded. Reptiles and mammals were noted. Plant samples were collected. Macroinvertebrates were caught with a dip net. As we had no access to a pirogue at this site, fish were obtained from fishermen.

Ecological notes: This water body was a large reservoir 500 meters wide, 3 km long, created by the blockade of water from the dam at Inga #1. The surrounding landscape was mountainous wooded savannah habitat. Soil was clay. Aquatic plants included wild rice (*Oryza barthii), Salvinia nymphellula,* and the invasive species of *Eichornia crassipes*, *Ipomea aquatica*, and *Mimosa pigra. Panicum maximim* and *Imperata cylindrica* were also present. The wooded savannah included the following trees: *Ficus mucosa* and *Hymenocardia acida*; the dominant savannah grass, *Hyparrhenia diplandra*; and the invasive shrub, *Chromolaena odorata*. The reservoir bottom was mud.

Conservation/development notes: The reservoir is not of much conservation interest. The aquatic habitat has been completely altered by the creation of the reservoir due to the dam at Inga 1. However, it remains an easy site for fishing, and is therefore of developmental interest.

Name: Nziya
Position: 5 o 32.25 S, 13 o 33.61 E

Date of visit: Sept. 24, 2002
Sept. 27, 2002

Procedures: Birds were observed and tape-recorded. Amphibians, reptiles and mammals were noted. Plant samples were collected. Cast nets and seines were used to capture fish. A dip net was used to capture aquatic invertebrates.

Ecological notes: This very steep cliff was covered with wooded savannah habitat. Soil was clay. Abundant plants in the wooded savannah included the grass, *Hyparrhenia diplandra,* and various grasses in the family Poaceae. At the bottom of the mountainous cliff, diverse aquatic habitats in this main part of the river included sand, rocky boulders, and grassy shore areas with a muddy bottom. The river was approximately 700 meters wide at this point. Currents were slow near the bank. The biting blackfly was ubiquitous.

Conservation/development notes: An animal trap was observed on the trail. An abundant small crustacean is caught for food.

Name: Shongho
Position: 5 o 31.43 S, 13 o 37.76 E

Date of visit: Sept. 25, 2002

Procedures: Birds, reptiles and mammals were observed. No amphibians were found during this rapid survey. Macroinvertebrates were captured with a dip net. We tried to use a dip net to catch fish, but were unsuccessful. Fish were obtained from local fishermen, who used a gill net and hook and line.

Ecological notes: The cliff was covered with wooded savannah habitat. The river width was approximately 1 km. The aquatic habitat comprised rapids, with bedrock and large boulder bottom. Currents were very strong. Large boulders were along the banks. The shore had bushy plants.

Conservation /development notes: We observed a fish net used as a mist net to catch birds.

Name: Fwamalo
Position: 5 o 28.13, 13 o 35.01 E

Date of visit: Sept. 25, 2002

Procedures: Birds, reptiles and mammals were observed. Seines and dip nets were used to capture fish.

Ecological notes: This site was the canal. Chanel width was roughly 100 meters. The channel river bottom was large rocky boulders and sand. A grassy wetland was present further upstream. The banks were covered with grass.

Conservation/development notes: As with the reservoir, this site is not of much conservation interest due to the change of aquatic habitat caused by the dam.

Name: Point 50
Position: 5 ° 31.69 S, 13 ° 36.47 E

Date of visit: Sept. 26, 2002

Procedures: Birds and amphibians were observed and tape-recorded. Plant samples were collected. A dip net was used to collect macroinvertebrates and to attempt to capture fish. Cast nets were also employed along sandy stretches for fish. On the way down to the rapids, we sampled a small forest stream.

Ecological notes: The terrestrial landscape was a very steep cliff, with wooded savannah habitat and new and old fallow. Soil was clay. At the bottom of the mountainous cliff, aquatic habitats were rapids, with bedrock, large boulders, and sand in parts. Plants in the wooded savannah habitat included the African baobab (*Andasonia digitata),* the invasive kapok tree (*Ceiba pentandra),* the dominant grass, *Hyparrhenia diplandra*, the invasive shrub, *Chromolaena odorata*, and unidentified plants called locally Mutumbilo. The width of the river was roughly 750 meters at this station. The blackfly was ubiquitous.

Conservation/development notes: Fishermen use inner tubes and handlines to fish the rapids (a technique invented by a local fisherman in the 1960s), along with gill nets. Given the treacherous nature of fishing rapids, as well as the difficulties in reaching the site, overexploitation is likely not an issue.

8.9. CONSERVATION AND MANAGEMENT

WWF (Thaime et al., 2003, in press) considers the Lower Congo Rapids to be among the highest priority for conservation. It has the highest category of biological distinctiveness, high integrity, moderate threats, but a low level of scientific understanding.

8.9.1. Threats and development issues

Over the last century, the ecosystem in this area has changed from lowland forest to wooded savannah (Ifuta, personal communication). Essentially, the savannah border moved further north. This no doubt has had an effect on the hydrology of the river, the local climate, and on the species composition of insects and plant food from allocthanous (land-based) sources.

Current threats include:

- Water pollution, including sewage, industrial chemicals from Brazzaville and Kinshasa, mining south of these two cities, and sedimentation.

- Future damming of the entire river: The greatest future threat to the extraordinary biodiversity of the region is the proposed Grand Inga dam. Inga 1 and 2 have only blocked a river channel; not the main river. However, the Grand Inga dam would block the entire river (SNEL, 2002).

8.9.2. Management

Fisheries: Without assessing abundance, having knowledge of the number of fishermen, or the number of fishing trips, we conclude that the fishing appears sustainable, given the large size of fish caught, the tremendous difficulty in reaching the fishing sites, and the difficulty in fishing, particularly the rapids. At the rapids of Shongo, fishermen used hook and line, baited with worms. The size of the hooks was the legal size of #8, #12, #16, and #18. They also used large mesh-sized gill nets stretched across the slower part of the rapids.

Recommendation: From a conservation standpoint, the best option would be 1) a net exchange program, swapping illegal nets for legal ones, 2) mapping of key spawning areas and fishing grounds, and 3) beginning monitoring of fishing effort. Note that Roberts and Stewart sampled in June-Sept.. Half of their sample were young fishes of 3 cm or less, and 1/5 of their sample was 2 cm or less, including species in the families Mormyridae, Distichodontidae, Bagridae, Cichlidae, and Cyprinidae, meaning spawning occurred just prior to this period. The authors suggest that spawning here is less seasonal than the larger part of the river.

From a development standpoint, we encourage a small grant proposal from the local Fishing Association. Their goals are to increase production and to develop the fishermen. They are seeking: a cold room, a store to sell fishing supplies, nets, life jackets, and mosquito repellant. Blackflies (of the *Simulium damnosum* species complex), which cause river blindness, or onchocerciasis, are extremely abundant here. One study reported that fishermen could receive up to 8000 bites a day! Blackflies have aquatic larvae.

Pollution: Lead levels are a major concern, particularly for the health of young children in the area.

Recommendation: Additional water quality surveys should be conducted to explore the seasonality of the lead input, and to identify the source of the lead. We need to know if this water is used as drinking water. In addition, it is essential to know whether the lead is accumulating in the benthic or predatory fish caught for consumption.

Dam: The future dam of the entire river is the greatest concern. While the landscape has already been changed, the aquatic ecosystem still harbors extraordinary richness of fish.

Recommendation: Given the length of time to secure funding for the Grand Inga Dam, we hope that discussions can take place over the next several years among a qualified hydrologist and the government to determine ways to build or modify the dam to best protect the region's flooding cycle and maintain some of the rapids areas.

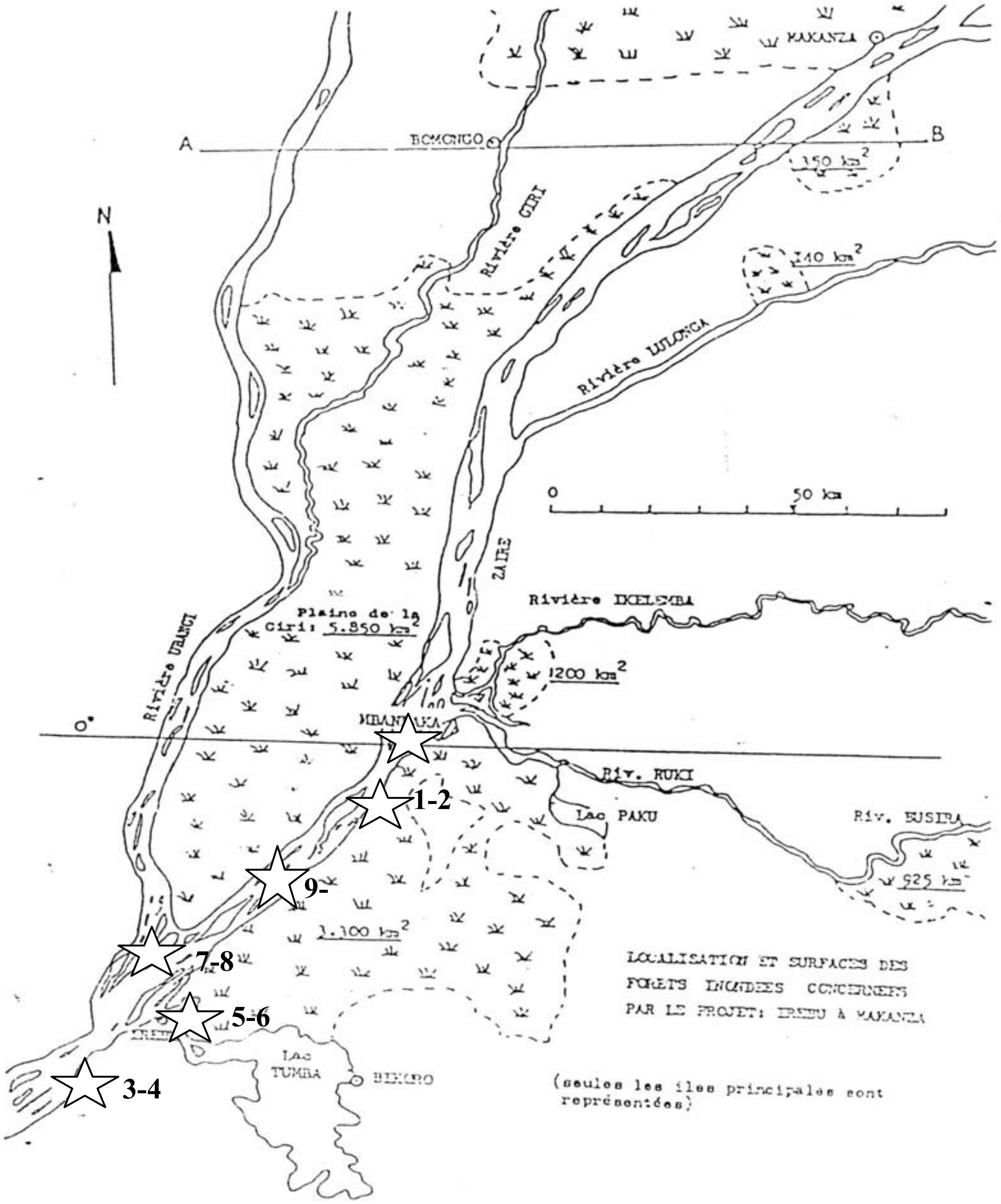
Restoration of the landscape: Over the longer term, it would be useful to make efforts to restore the landscape back to forest, if the concern over the dam could be addressed.

TRIP # 3: EQUATEUR PROVINCE: MBANDAKA TO GOMBE

8.10. SUMMARY

8.10.1. Map of station sites in Equateur

Stars mark sampling sites; bold numbers indicate water quality stations. All species and water quality were sampled at Bodjia (stations 1-2), Gombe (stations 3-4), and near the confluence of Ubangi river (stations 7-8). Fish, macroinvertebrates, and water quality were sampled at Irebu (stations 5-6). Water quality was sampled midway between Mbandaka and Gombe (stations 9-10). Only fish were sampled at the markets in Mbandaka and Maita (near station 9-10).



Map source: FAO (1990). Reprinted with permission from the Food and Agriculture Organization of the United Nations.

8.10.2. Background

Our sampling sites encompassed 4 ecoregions. One of our sampling sites (Irebu) lies within the *Lake Tumba ecoregion* (ecoregion # 13, Thieme et al., 2003, in press); the confluence of the Ubangi and Congo River site is the transition zone between two ecoregions, the *Sudanic Congo (Oubangui) ecoregion* (# 30) and the *Lake Tumba ecoregion* (#13; two sampling sites, Bodjia and Mbandaka, fall within the *Cuvette Central* ecoregion (#18), and Gombe lies just within the *Sangha ecoregion (#27),* but may be considered in a transition zone between *Sangha* and two other ecoregions, *Lake Tumba* and the *Sudanic Congo*. WWF (Thieme et al., 2003, in press) considers the Cuvette Centrale to be of highest conservation importance; the Lake Tumba ecoregion to be of high conservation importance due to its intact habitas and rich invertebrate and fish faunas; the other ecoregions bioregionally outstanding. IUCN considers both the Lake Tumba region and the swamp forest of Giri to be critical sites for forest conservation.

The flooded forest region in the confluence of the Ubangi and Congo river covers nearly 38,000 km2, depending on season. This is the most extensive zone of swamp forest and inundated forest on the African continent (Thaime et al., 2003, in press). The flooded zones receive decomposed organic materials from forest plants, rendering the water acidic.

Due to the biannual forest flooding, a number of fauna are uniquely adapted to this flooded habitat. Some fish species found predominantly in the flooded forest areas include: Polypterus, Protopterus, Clarias, Ophicephalus, Channidae. As such, the presence of these species could potentially provide an indicator for this type of habitat. Many endemic plant species have been recorded here. WWF notes that one key primate in the region is Allen's swamp monkey (*Allenopithecus nigroviridis*), of evolutionary interest due to the fact that it is believed to be a holdback from the swamp-dwelling ancestor of modern arboreal monkeys.

The Giri swamp forest (aka Bangala swamp) is to the west of the Congo river, between the Congo and Ubangi Rivers. WCMC (as cited in Thaime et al., 2003, in press) notes that mammal species in the region include hippopotamus (*Hippopotamus amphibius*), buffalo (*Syncerus caffer*), Allen's swamp monkey (*Allenopithecus nigroviridis*), and possibly red colobus (*Procolobus badius*). The area is also important for birds. WWF notes that "this is a large and relatively intact area, with high potential for research and conservation."

The Cuvette Centrale (site of Bodjia and Mbandaka) contains the largest block of rainforest in Africa (Thieme et al., 2003, in press). It is considered to be rich in fish species, with many endemics. According to WWF (Abell et al., 2002), this low-lying depression is also thought to provide key habitat for Allen's swamp monkey and the threatened Hartlaub's duck (*Pteronetta hartlaubii*). Known aquatic mammals in the region include giant otter shrew (*Potamogale velox*), Congo clawless otter (*Aonyx congica*), sitatunga (*Tragelaphus spekei*) and chevrotain (*Hyemoschus aquaticus*).

8.11. RESULTS

8.11.1. Summary

Aquatic habitats: Aquatic habitats in this region included: islands, flooded swamp forest, floating grass islands, sand banks, and swamp grasslands. We rapidly sampled 5 sites: Bodjia, Gombe, Irebu, the confluence of the Ubangi and Congo Rivers, midway between Gombe and Mbandaka (at the Maita market, the river center and bank) and Mbandaka (market only). Note: Immigration and logistical travel difficulties considerably reduced the amount of time available for the survey in this province.

Terrestrial habitats: Terrestrial habitats included cropland, lowland swamp forest, islands, swamp grassland, and pockets of dryland forest.

Species: We found 54 species of fish, comprising 16 families. While some of these species may possibly be new, this awaits confirmation from the AMNH. Dominant families include Mormyridae (comprising 34% of the species), Characidae and Distichodontidae, both at 9%, Bagridae and Mochokidae, both at 8%, and Clariidae and Cichlidae, both at 6%. All of these families have been reported to be frequently captured in Equateur, with the exception of Clariidae and Characidae (COOPEQUA, 2002). Other families reported to be frequently captured, but not present in our sample include Phractolaemidae, Malapteruridae, Ophiocephalidae, Hepsetidae, Centropomidae, Tetraodontidae, Mastacembelidae, Amphiliidae, and Pantolidae.

Given the limited time available for our survey of sites in this province, we found 32 species of birds; 8 species of amphibians; 3 species of reptiles; and 19 species of aquatic macroinvertebrates from 8 families. The African soft-shelled river turtle, *Trionyx triunguis*, eats fish. As with the other provinces, we recorded 3 species of mammals, but none were found alive; all were observed as bushmeat. We identified 13 species of plants, 3 (23%) of which were invasive.

Management: With the help of experienced fishermen, we completed the compilation of names for the field guide to fishes in the local languages, Lingala and Kikonga.

8.11.2. Systematic account of all species for Equateur province.

Table 1d. Provisional list of fishes recorded. Note: Identification to species will take 6 mos-1 yr.
+ = recorded; sp. = unidentified single species, may not be the same across sites; spp. = unidentified multiple species; M = marketed fish.

		STATION					
FAMILY	**SPECIES**	**Bodjia**	**Maita**	**Gombe**	**Confl. Ubangi/ Congo**	**Irebu**	**Mbandaka**
PROTOPTERUS	*1. Protopterus dolloi*		+ M				
POLYPTERIDAE	*2.Polypterus sp.*		+ M				
CLUPEIDAE	*3.Clupeidae sp.*	+ sp.				+ sp.	
MORMYRIDAE	*4. Campylomormyrus tamandua.*						
	5 Campylomormyrus sp.					+ sp.	
	6.Marcusenius greshoffi						
	7.Marcusenius sp. 1						
	8. Marcusenius sp. 2						
	9.Marcusenius monteiri						
	10.Hippopotamyrus discorhynchus					+ sp.	
	11. Hippopotamyrus plagiostoma			+			
	12. Hippopotamyrus sp.			+			+M
	13.Mormyrops anguilloides						+M
	14.Mormyrops nigricans						
	15.Petrocephalus sauvagii						+ M
	16. Petrocephalus sp. 1					+ sp.	
	17.Petrocephalus sp.2						
	18.Mormyrus caballus bombanus						
	19.Mormyrus proboscirostris						
	20.Mormyrus ovis						
	21.Gnathonemus sp.						
CHARACIDAE	*22. Hydrocynus goliath*		+ M			+	+ sp.
	23. Alestes sp.						
	24. Characid sp.	+ sp.				+ sp.	
	25. Brycinus sp.						
	26. Bryconaethiops sp.						
DISTICHODONTIDAE	*27. Ichthyoborus ornatus*					+	
	28. Distichodus notospilus	+					+M
	29. Distichodus atroventralis	+					+M
	30. Distichodus antonii			+			+M
	*31. Distichodus lusosso**						
CITHARINIDAE	*32.Citharinus gibbosus*						
CYPRINIDAE	*33.Labeo lineatus*		+ sp. M				
	34.Leptocyrus sp.						
BAGRIDAE	*35.Bagrus ubangensis*						+ M
	36.Chrysichthys sp. 1		+ M			+ sp.	+ sp. M
	37.Chrysichthys sp. 2						
	38.Auchinoglannis occidentalis		+ M				+ M
SCHILBEIDAE	*39.Schilbe mystus*					+ sp.	+ sp.
ANABANTIDAE	*40. Ctenopoma pellegrini*	+	+ M				M
	41. Ctenopoma kingsleyae			+			

OSTEOGLOSSIDAE	*42. Heterotus niloticus*				+		
MOCHOKIDAE	*43. Synodontis sp. 1*						
	44. Synodontis sp. 2						
	45. Synodontis sp. 3						
	46. Synodontis acanthomias						
CLARIIDAE	*47.Heterobranchus longifilis*		+ M				
	48.Clarias sp. 1		+ M				+ M
	49.Clarias sp. 2						
CICHLIDAE	*50.Tylochromis sp.*					+	
	51. Hemichromis elongatus	+					
	*52. Haplochromis demeusii**						
	53. Tilapia nilotica						
CHANNIDAE	*54.Parachanna obscura*						+ M

Table 2d. Birds. For common names, see Table 2a.

		STATION		
FAMILY	**SPECIES**	**Bodjia**	**Gombe**	**Confluence Ubangi/Congo**
JACANIDAE	*1.Actophilornis africanus*		+	
ARDEIDAE	*2. Egretta alba*		+	
	3. Egretta ardesiaca			
	4. Bubulcus ibis			+
ANHINGIDAE	*5. Anhinga rufa*		+	
MEROPIDAE	*6. Merops pusillus*		+	
PASSERIDAE	*7. Passer griseus*		+	
COLUMBIDAE	*8. Turtur afer*		+	
BUCEROTIDAE	*9. Tochus fasciatus*			
PSITTACIDAE	*10. Psittacus erythacus*			
PLOCEIDAE	*11. Ploceus cucullatus*		+	
	12.Ploceus pelzelni		+	
	13. Ploceus melanocephalus		+	
	14. Ceryle rudis		+	
	15. Quelea quelea		+	
	16. Brachycope anomala		+	
RALLIDAE	*17. Porphyrio alleni*		+	
PYCNONOTIDAE	*18. Pycnonotus barboratus*		+	
	19. Pycnonotus sp.	+		
ESTRILDIDAE	*20. Estrilda sp.*			
CORVIDAE	*21. Corvus albus*			
VIDUIDAE	*22. Vidua macruora*			
TURPIDIDAE	*23. Saxicola saxicola torquata*		+	
APODIDAE	*24. Raphidura sabini*		+	
NECTARINIDAE	*25. Anthrepes collaris*	+		
ACCIPITRIDAE	*26. Milvus migrans*		+	
	27. Gypohierax angolensis		+	
ALCEDINIDAE	*28.Halcyon senegalensis*	+	+	
	29. Halcyon leucocephala		+	
CAPRIMULGIDAE	*30. Macrodypteryx vexillarius*			+
CUCULIDAE	*31. Centropus senegalensis*			+
COLUMBIDAE	*32.Streptopelia semitorquata*		+	+

Table 3d. Amphibians.

		STATION		
FAMILY	**SPECIES**	**Bodjia**	**Gombe**	**Confluence Ubangi/Congo**
BUFONIDAE	*1. Bufo regularis*	+	+	
	2. Bufo funerius	+		
RANIDAE	*3. Rana mascariensis*	+	+	
	4. Discroglossus occipitalis	+	+	
	5. Rana fuscigula nutti		+	
	6. Rana fuscigula angolensis	+	+	
	7. Rana sp.		+	

Table 4d. Reptiles.

		STATION		
FAMILY	**SPECIES**	**Bodjia**	**Gombe**	**Confluence Ubangi/Congo**
TRIONICHYDAE	1.*Trionyx triunguis* (African soft-shelled turtle)		+	
	2.*Cycloderma auluryi* (Aubrey's flapshell turtle)		+	
SCINCIDAE	3. *Mabuya sp.* (skink)	+	+	

Table 5d. Mammals.

		STATION		
FAMILY	**SPECIES**	**Bodjia**	**Gombe**	**Confluence Ubangi/Congo**
CERCOPITHECIDAE	1. *Cercopithecus mitis* (blue monkey)		+	
	2. *Cercopithecus ascarius* (red-tailed monkey)			
	3. *Papio anubis* (anubis or olive baboon)		+	

Table 6d. Macroinvertebrates.

			STATION		
ORDER	**FAMILY**	**SPECIES**	**Bodjia**	**Irebu**	**Confluence Ubangi/Congo**
DECAPODA	ATYIDAE	1. *Caridina africana*		+	+
		2. *Caridina sp.*		+	+
	PALAEMONIDAE	3. *Palaemon dux congoensis*			
	THERIDIIDAE	4. *Theridiid sp.*			
HETEROPTEA	HYDROMETIDAE	5. *Hydrometra sp.*		+	+
	NEPIDAE	6. *Ranatra grandicollis*		+	+
	GERRIDAE	7. *Gerris sp.*1		+	
ODONATA	COENAGRIONIDAE	8. *Megaloprepus caerulatus*		+	
	LIBELLULIDAE	9. *Palpopleura lucia*		+	
		10. *Libellulula quadrimaculata*			
COLEOPTERA	DYSTICIDAE	11. *Cybister tripunctatus*		+	
HEMIPTERA	NOTONECTIDAE	12. *Anisops varia*			
	BELASTOMATIDAE	13. *Belostoma niloticum*		+	
		14. *Belastoma sp.*		+	
SIGMURETHRA	ACHATINIDAE	15. *Achatina schweinfurthi*		+	
		16. *Achatina zebriolata*		+	
		17. *Achatina greyi*			
CAENOGASTROPODA	AMPULARIIDAE	18. *Aetheria elliptica*			
ARANAE LABIDOGNATHA suborder	ARACHNIDAE	19. *Unknown sp.*		+	

Table 7d. Plants.

FAMILY	**Species (common name, where available)**	**Comments**
POACEAE	1.*Panicum repens L.* (Australia torpedo grass)	Invasive grass
	2.*Panicum maximum* (guinea grass; colonial grass)	Medicinal value
	3.*Oryza barthii* (species of wild rice)	Valuable for agricultural diversity
	4.*Imperata cylindrica* (cogon grass or speargrass)	Invasive, one of the ten worst weeds in the world
	5. *Hyparrhenia diplandra*	Dominant grass species of flooded wood savannah regions
PONTEDERIACEAE	6. *Eichornia crassipes* (water hyacinth)	Invasive floating plant
FLACOURTIACAE	7.*Coloncoba glauca (P.Beauv.) Gilg.*	Tree; seeds used to destroy rats; oil used to treat leprosy
PALMAE	8. *Elaeis guinensis* (African oil palm)	
ARECACEAE	9. *Raphia sp.* (palm)	
EUPHORBIACAE	10. *Alchornea cordifolia*	Shrub; medicinal value
CAESALPINIACAE	11.*Griffonia tessmannii* (De Wild) Compere	Shrub; medicinal value
MORACEAE	12. *Ficus mucosa* (fig tree)	Medicinal value; documented to be used by chimps for same reason; timber species
	13. *Ficus sp.*	

8.11.3. Water quality analysis

As with the other two provinces, all stations showed poor productivity due to low nutrient content (phosphates < 0.25 mg; nitrates < 5 mg/l), routinely acid waters (pH = 6) and limited transparency. The acidity of the water is due to the decomposition of organic material over the flooded forest, ending up in the river. (Note, though, that transparency measures were 1.4-1.7 times greater than at the other two provinces. The most transparent waters were found at the Irebu site.) Mean total turbidity was 84.5 (FTU); mean true color was 181.7 (Pt-Co units). Thus, the beginning of the food chain in the river originates from the land: specifically, (allocthanous) terrestrial plant matter and insects. These natural characteristics mean that destruction of the terrestrial ecosystems along the river can significantly affect the riverine food web.

The lowest dissolved oxygen measures were for Bodjia: 44.3% (3.42 mg/L) and 59.3% (4.74 mg/L), possibly indicating sewage input at this site. These levels were the lowest found for all 3 provinces, and are in the range where aquatic animals would exhibit stress. Conductivity was also lowest at the Bodjia site (10 µS). Interestingly, water temperatures dropped 5-6^{o} C at the confluence of the Ubangi and Congo river (station numbers 7-8), even with air temperatures as high as 33.7^{o} C. Such a change in temperature may influence the faunal composition at this site. These water temperatures are the lowest recorded for all provinces.

Table 8d. Summary of water quality data for Equateur province.

STATION NUMBER

	1	2	3	4	5	6	7	8	9	10
Site Description	Iyonde Bank (Bodjia)	Iyonde Center	Gombe Bank	Gombe Center	Irebu Bank	Irebu Center	Ubangi Confluence Bank[1]	Ubangi Center	Bank – midway between Gombe/Mbandaka	Center -midway between Gombe/Mbandaka
GPS Location (lat/long, in degrees)	0°2. 34S 18° 10.94E	0°2.34S 18° 10.94E			0° 35.84 S 17°46.96E	0° 35.84 S 17°46.96E	0°30.75S 17°43.16E	0°30.75S 17°43.16E	0°16.84S 17°59.03E	0°16.84S 17°59.03E
Depth at measured Site (feet)	1.6	36.6	12.2	78	25.9	30.3	31.4	12.2	11.5	25.6
Water Temp. at Surface (°C)	27.3	25.2	27.2	27.8	27.2	27.6	21.7	19.8	21.4	25.6
Current (qualitative)	Slow	Slow	Fast	Fast	Fast	Fast	Medium	-	Medium	Medium
pH	6.0	6.62	<6.0	6.0	<6.0	< 6.0	6.0	6.6	6.1	6.0
Conductivity (µS)	10	10	20	30	26	20	20	20	20	30
Secchi Disk (cm)	Too shallow to record	70.5	75	72	120	102	72	71	57.3	100
Turbidity (FTU)	57	64	87	105	63	64	98	104	100	103
Color	Black	Black	Black	Black	Black	Black	Clear, Brown-tinged	Clear, Brown-tinged	Clear, Brown-tinged	Clear, Brown-tinged
True Color (Pt-Co Units)	137	140	203	236	132	132	210	215	203	209
General Hardness (ppm)	35.8	17.9	53.7	35.8	35.8	35.8	17.9	35.8	35.8	35.81
Carbonate Hardness (ppm)	17.9	17.9	35.8	35.8	17.9	17.9	17.9	17.9	35.8	17.9
Dissolved Oxygen (%)	44.3%	59.3%	90.2 %	88.7 %	77.8%	81.0%	71.3%	88.0%	69.0%	74.2%
Phosphate (PO_4) (mg/L)	<<0.25	<<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0.25
Nitrate (NO_3) (mg/L)	<5	<5	<5	<5	<5	<5	<5	< 5	<5	<5
Calcium (mg/liter)	40	20	60	40	40	60	20	20	40	40

Water quality: (- = no test; 0 = zero test value; empty cells indicate columns of additional samples for laboratory analysis). [1]This GPS reading is slightly to the east of the water quality test, conducted on the Ubangi side of the confluence.

8.11.4. Sampling station reports, Trip #3

Name: Iyonde (Bodjia village)
Position: 0° 2.34 S; 18° 10.94 E

Date of Visit: Oct. 6, 2002

Procedures: Birds and amphibians were observed and tape-recorded. Reptiles and mammals were noted. Plant samples were collected. Macroinvertebrates were caught with a dip net. Fish were sampled with cast nets.

Ecological notes: The terrestrial landscape by this small fishing village, 25 km south of Mbandaka, was a plain, with cropland (new or old fallow). Abundant plants included: aquatic grasses of the Poacae family, *Alchornia cordifolia*, *Eichornia crassipes*, *Raphia spp*., *Elaeis guinensis, and Ficus sp*.. In the center of the river, a few drifting *Eichornia crassipes* islands passed by.

Name: Gombe
Position: Not recorded.

Date of Visit: Oct. 8, 2002

Procedures: Amphibians and birds were observed and recorded on tape. Birds were also caught with a mist net.
Reptiles, mammals, and plants were noted. Macroinvertebrates were collected with a dip net.

Ecological notes: The terrestrial landscape by this large village was a plain, with cropland (new or old fallow). Abundant plants included: the shrub, *Alchornia cordifolia*, fig tree, *Ficus mucosa,* and the grass, *Hyparrhenia diplandra.* Other plants included the grass, *Panicum maximum*, and the invasive grass, *Imperata cylindrica*.

Conservation/development notes: Numerous pirogues line the banks.

Name: Irebu
Position: 0° 35.84 S; 17° 46.96 E

Date of Visit: Oct. 9, 2002

Procedures: Macroinvertebrates were collected with a dip net. Fish were collected near a grassy wetland and near a tree root with the use of a cast net. Fish were collected in the middle of the river with an artisanal gill net method (200 m gill net rotated by two pirogues with 4 fishers).Water quality samples were collected.

Ecological notes: Swamp grasslands along banks, with hanging tree roots nearby. Abundant floating and emergent water plants included *Oriza bartilli* and *Eichornia crassipes.* Macroinvertebrates were collected over a muddy river bottom. The village of Irebu was roughly one hundred meters downstream.

Conservation/development notes: One of the two gill nets used by the fishers was an illegally sized 2.5 cm mesh net.

Name: Ubangi Confluence
Position: 0° 30.75 S; 17° 43.16 E

Date of Visit: Oct. 9, 2002

Procedures: Fish were collected with a cast net and dip nets. Amphibians, reptiles, and birds were observed. Macroinvertebrates were collected with a dip net over a sandy bottom. Water quality samples were obtained.

Ecological notes: Abundant floating and emergent water plants included *Oryza barthii* and *Eichornia crassipes.* The terrestrial habitat was flooded forest. Water temperatures were much lower than the other sites.

Name: Midway between Mbandaka and Gombe
Position: 0° 16.84 S; 17° 59.03 E

Date of Visit: Oct. 10, 2002

Procedures: Only water quality samples were taken at this site. Nearby, we recorded fish at the fish market in Maita.

Ecological notes: Littoral plants predominantly consisted of the shrub, *Alchornea cordifolia*, along with some *Eichornia crassipes*.

Conservation/development notes: At Maita, we were surprised by the absence of mormyrids, cichlids, and carps in the market. We noted the presence of the African soft-shelled turtle (*Trionyx triunguis*) at the market.

Name: Mbandaka
Position: not recorded.

Date of Visit: Oct. 6, Oct. 12, 2002

Procedures: Fish were purchased at the fish market.

Ecological notes: Densely populated city.

Conservation/development notes. Malaria is rampant in this city. We met a former pet-trader, Jean Kongolo. He was transferred to Mbandaka in 1993 for the pet trade, but trade collapsed in 1997 due to the war, and has not yet resumed. Large fish are caught in the middle of the river. Fish are sold both in Mbandaka and on the Congo-Brazzaville side.

8.12. CONSERVATION AND MANAGEMENT

WWF (Thaime et al., 2003, in press) considers the Cuvette Central to be among the highest priority for conservation. It has the highest category of biological distinctiveness, highest integrity, low threats, but a low level of scientific understanding. It considers Tumba to be among a high priority for conservation, having high biological distinctiveness, high integrity and moderate threats. The seasonally flooded forest regions are considered by WWF to be a globally rare ecosystem (Thaime et al., 2003, in press)

8.12.1. Threats and development issues

The two most immediate threats for the region included in the project are bushmeat hunting and overfishing.

- Bushmeat hunting: As in the other two provinces, all of the mammals observed were dead bushmeat, of potential concern. An important caveat to our results is that we had limited time, did not survey at night, and did not record presence of mammal dung (feces). However, WWF (Thaime et al., 2003, in press) corroborates that there is considerable hunting pressure in the south of the Ubangi ecoregion. The area is thought to be habitat for hippos, but none were observed. As noted in the section on Bandundu, hippopotami are critical for maintaining the integrity of riverine systems, and their disappearance affects the species composition of riverine plants and animals alike (Naiman and Rogers, 1997).

- Overfishing: The area has high levels of fishing and trade, due to the proximity of Mbandaka. High-value fresh fish at the market include: *Chrysichthys chrysichthus* (Libonu), *Auchenoglanis occidentalis* (mpoka), and *Labeo velifer* (Momgaza) (COOPEQUA, 2002). Fishermen use stationary or moving gill nets (requiring two pirogues and four fishers), seine nets, cast nets, handlines, and nonmotorized canoes (FAO). Environmentally unsound fishing methods include: defoliating the banks, using poisons and herbicides, and using nets smaller than 3 cm. We directly observed the use of illegally sized gill nets (2.5 cm) at Irebu. 3 cm is legal. We also saw the use of illegally-sized cast nets (1.5 cm) to catch small distichotids (6 inches or less). Large chrysichthids (3-4 ft.) are caught with hooks on handlines. COOPEQUA (2002) notes that there has been a reduction in abundance of Chrysichthyes along the river. At Maita, the absence of mormyrids, cichlids, carps in the market was noted. Given the preponderance of mormyrids at other stations in this province, the absence of mormyrids may indicate overfishing, or it could indicate market preference for other fish.

  Potential annual fisheries yield estimates for the region range from 100,000-120,000 t, but fishing is dispersed and the true yield is unknown. (FAO, 2002, cited in COOPEQUA, 2002). In 1986, fish production in Equateur was estimated at 30,000 tonnes for 20,000 fishers, In 1997, it was estimated at 36, 492 tonnes, an increase of nearly 22% (Source: Plans d'action provinciaux de la biodiversite, Juin, 1999). Estimated potential (kg/ha) is 25.

  Fishing closely follows the water cycle. The best period for fishing is July to middle of September, corresponding to the period of water decline. During this period, the fish move from the forest towards the river. Production is estimated at 20-30kg/unit of fishing, with 20 days fished/month (COOPEQUA, 2002). Monthly production is estimated at 400-600 kg/unit of fishing.

The second best period is Jan-March and October, during the period of water rise, when the fish make the reverse move. Production is estimated at 10-30kg/unit of fishing, with 15 days fished/month (COOPEQUA, 2002). Monthly production is estimated at 150-225 kg/unit of fishing.

The worst period for fishing occurs during the highest water period (April – June; Nov.-Dec.), when the fish are in the forest proper, reproducing in the inundated areas or along the banks. Production is estimated at 2-8 kg/unit of fishing, with 10 days fished/month (COOPEQUA, 2002). Monthly production is estimated at 20-80 kg/unit of fishing.

- Logging (future threat for lowland rainforest, not swamp forest): The province of Equateur had an estimated 99.7% forest coverage in 1990 (Thaime et al., 2003, in press). In the late 1980s, it also had the greatest volume of veneer and sawmill production. While the war in this province has considerably slowed or even stopped logging efforts, given the extent of forest in this region, this is likely to rapidly become a threat when peace resumes throughout the region. However, given the difficulties in harvesting a swamp forest, the region within this project is much less likely to be threatened.

- Pollution (Bodjia and Mbandaka): A localized threat is the low level of dissolved oxygen by Bodjia. Given the size of Mbandaka, sewage is likely to be a problem here as well.

8.12.2. Management

Recommendation:

1. Survey birds, mammals, and fish more intensively. This region is of both high conservation importance and scientific importance. The area has a virtually intact flooded forest (with the exception of large mammals). The project could greatly contribute to international understanding of this unique ecosystem by conducting a more thorough bird and mammal survey in the region, as well as to resample the fish seasonally. This would set the stage for monitoring the impact of the health of the flooded forest regions, an important first step in improving forest management.

2. Promote awareness of the importance of maintaining viable populations of key animals for the riverine ecosystem, specifically, hippos and terrestrial plants. Both are important for maintaining the extraordinary diversity of fishes in the region.

Bushmeat hunting:

Recommendation: The mammal survey would also help us determine how much of a threat bushmeat hunting is in the area. In addition, support a sociological study to better understand the nature of the threat of bushmeat hunting, as suggested by WWF (Thaime et al., 2003, in press).

Overfishing:

According to COOPEQUA (2002), fishing closely follows the seasonality of the water cycle. The best period for fishing is July to middle of September, corresponding to the period of water decline. At this time, the fish move from the forest towards the river. Production is estimated at 20-30kg/unit of fishing, with 20 days fished/month. Monthly production is estimated at 400-600 kg/unit of fishing.

The second best period is Jan-March and October, during the period of water rise, when the fish make the reverse move. Production is estimated at 10-30kg/unit of fishing, with 15 days fished/month (COOPEQUA, 2002). Monthly production is estimated at 150-225 kg/unit of fishing.

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Recommendation: Support 1) a net exchange program, swapping illegal nets for legal ones, 2) mapping of key spawning areas and fishing grounds, and 3) beginning monitoring of fishing effort. From a development standpoint, we encourage a small grant proposal from the local Fishing Association to improve their fishing materials, contingent on their agreement to undertake monitoring.

Pollution:

Recommendation: If Bodjia is to become part of the project, it would be useful to 1) retest the oxygen levels at another time of the year; and 2) determine the cause of the low oxygen levels. It would also be useful to conduct water quality analysis in Mbandaka.

8.12.3. Potential partner options

1. Action Contre la Faim (Mbandaka)
2. Fishing Association (Bodjia)
3. Fishing Association (Gombe)

9. DISCUSSION AND RECOMMENDATIONS

> *"Freshwater conservation requires attention to large-scale dynamics, complex interactions, and linkages to terrestrial systems, all issues that are poorly understood and difficult to address effectively.."*
>
> Thieme et al., 2003, in press

9.1. OVERVIEW

The goal of CREDP is to augment production while maintaining the biodiversity of the region. What does this mean, exactly? We hope to maintain keystone species, habitats, and processes, unique communities, and intact areas of global importance. The unique features of a river system are that one does not manage for stability. On the contrary, one must manage to allow for variability, in both time and space, and to maintain connections between the water and its surrounding landscape (Naiman and Rogers, 1997). For example, rivers experience year-to-year variability in rainfall that affect both the physico-chemical characteristics and population abundance.

This 5-week biodiversity survey, or inventory, rapidly sampled the number of species of various groups at the project sites in the 3 provinces, and also sampled water quality. Both actions were recommended by the CREDP Technical Commission #3. This inventory served 4 purposes:
1) It was the first step in stewardship planning of the freshwater ecosystems.
2) It can be used to identify what needs to be monitored over time.
3) It began development of a field guide for Congolese fish species, in both scientific names and the local languages. Note that a recent WWF meeting on the Guinea-Congo forest basin recommended this action within the next ten years.
3) Finally, the survey helped residents of the regions to become more appreciative of the extraordinary biodiversity in their midst.

This survey did not determine relative abundance, quantify resource use, or determine reproductive cycles. Note that a single sample *cannot* adequately determine the number of species present, their relative abundance, or life histories, because it does not take into account diurnal and seasonal movements and year-to-year natural variations in abundance. One of the key characteristics of riverine species is their movement to different habitats at different times of their life cycle – particularly during the spawning period. The World Bank recommends at least one full year of intensive sampling as the minimum requirement for an environmental assessment, with sampling to include both daytime and nighttime periods.

Freshwater ecosystems are inextricably linked to the surrounding landscape. From a management standpoint, ideally, one would manage the entire ecoregion as one unit. Since this is not possible for the first phase of CREDP, *the next best option is to work toward the management of entire small(sub) catchment basins*. Note that WWF has a map of the smaller catchment basins for the region. If this is not possible, *then the third best option is to focus on riparian protection.*

9.2. SUMMARY OF THREATS AND RECOMMENDED ACTIONS

In trying to maintaining the health of a riverine ecosystem, one has to consider connections in 4 dimensions: time, lateral (from the river to the riparian forest and vice-versa), longitudinal (i.e., upstream effects on downstream areas), and vertical (from the groundwater to the river).

The following matrix provides a summary of conservation threats, their time-frame, possible conservation actions, and possible development options for each province. These recommendations have taken into consideration the recommendations of the Biodiversity Commission (#2, 2002), with one exception: water hyacinth. We do not consider the presence of water hyacinth a serious problem at this time, with the exception of the reservoir at Inga. However, the reservoir is of low conservation priority due to the fact that it represents a completely altered habitat; the extraordinary biodiversity in the region is associated with rapids habitat, not the reservoir.

Each province has some distinctive threats, and unique opportunities. For more detail about the threats in each province, see the Conservation sections in Results.

Key to the success of the CREDP project is linking up with local partners who are committed to the project. This appears to be more likely in certain project sites than others. Aime Kamamba noted in one of his trip reports, that "because the participants don't consider themselves partners, it is not at all evident that they will assume their responsibilities (Kamamba, 2002).

PROVINCE	**THREATS (L, M, H)**	**CONSERVATION ACTIONS**	**DEVELOPMENT OPTIONS**
BANDUNDU	Bushmeat - M	Survey mammals and large reptiles thoroughly, educate on importance	
	Logging/Agricultural expansion - M	Map landscape to document rate of habitat conversion	
	Overfishing – M	Net exchange/map spawning areas /begin monitoring	Boost fishing production Other (future): Pet trade Sports fishing
	Mining – L		
	Oil – L (future)		
BAS-CONGO	Dam-H (future)	Begin discussions with hydrologists to seek ways to partially maintain flooding and rapids	
	Pollution – H	Survey water quality again	
	Overfishing – L	Net exchange/map spawning areas/begin monitoring	Boost fishing production Agricultural effort Other (future): White-water rafting?
EQUATEUR	Bushmeat – M	Survey birds, mammals, fish	
	Overfishing – M	Net exchange/map spawning areas /begin monitoring	Boost fishing production

9.3. CONSERVATION ISSUES

9.3.1. Terrestrial-aquatic links

Riparian habitats are structured by 3 factors, in order of priority (Naiman and Rogers, 1997):

- Physical factors: e.g., matter, energy, water;
- Movement of large animals. We now recognize the importance of large animals in structuring land, marine, and freshwater ecosystems (e.g., Jackson et al., 2001); and
- Plants and microorganisms, which determine the distribution and cycling of nutrients.

All factors connect the river with its surrounding landscape. The influence is two-way.

<u>Examples of the impact of the riparian land on river systems</u>
(sources: Thieme et al., 2003, in press, Naiman and Rogers, 1997)
Riparian vegetation influences river channel form and evolution. Fallen trees and branches have a major impact on channel form.
Riparian vegetation creates microhabitats. For example, fallen trees and tree branches provide important fish habitat.
Riparian vegetation influences temperature, light available for photosynthesis.
Riparian vegetation provides organic carbon to the river ecosystem.
Riparian vegetation provides insect food to river fishes.
Large riparian animals move significant amounts of nutrients from the forest to the water. For example, a single hippo can consume 135 kg of grass/day, transferring 9 metric tons of feces to water annually.

<u>Examples of the impact of the river on terrestrial ecosystems</u>
The river moves sediments and nutrients from the river onto the floodplain
The periodic flooding of the river onto the floodplain affects vegetational succession.
The river provides food and water for many terrestrial species.

Since hotspots of freshwater biodiversity in rivers are associated with habitat diversity (Thieme et al., 2003, in press), maintaining habitat diversity is a key conservation goal. This can be best achieved by protecting riparian forests and by maintaining populations of large animals (Fig. 1).

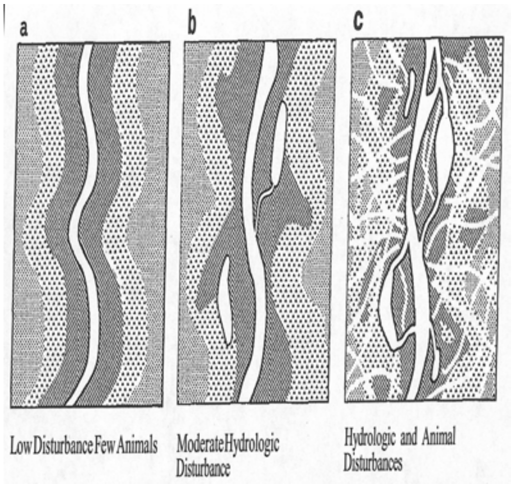


Figure 1. Republished with permission of R.J. Naiman and K. H. Rogers from Large animals and system-level characteristics in river corridors, Naiman, R.J. and K.H. Rogers, Bioscience Vol. 47. No. 8, pp. 521-529, ©1997; permission conveyed through Copyright Clearance Center, Inc.

Figure 1a shows that when a river corridor is artificially stabilized, there is limited interaction among the river and its riparian landscape, and diversity is low. When a corridor has intact riparian habitat, but few large animals (Fig. 1b), diversity modestly increases. But when large animals are abundant (Fig. 1c), they create numerous corridors between the water and the land, resulting in a much more heterogeneous landscape.

What do the larger animals do? By eating plants, dispersing seeds, and by their movements, larger animals (mammals, reptiles, birds) can change vegetative structure, modify channel morphology, biodiversity and help create microhabitats. They also modify function (productivity, connectivity and resilience) of river corridors.

In southern Africa, hippos are the main animals responsible for modifying the physical environment. In daytime, the hippos wallow in pools. Their movements create deeper pools along the banks, habitat for hippos, crocodiles, and larger fish. At night, hippos feed on terrestrial grasses. Their nightly foraging paths create corridors for other animals as well as new channels for water, which promote the movement of fish, amphibians, water and nutrients. Naiman and Rogers (1997) note that "The exclusion or removal of elephant and hippos from river corridors in Africa has led to pools filling with sediment, to the closure of riparian forest canopies and to altered species composition."

So how do you manage a riparian system? To maintain spatial heterogeneity and connectivity, Naiman and Rogers suggest allowing hippos freedom of movement. To maintain nutrient fluxes from land to the water, they suggest reintroducing hippos for terrestrial grazing, ensuring roosting sites for bats and birds; and maintaining viable populations of those large animals (e.g., kingfisher, heron) that consume aquatic animals and plants but defecate in terrestrial environments, or reverse.

9.3.2. Bushmeat

Our rapid survey of mammals was limited to observation. We did not encounter a single live mammal; all of the observations were of (dead) bushmeat. Although we must note that our survey was limited (we did not record the presence of mammal feces or set mammal traps), it is still of concern that no live mammals were recorded. WWF (Thaime et al., 2003, in press) highlights the threat to predators, large frugivorous birds, crocodiles, and primates for the Guinea-Congo region. They remark that 'large parts of Equatorial Guinea and Cameroon have become devoid of any wildlife larger than a blue duiker." Recent conservation reviews indicate a decline of rodents (Lidicker, 1989), bats (Mickleburgh et al., 1992, Hutson et al. 2001), and insectivores (Nicoll and Rathbun, 1990) throughout Africa (cited in Davies, 2002).

Bushmeat has traditionally been eaten, and formerly was sustainable. Today, however, bushmeat hunting is unsustainable in many parts, due to increasing human populations and the beginning of commercialized hunting for bushmeat to meet urban demand (Thaime et al., 2003, in press).

It is important to better understand the nature and extent of this threat, particularly in Bandundu (where habitat conversion is also occurring), and secondarily in Equateur province. This could be accomplished in two ways: 1) With a student, regularly recording the presence and type of bushmeat at the market. It would be helpful to know where the animal was killed, if possible.

The origin of smoked meat can be difficult, though, as it can travel a long distance to the market through various intermediaries. 2) Conducting a more thorough mammal and reptile survey for Bandundu. We need to have a better understanding of occurrence, distribution, and population status, particularly of hippos and crocodiles. As noted above, large animals are important for maintaining diversity along the riparian corridor. Naiman and Rogers (1997) claim that under natural conditions, the abundance of hippos should be on the order of one for every 10 ha.

9.3.3. Fish ecology

a. Habitats

Main biotopes of the Congo river include lower rapids, swamps, main river, flooded zones, streams, and marginal waters (Muzigwa et al., 1992). Marginal waters are defined as waters in the transition zone between open water and the flooded areas, including the banks.

Table 9, from Lowe-McConnell (1991) shows the trophic groups and preferred biotopes for different fish species in the Congo River. Generally, most of the Congolese fishes prefer a particular biotope. A number of these biotopes have distinct fish assemblages, including:

1) the littoral zone, divided into rocky shores, sandy beaches, marshy shores;
2) channels, creeks and oxbows, with shaded calm pools, little current, sand or mud bottoms rich in vegetable debris;
3) floating meadows, along banks; and
4) inundation zones. (Source: Mathes, 1962).

Table 9. Fish trophic groups and their preferred habitats. From Lowe-McConnell (1991). Reprinted with the permission of Cambridge University Press.

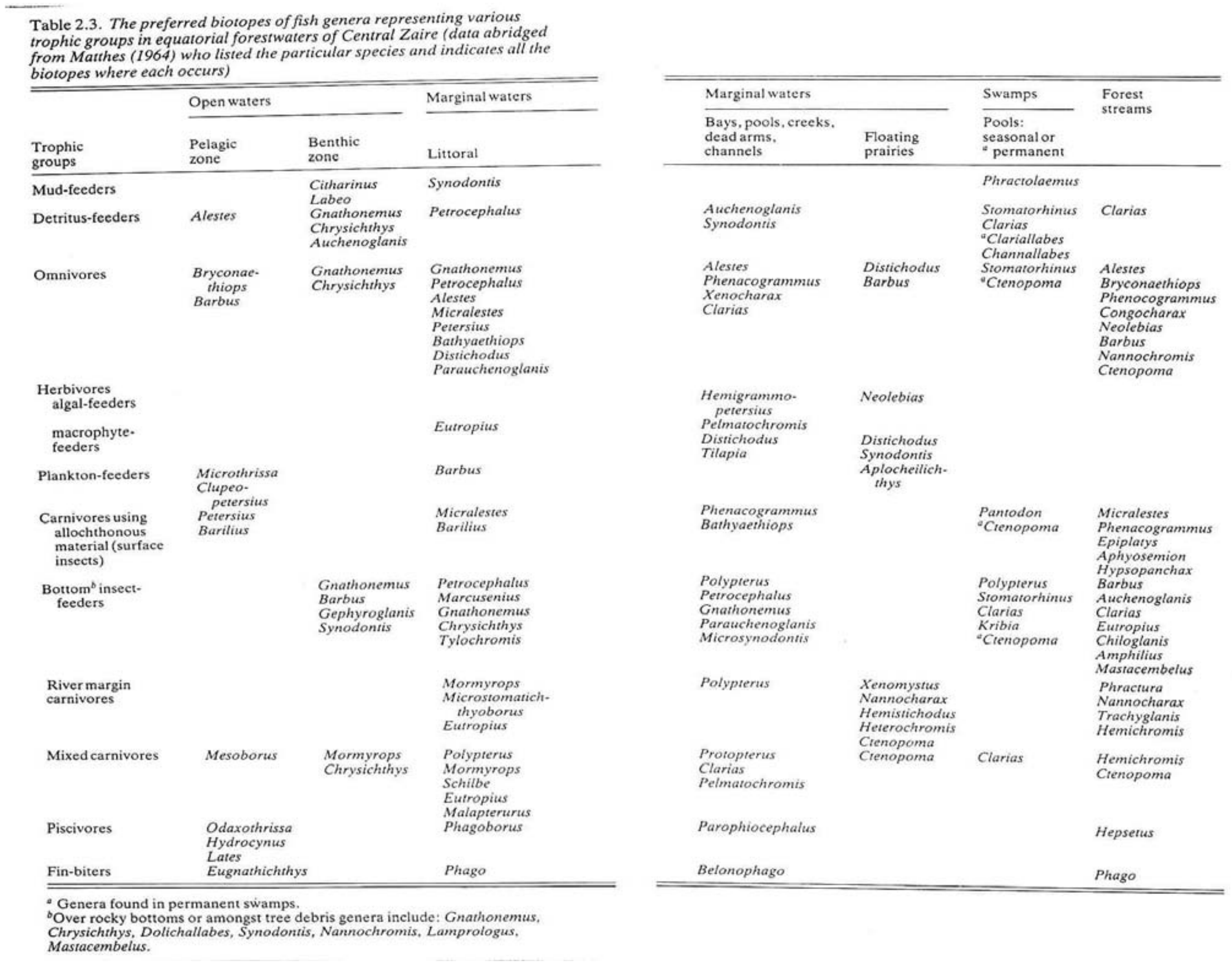


Table 2.3. *The preferred biotopes of fish genera representing various trophic groups in equatorial forestwaters of Central Zaire (data abridged from Matthes (1964) who listed the particular species and indicates all the biotopes where each occurs)*

	Open waters		Marginal waters			Swamps	Forest streams
Trophic groups	Pelagic zone	Benthic zone	Littoral	Bays, pools, creeks, dead arms, channels	Floating prairies	Pools: seasonal or [a] permanent	
Mud-feeders		*Citharinus* *Labeo*	*Synodontis*			*Phractolaemus*	
Detritus-feeders	*Alestes*	*Gnathonemus* *Chrysichthys* *Auchenoglanis*	*Petrocephalus*	*Auchenoglanis* *Synodontis*		*Stomatorhinus* *Clarias* [a]*Clariallabes* *Channallabes*	*Clarias*
Omnivores	*Bryconaethiops* *Barbus*	*Gnathonemus* *Chrysichthys*	*Gnathonemus* *Petrocephalus* *Alestes* *Micralestes* *Petersius* *Bathyaethiops* *Distichodus* *Parauchenoglanis*	*Alestes* *Phenacogrammus* *Xenocharax* *Clarias*	*Distichodus* *Barbus*	*Stomatorhinus* [a]*Ctenopoma*	*Alestes* *Bryconaethiops* *Phenocogrammus* *Congocharax* *Neolebias* *Barbus* *Nannochromis* *Ctenopoma*
Herbivores algal-feeders				*Hemigrammopetersius* *Pelmatochromis*	*Neolebias*		
macrophyte-feeders			*Eutropius*	*Distichodus* *Tilapia*	*Distichodus* *Synodontis* *Aplocheilichthys*		
Plankton-feeders	*Microthrissa* *Clupeopetersius*		*Barbus*				
Carnivores using allochthonous material (surface insects)	*Petersius* *Barilius*		*Micralestes* *Barilius*	*Phenacogrammus* *Bathyaethiops*		*Pantodon* [a]*Ctenopoma*	*Micralestes* *Phenacogrammus* *Epiplatys* *Aphyosemion* *Hypsopanchax*
Bottom[b] insect-feeders		*Gnathonemus* *Barbus* *Gephyroglanis* *Synodontis*	*Petrocephalus* *Marcusenius* *Gnathonemus* *Chrysichthys* *Tylochromis*	*Polypterus* *Petrocephalus* *Gnathonemus* *Parauchenoglanis* *Microsynodontis*		*Polypterus* *Stomatorhinus* *Clarias* *Kribia* [a]*Ctenopoma*	*Barbus* *Auchenoglanis* *Clarias* *Eutropius* *Chiloglanis* *Amphilius* *Mastacembelus*
River margin carnivores			*Mormyrops* *Microstomatichthyoborus* *Eutropius*	*Polypterus*	*Xenomystus* *Nannocharax* *Hemistichodus* *Heterochromis* *Ctenopoma*		*Phractura* *Nannocharax* *Trachyglanis* *Hemichromis*
Mixed carnivores	*Mesoborus*	*Mormyrops* *Chrysichthys*	*Polypterus* *Mormyrops* *Schilbe* *Eutropius* *Malapterurus*	*Protopterus* *Clarias* *Pelmatochromis*	*Ctenopoma*	*Clarias*	*Hemichromis* *Ctenopoma*
Piscivores	*Odaxothrissa* *Hydrocynus* *Lates*		*Phagoborus*	*Parophiocephalus*			*Hepsetus*
Fin-biters	*Eugnathichthys*		*Phago*	*Belonophago*			*Phago*

[a] Genera found in permanent swamps.

[b] Over rocky bottoms or amongst tree debris genera include: *Gnathonemus, Chrysichthys, Dolichallabes, Synodontis, Nannochromis, Lamprologus, Mastacembelus.*

The shallow waters along the river banks and islands have more fish than the open waters, for two reasons: the reduction of current and the presence of plants. Areas with slower currents have a more stable bottom and clearer water, enable greater development of planktonic and benthic plants and animals. Aquatic plants along the shores and islands, including water hyacinth, provide protection to young catfish, characids, and mormyrids. The plants and the macroinvertebrates by the plants provide food for the young and adults of many fish species. Fallen trees and submerged logs from riparian forests are an important habitat for certain species of labeo, nannocharax, and amphiliied catfish.

A rock bottom, such as found in numerous areas in Bas-Congo, provides a stable substrate, and often has high diversity (Classification of U.S. wetlands, 1979).

Certain genera are adapted for the low oxygen and varying water levels in swamps, including Polypterus, Protopterus, Papyrocranus, and Phractalaemus, among others.

b. Life cycle

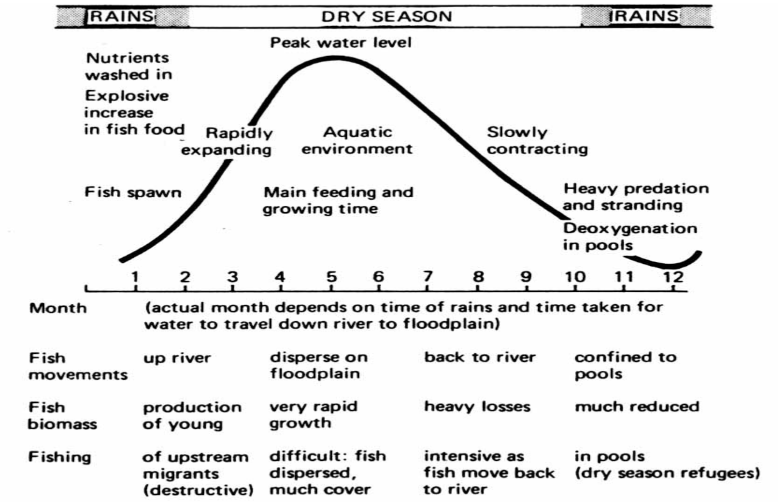
A key aspect of freshwater fish ecology to appreciate is that many riverine species move to different habitats during different parts of their lifecycle. For example, reproductively viable adults move to different habitats for spawning and feeding seasonally. The young start out in the protected habitat of flooded zones, moving into other areas as juveniles, and to the main part of the river as they mature. Some young fish end up isolated in forest pools as the water level falls. WWF notes, “In many cases, understanding the life histories of focal species is more important than charting the demographics of their populations,” (Thieme et al., 2003, in press). This is fortunate, since we know little about the demographics of most commercially important species!

c. Spawning

Riverine fishes generally breed at the beginning of the rainy season. The most important reproductive period for Congolese fishes is during the major rainy season (Sept.-Oct., in general), with a second, lesser breeding period during the rainy season in April-June. Fish are thought to be reproductively mature at 2 years (Lowe-McConnell, 1991).

Figure 10 shows the cycle of reproductive, feeding, and fishing events on a floodplain river (source: Lowe-McConnell, 1991). Note that the peak period for larval feeding and growing is during the peak water level, when water floods the forest. At this time, the water sparks a surge in microorganisms and aquatic vegetation, which leads to an increase in macroinvertebrates, a key fish food.

Fig. 10. Seasonality in a floodplain river. From Lowe-McConnell, 1991. Reprinted with the permission of Cambridge University Press.



Fish movements	up river	disperse on floodplain	back to river	confined to pools
Fish biomass	production of young	very rapid growth	heavy losses	much reduced
Fishing	of upstream migrants (destructive)	difficult: fish dispersed, much cover	intensive as fish move back to river	in pools (dry season refugees)

d. Food sources

Given the low productivity of the water, food sources for fish are limited. Sources include: 1) higher plants, including fruits and leaves; 2) aquatic and terrestrial insects; 3) detritus (mud or earth, including interstitial organisms, dead organic matter, and possibly bacteria.); and 4) other fishes (Roberts, 1972).

Biological production depends on the amount of food from the land, which is proportional to the amount of shore. This is why the health of the riverine forest and swamps is so critical to the productivity of the fisheries (FAO, 1996). Furthermore, this is also why riverine areas with islands have higher fish productivity than areas without. Roberts (1972) notes, ""In a given section of the middle Congo, fish productivity probably bears a strong relationship to the number and size of the islands present in it."

e. Water quality

Water quality changes seasonally. During flooding, water velocity and turbidity increase and water temperature decreases. In flooded forest areas, oxygen levels drop sharply and acidity increases as submerged forest vegetation rots.

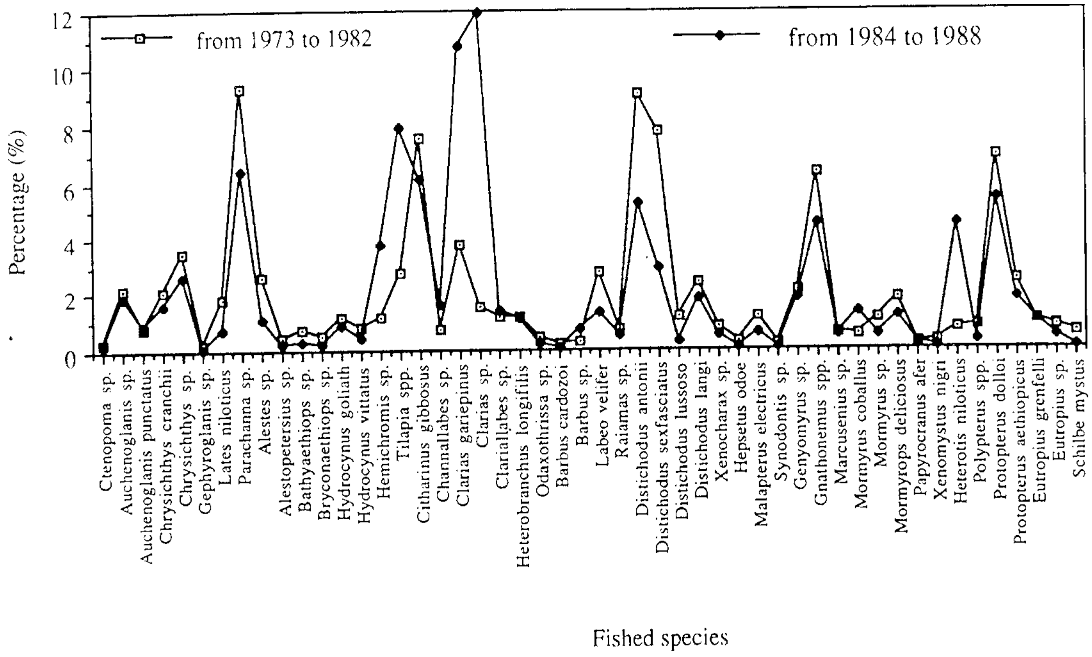
9.3.4. Fisheries

In 1984, the potential of the riverine fishery was estimated at 90,000-120,000 tonnes/yr. Current capture is roughly estimated at 45,000 tonnes, or half of the potential. A single fisher is estimated to produce 2 tonnes/fish/year. It is important to note that these are rough estimates only: true yields remain unknown at this point.

Fishermen use gill nets, seine nets, cast nets, handlines, and fish baskets. Environmentally unsound methods include: defoliating the banks, using poisons and herbicides, using illegally-sized nets smaller than 3 cm.

There have been some changes to the river over the last 50 years, caused by overfishing, species introductions, and probably deforestation. As shown in Fig. 11, the following species declined in the Kinshasa market between 1973 and 1988: *Parachanna spp.*, *Distichodontus spp.*, *Gnathonemus spp.*, and *Protopterus spp*. Two introduced species increased significantly: *Tilapia spp.* and *Heterotis niloticus*. There has been no documentation of how the extensive deforestation has affected species number, fish communities, or the hydrological cycle (e.g., level of precipitation, etc.). Given the ecological connections between the land and the water (see section 7.2.1.), however, deforestation must certainly have had an impact (Tuegels and Guegan, 1994).

Figure 11. Trends in fish species sold in the Kinshasa market (from 1973 to 1988). From Muzigwa et al., 1992. Reprinted with the permission of the European Aquaculture Society.



<u>Rare/threatened fish: </u>Muzigwa et al. (1992) report that the number of threatened and endangered fish stock has increased, with a decrease in diversity among the Bagridae, Characidae, Cyprinidae, and Distichontidae families. According to Fishbase, there are 5 threatened freshwater species in the DRC: *Caecobarbus geertsii* (Congo blind barb, found in Lower Congo River), *Opsaridium zambezense* (Barred minnow, found in lower tributaries of the river), *Sarotherodon galilaeus galilaeus*, (Mango tilapia, found in Central Congo), and *Urogymnus ukpam* (Thorny freshwater stingray, found in freshwater, brackish, and marine waters). COPPEQUA (2002) notes a reduction in Chrysichthyes in Equateur.

Fisheries management in the country suffers from the following problems: maximum sustainable yield (MSY) has never been determined, spawning grounds have not been determined, and enforcement of fisheries regulations is lacking (Muzigwa et al., 1992).

Although our rapid survey gave a snapshot of fish species in the regions and could not assess resource use or abundance, we conclude that overfishing is only a medium threat for Bandundu and Equateur (due to increasing populations in these areas), and a low threat for Inga (due to the difficulty in fishing at this site). We base our conclusion on the following:

1) **Diversity of fishes**: The markets are remarkably diverse, with a range of catfishes, electric fishes, perch, and cyprinids. The diversity of the markets ensures equal pressure on fishes throughout the food chain.
2) **Size of fishes**: We did not see serious signs of general overfishing, as indicated by the large size of market fishes. Generally, overfishing is first observed as a biomass shift in the fish populations of many species, with large individuals becoming more scarce.
3) **Illegally-sized nets.** We did observe illegally-sized nets, however, in every province.

In an unselective fisheries such as this, size and species composition of the catch are determined by the fishing area, fishing method, and season (FAO, 1995). To begin to quantitatively assess fishing pressure requires data on resource use, abundance, and seasonal changes in distribution. See section 7.3.4.1. for more details.

9.4. RECOMMENDATIONS

9.4.1. Ecological monitoring: Suggested ecosystem integrity indicators

Since each province has different threats, monitoring needs are also site-specific. The following table lists our recommended monitoring needs for each province. Given CREDP's limited financial and human resources, it may make sense to focus exclusively on the medium to high monitoring needs. This would mean, for example, that fish monitoring would not take place in Bas-Congo. On the other hand, this was one area where the Fishing Association appeared to be a strong and enthusiastic partner.

PROVINCE	THREATS (L, M, H)	MONITORING NEEDS (L,M, H, S (scientific value)
BANDUNDU	Bushmeat - M	Monitor riparian integrity (M)
	Logging/Agricultural expansion – M	
	Overfishing – M	Monitor fisheries resource use/abundance (M)
	Mining – L	Monitor water quality (L)
	Oil – L (future)	
BAS-CONGO	Dam-H (future)	
	Pollution – H	Monitor water quality (H)
	Overfishing – L	Monitor fisheries resource use/abundance (L)
EQUATEUR	Bushmeat – M	Monitor flooded forest integrity (S)
	Overfishing – M	Monitor fisheries resource use/abundance (L)

a. Participatory monitoring: The process

> *"One of the most important lessons learned by researchers is that participatory monitoring and evaluation can work most effectively when dealing with data which are of mutual importance and usefulness to researchers and (local stakeholders)."*
>
> Campilian, 1996, in Abbott and Guijt, 1998

A recent book, *Changing Views on Change* (Abott and Guijt, 1998) provides useful lessons for the participatory monitoring process:

1) Monitoring must provide benefit to all stakeholders, especially local people.
2) It is most useful if project personnel work with community members to reach consensus on the objectives, indicators, methods, and end-users of the monitoring information. Objectives must be clear. Indicators must be accurate and 'resonate' with local people.
3) Once monitoring has begun, we need to periodically evaluate its usefulness and the cost/benefit of the frequency of monitoring.

For this project, monitoring serves several purposes. For CREDP, monitoring is essential to document the project's progress, and to report the project's results to the development and scientific community. For local communities, monitoring enables communities to begin to learn about changes to their resources and ecosystem, and boosts their capacity for adaptive management. Given these dual needs, it would be useful to use both scientific indicators and indigenous indicators. Indigenous indicators have a number of advantages. If identified by the community, the information becomes more relevant and useful to the stakeholders for day-to-day decision making.

b. Monitoring fish resource use and abundance

See section 9.4.4b and c.

c. Monitoring riparian integrity

> *There are few approaches to assessing and monitoring plant and animal populations that are reliable and easy to understand and implement.*
>
> Abbott and Guijt, 1998

We have already noted the importance of riparian forest to freshwater integrity. They are considered keystone habitats, "whose removal or decline would have a disproportionate negative effect on the persistence of other species or ecological processes in the region." (Thieme et al., 2003, in press)

To accurately monitor ecosystem integrity would require monitoring over different seasons for several years. This is because we would need to begin to understand the natural variability in the system, as well as seasonal behavioral changes. Furthermore, the impact of species loss on ecosystem processes may take several years to be felt.

The most viable option to begin to monitor riparian integrity is determining the relative abundance of indicator species. For most freshwater species, we do not know minimum population sizes or habitat requirements (Thieme et al., 2003, in press). However, it is important to note that indicator species are unlikely to indicate the health of all animal groups. For example, small birds are not likely to be affected by large mammal hunting.

The indicator species should have most of the following biological characteristics (Thieme et al., 2003, in press). If populations of these species are in good condition, it is likely other less sensitive species are in good shape as well:

Largest member of feeding guild/large-bodied
Wide-ranging, space-demanding
Low reproductive rate
Specialized dietary or habitat requirements
Aggregate during part of life cycle
Adapted to particular flow regime, water level, flood cycle
Narrow temperature or water chemistry requirements
Sensitive to pollution
Migratory with specialized spawning sites
Population is small or declining
Population is threatened by exploitation

Scientifically, the two best indicators for monitoring riparian integrity, fish and birds, are described below. Note that there is currently no data on abundance of birds, fish, amphibians, reptiles, or mammals for the Congo (Etude Sur La Biodiversity Aquatique (Vertébrés) Rapport Intérimiare. (1996)

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d. Indicator species - fish

Fish are a useful group for monitoring. The condition of the fishery can provide an indirect measure of the condition of the riparian ecosystem. Fish assemblages have been shown to change with deforestation of the riparian forest (Lee et al., 2001); as such, this indicator may best promote an appreciation of the connectivity between the water and the land. "(Fish) are species-rich, capture methods are well-known, different species show different responses to pollution; they are economically valuable, nutritionally important, and appear to be good surrogates for other forms of freshwater biodiversity (such as shrimps, molluscs, and insects)" (World Bank, 1998).

We have three alternative approaches. I favor Number 2 for the reasons outlined below:
1) We could develop an Index of Biotic Integrity for the different sites. However, this would take considerable effort and time. The Index of Biotic Integrity (IBI) is a measure of fish assemblages that was developed in the 1980s to assess the biological quality of flowing water systems, using the fish community, in several areas of the United States. It has been applied world-wide. Its usefulness lies in its ability to distinguish between anthropogenic and natural disturbances. The IBI has documented significant species changes between streams with a 200 m riparian zone and more pristine sites (Lee et al., 2001); a trend toward species changes between streams with both a riparian buffer and a wooded upstream area and those without; and significant differences between streams near urban and agricultural land and those in more pristine sites (Diamond and Serveiss, 2001).

The (up to) 12 metrics essentially comprise 3 classes: metrics representing species richness; metrics representing trophic composition; and metrics on the population size and condition of individuals. For example, Schulz et al. (1999) used the following fish assemblage metrics for a comparison of Florida lakes: number of fish species, number of native fish species, number of alien species, number of piscivorous fish species, number of generalist fish species, number of invertivore species, number of species intolerant of increased turbidity or decreased oxygen, among others.

The IBI has now been adapted for two African rivers: the Okavango (Hay et al., 1996) and the Lower Ntem River, Cameroon (Toham and Teuguls, 1999). Toham and Teugels considered data from 30 non-impacted sites to develop a metrics of high biological integrity. These data were compared with deforested sites. There was close agreement between an index of environmental quality based on water and habitat quality and the IBI scores.

2) Alternatively, and simpler, we could create our own diversity index, monitoring species richness over time within a few families. For example, Gerald Allen created a coral reef diversity index for a Conservation International supported rapid biodiversity assessment, counting the number of species from just 6 families (Werner and Allen, 2000). He chose those particular families for the following reasons: 1) they were taxonomically well-documented; 2) they were among the most speciose; and 3) they represented more than 50% of observable species. If we applied Gerald Allen's approach here, we would focus on just keeping track of the number of

mormyrids, characids, distichodontids, mochokids, and bagrids at the market. The families chosen would vary from province to province.

3) A third alternative is to focus on those species most likely to be affected by loss of riparian forests. An examination of Table 1 shows that the feeding guild most likely to be affected are surface insect feeders. Surface insectivores found predominantly in swamps, littoral areas, and floating prairies are: *Micralestes*, *Bariulius*, *Pantodon*, and *Ctenopoma*. Surface insectivorous species found predominantly in forest streams include *Micralestes*, *Phenacogrammus*, *Epiplatys*, *Aphysosemion, and Hypsopanchax*. However, we would not be able to obtain this data at the market: only Ctenopoma is found in the market, comprising only a small percentage of the marketed fish. This approach would require either CREDP itself or the fishermen to actively catch these fish for monitoring purposes.

e. Indicator species - birds

Birds are the best known vertebrate group for forests. They make good indicators for monitoring environmental change, because they have been well-studied, are easily surveyed, are found across a range of habitats, and include both specialized and generalist species.

For Equateur, in particular, it would be worthwhile to begin to monitor birds of the flooded forest. There are three categories of forest birds: forest specialists, forest generalists, and birds often found in the forest, but not dependent upon it. For example, seed-eating birds (e.g. *Ploceidae* and *Estrildidae*) and frugivorous birds (e.g. *Pycnonotidae* and *Turdidae*) contribute by their feeding behavior to the dissemination of seeds and consequently to forest regeneration.Among these categories, different feeding guilds respond differently to environmental changes. The guilds for forest birds include:

Frugivore
Frugivore-insectivore
Insectivore
Seed eater
Seed eater-insectivore
Nectarivore – insectivore
Omnivore
Raptor

Possible indicator birds for various ecosystems include the following (Davies, 2002):

- Aquatic birds in the lowland forest: *Gypohierax angolensis* (falcon, observed in our survey) and *Podia senegalensis*.
- Aquatic birds feeding on fish and aquatic macroinvertebrates(i.e. All Alcedinidae, *Anhinga rufa*, *Phalacrocorax africanus*, *Gypohierax angolensis*, *Actophilornis africanus*, *Vanellus albiceps*, Tringa sp., *Rhaphidura sabini*);
- Birds characteristic of the savannah: *Actophilornis africanus*.(observed in our survey).
- Birds characteristic of swamps: *Rostralula lenghalensis*, *Himantopus himantopos*, *Pisobia minuta*, *Haplopterus spinosus*, *Haplopterus armatus*.
- Semi-aquatic birds living in islands and sandy banks (i.e. All *Ardeidae, Meropidae, Bucerotidae*, etc.).

I favor a relatively simple way to record relative abundance: a technique called “MacKinnon list” or “Fjeldsa’s method”. This is not a timed count. Essentially, within a spatially defined site, each team member records every bird seen and heard up to 20 birds. When 20 is reached, a new list is started. The advantage of this simple technique is that “relative abundances calculated this way correlate very strongly with measured derived from intensive point count observation” (Davies, 2002).

Another option for assessing relative abundance is timed species count. However, Earthwatch (Davies, 2002) states that it is not very useful for monitoring because one can’t sum up the guilds. Note that Earthwatch recommends combining observational efforts with mist netting, but more people are required for such an intensive effort.

f. Monitoring flooded forest integrity

Given the global importance of this rare ecosystem, CREDP could provide global conservation benefit by beginning an effort to better understand the ecology of flooded forests. Bird, fishes, and mammals should be surveyed.

g. Monitoring water quality

The water quality analyses that were conducted give a baseline ‘snapshot’ of the state of the water. Where needed (*especially* in Bas-Congo; of lesser importance in Bandundu), it is now necessary to measure water quality changes over time. In the U.S., volunteer water quality monitoring programs are often conducted monthly. Subsequent water testing should also include bacterial measurements, to help monitor the water for water-borne diseases.

Given the complexity of some of these measurements, monitoring is best overseen by the resident University of Kinshasa student, although fishermen would be welcome to participate in the tests. The student should regularly report to the community his/her findings.

9.4.2. Management: First step – mapping

An essential first step in managing these freshwater ecosystems is to map both the aquatic and terrestrial landscape. In particular, it is important to estimate the degree of alteration in the various regions. Unfortunately, according to a UN officer at Mbandaka, no bathymetric or satellite maps exist of the river at this point.

The most important elements to map are the fish spawning grounds and flooded zones.

Ideally, one would consider the historical features of the area. These give important clues as to which keystone species were important for the landscape, and help guide a management effort. For example, we know that hippos and crocodiles were common along the Kasai (WWF, 2003, in press; Mankoto, 2002), and were found along the main river channel in Equateur as well (Thaime et al., 2003, in press). We know that the terrestrial landscape has changed in Bas-Congo. Unfortunately, we don’t have historical records of most species abundance and distribution.

After maps have been created, the ecological status of the regions can be determined by the community. I have revised suggestions for assessment by WWF, which were based on a cold temperate stream, to what makes sense for the Congo River. The following percentages for each category are in parentheses:

1. Degree of alteration of catchment basin (20 %)
2. Water quality (20 %)
3. Effects of alien species (20 %)
4. Riparian modification (20 %)
5. Rate of habitat conversion (20 %)

Degree of alteration of catchment basin (i.e., associated landscape): Changes that affect aquatic systems, including increased sedimentation, pollutants, increased access to fishermen and loggers, and loss of habitat for species with both aquatic and terrestrial requirements, such as turtles and amphibians. Five categories of threat could be determined here (e.g., 81-100% of habitat altered), with a numerical ranking.

In general, studies find that the greater the size, connectivity, and dominance of forest patches, the better the water quality of aquatic habitats. So we could use % of catchment covered by forest as a measure here.

Water quality: Three levels of threat could be determined here.

Effects of alien species: This criterion estimates the level of degradation of aquatic ecosystem due to the introduction of alien species.

Riparian modification: This criterion describes the percentage of habitat loss due to destruction of riparian forests, agricultural conversion, intensive grazing, inadequate buffer zones in logged areas (e.g., < 225 m on either side), road building, etc.

Rate of habitat conversion: This criterion estimates the percentage rate of change in physical and chemical parameters of habitats within an ecoregion. Perhaps a good proxy for this estimate is the rate of population growth for the different regions.

After determination of these categories, a ranking of the different areas can be assigned (stable, relatively stable, vulnerable, threatened). A threatened ranking considers that most habitat clusters will be eliminated in the next 15-20 years. A vulnerable ranking considers that many intact habitat clusters will remain for this period, but sensitive or exploited species (top-level predators) have already declined or been extirpated from the region. A relatively stable ranking considers that declines in exploited populations and disruption of ecosystem processes have a local effect only. Sensitive species are present, but at densities below the natural range of variation.

After the mapping exercise is completed, it may be necessary to monitor highly degraded areas for erosion, increased siltation, and turbidity of the surrounding waters. Increased siltation can affect the light levels, chemistry and temperature of the waters, which negatively affects aquatic species.

9.4.3. Further surveys

Two regions would benefit from additional surveys:
1) Bandundu, for a seasonal survey of mammals, particularly large mammals. Surveys across different seasons are the only way to obtain an accurate assessment of species abundance in a given area. In addition, crocodiles should be better surveyed. Large predators such as crocodiles play an important role in maintaining the health of the ecosystem. Both crocodiles and hippos contribute to nutrient cycling.

2) **Equateur** – to seasonally survey the birds, mammals, and fishes of the flooded forest. Little is known about flooded forest ecology, and CREDP has the opportunity to provide this information for such a globally rare habitat. Note that this has been determined a research priority by the recent WWF meeting on the Guinea-Congo forest basin.

The blue duiker (the most commonly seen encountered ungulate in the day) may be a useful indicator for bushmeat hunting. These animals rapidly reproduce, but their populations are often low or absent from forested areas near large human settlements and roads.

Dung counts along a transect may be the simplest option available for a more systematic mammal survey, since dung is the most frequently encountered sign of many larger forest mammals (who have lower population densities than smaller mammals), and the measure can be obtained during the day. This measure can provide an estimate of relative abundance (Davies, 2002). However, to obtain abundance from this measure, one needs to calculate the length of time it takes the dung to disappear (dung decay rate) and know the number of dung piles produced per animal per day (defecation rate). Note that it is difficult to identify dung to species level. Other options for surveying mammals include net drives and a systematic transect walk, just observing animals at this time. For the transect walk to provide useful information, however, it would be best to conduct the walk at night: most mammals are nocturnal.

Alternatively, Abbott and Guijt (1998) report a survey effort in Zambia that used local hunters to count the number of animals observed as a function of time in the field. They cite the advantages as: boosting capacity of local hunters to collect data and analyse change, and allowing frequent assessment of both the smaller as well as larger animals.

9.4.4. Fisheries recommendations

1) *Support a net exchange program*, swapping illegal nets for legal ones. At all sites, we observed illegal net sizes. A Kinshasa-based fisheries officer confirms that the greatest problem is illegal net sizes. Existing fisheries regulations should be provided to all fisheries associations.

2) *Map key spawning areas* (a recommendation of the CREDP Biodiversity Commission, 2nd meeting, 2002), *fishing grounds, and seasonally inundated areas*. Landsat photos can help us define seasonally inundated zones.

3) Begin to monitor resource use (fishing effort) and abundance, with the Fishing

Associations and students. As noted, our rapid biodiversity survey identified species but could not determine abundance, resource use, or location of fishing for those species obtained at the market. At this point, we do not know how far the fishermen travel to fish. We must know this. Suggestions for monitoring are provided below.

4) *Support small grant proposals from the local Fishing Association to improve their fishing materials, contingent on their agreement to undertake monitoring.*

a. Participatory monitoring options leading to adaptive management.

We lack basic fisheries, physical, biological, and statistical information to provide estimates of production and maximum sustainable yield. We don't know about growth rates or have information about specific breeding locations for economically important fishes. Such information provides the basis for management.

For a simple capture fishery, data on effort, catch, length, species composition, and location of fishing is enough (FAO, 1997). In other words, we should map important fishing areas, monitoring resource use (fishing effort), and determine abundance. Armed with this information, the Fishing Associations will have sufficient data to begin adaptive management of these multi-species fisheries.

b. Monitoring resource use (fishing effort)

Currently, the riverine fisheries are not managed. We need to begin the process by which the Fishing Associations feel empowered to oversee the stewardship of their own resources. How? We must provide them with opportunities to identify local problems and take action themselves. We need to make clear to the fishermen that obtaining this data is a necessary condition for receiving inputs of fishing materials, and that the purpose of collecting such data is for them to be able to manage their resources in perpetuity. The data will not be used against them. However, where there is good will between fishers and government fisheries personnel, it would be helpful to involve the latter in this effort.

We suggest a workshop at each site, where fishermen identify the best measures to monitor resource use for their region. The workshop would focus on problem analysis, presentation of options, planning, and decision-making. In this way, the fishing associations can boost their skills and confidence as researchers, policy-makers, and as planners. There is precedence for this approach in the Indonesian Farmer Field Schools (see **www.communityipm.org**).

The fishermen should first brainstorm possible indicators of effort themselves, a first step in assessing resource use. If this doesn't happen, I have provided a range of options for determining effort. Most of the suggestions below have been selected among a list provided by the Ad Hoc Consultation on the Role of Regional fishery Agencies in Relation to High Seas Fishery Statistics (1993). Ideally, such measures would be monthly, to begin to acquire data on seasonal changes.

In my opinion, the two best measures would be measuring the number of fishing vessels/site and number of days fished/month, but the fishermen should determine the most workable measure for themselves.

1. Number of fishing vessels/site. Note: Generally, a fishing vessel contains 2 fishers.
2. Number of days fished: the number of days (24-hour period) in which any fishing took place.
3. Number of trips made: Any voyage during which fishing took place in only one fishing area is to be counted as one trip. If more than one site is visited, apportion appropriate fraction of the trip time to it.

Gillnets: Number of effort units: length of nets expressed in 100 meter units times the number of times the net was used (cleared)

Seines: Number of sets; Number of times the gear has been set, whether or not a catch was made.

Longlines: Number of hooks fished in a given time period.

c. Monitoring abundance

Generally, men fish, and the women sell the fish. To incorporate other key community members in the CREDP effort, we recommend that a University of Kinshasa student monitor abundance of commercially important species, length (or weight), and species composition at the market. As much as possible, the student should try to engage resident women in his/her effort.

As with monitoring resource abundance, it would be best if the women themselves attend a workshop to determine the best measure for monitoring and frequency of monitoring. Because the fish move throughout their life cycle, and seasonally, ideally, such measures would be bimonthly, or at least monthly. This lets us begin to acquire data on seasonal changes. I have provided a range of options below.

In my opinion, the best measure is number of fish longer than from their elbow to the end of their hand (or number of fish over 3 kg), but the women should determine the most workable measure themselves. Length estimates are a useful measure for monitoring fishing pressure.

1) Number of live fish baskets/seller.
2) Total number of live fish baskets in the market.
3) Number of women with fresh fish.
4) Number of fish over 3 kg, or longer than, say from their elbow to the end of their hand. (The student could measure the actual length of each seller.)

The student would be tasked with determining species composition of the catch, by photographing the different species at the market. Each region would begin to accumulate a notebook of photographs of their fish, which should help generate pride and a sense of ownership in the local species. Note that Dr. Paul Butler of the NGO Rare has had tremendous success instilling pride in local species in his work throughout the Caribbean and Southeast Asia. The photographs would be used to complete our local fish field guide.

The matrix below summarizes the recommendations to date, with the recommended personnel noted:

Task	IRM	Fishers	Women sellers	Students	ERGS
Map spawning grounds and flooded areas	X	X			
Workshop on monitoring	X	X		X	
Monitor resource use	X				
Monitor abundance			X		
Identify market species				X	
Analyze resource practices				X	
Water quality					X

d. Management

Managing multi-species artisanal fisheries is more difficult than managing a single species fishery, and requires creative thinking about the best ways to ensure a sustainable yield. As an aside, many countries find it socially and practically difficult to regulate fishing effort in the artisanal industry. I think it can be done, with community management and/or co-management. Fishers can undertake data collection, policing and record-keeping functions, and empowered through legal and protected rights to carry out this function. Fishers can and should also be part of the policy-making process.

To design effect management strategies, the Fishing Associations must agree on the management objectives, subsequent management actions, and how they will assess their management performance. A discussion of this sort should wait, however, until a full year of monitoring has been achieved.

Generally, regulations fall into closing areas, closing seasons, gear prohibitions, gear restrictions (e.g., limiting mesh size), length at first capture, number of fishes, and quotas/licensing. (FAO, 1996). The following management measures have previously been recommended for the Congo River (Muzigwa et al. (1992): 1) closing spawning grounds during peak flooding periods (most critical: Nov – Feb.); and 2) prohibiting gill nets with specific mesh sizes in marginal waters during high water levels to protect early stage fingerlings.

9.4.5. Other (future) development options

a. Pet trade

Resurrecting the pet trade, and ensuring that it is sustainable, is most viable for Bandundu. The New England Aquarium has years of experience in establishing a sustainable pet trade (tetras) in the Amazon. Potential partners that could assist with the issues of collecting the fish and transporting the fish to Kinshasa include: SAQUA (an NGO established for the pet trade) and COPADEM (a development NGO located in Mushi). COPADEM has a boat.

According to a recent biodiversity study (Etude Sur La Biodiversity Aquatique,1996), a number of Congolese fish have been prized in the pet trade, including: *Gnathonemus leopoldianus*; *Pheacogrammus sp.*; *Distichodus fasciolatus*; *Teleogramma gracile*; *Lamprologus mocquardii*; *Serranochromis gibbiceps*; *Steatocranus gibbiceps*; *Tutropius sp.*; *Polypterus ethipicus*; *Leptotilapia rouxi*; *Leptotilapia tinanti*; *Pantodon bucholzi*; *Barbus tropidolepsis*; *Barbus holotaenia*; *Lamprichthys sp.*; and *Hemichromis bimaculatus*. We directly observed a number of other species of potential interest for the trade, including: *Synodontis flavitaeniatus, Atheiomasta cembelus sp.*, *Nannochromis sp. kasai*, and *Polypterus ornatippinus*.

There are a number of issues that would need to be resolved, however, before a pet trade could be reestablished, including: certifying that the fish collecting method is sustainable and providing continual monitoring to ensure that it remains sustainable; ensuring a steady supply of fish and a reliable air transport system, creating holding facilities with tanks to prepare fish for the long journey (e.g., ensuring that they are not fed one day before to minimize ammonia release into the bag, checking for disease);. This development option may be best suited for the next phase of CREDP, depending on the remaining budget.

b. Sport fishing

In general, tourism cannot be recommended as a development option for these regions, given the logistical travel difficulties, cost, lack of tourist facilities, and immigration problems. However, one sector that is promising and lucrative for the future is sport fishing. Anglers would pay well to have the opportunity to catch the large fish in the river, surrounded by the beautiful landscape. The most viable option would be to offer a guided trip on a boat leaving from Kinshasa. Room and board would need to be offered on the boat, with the exception of some eating opportunities in the larger villages.

c. White-water rafting or innertubing

A possible tourism option for Bas-Congo only is providing an opportunity for white-water rafting or innertubing. This option has the advantage of providing a monetary incentive to preserve at least some of the rapids – considered by WWF (Thieme et al, 2003, in press) to be of the highest conservation importance due to the rapids providing unique habitat for numerous endemic fishes.

9.5. CAPACITY BUILDING

This survey raised capacity in a variety of ways. All of the Biodiversity Survey team members learned how other vertebrate experts collected their data. We brought new techniques to the area, showing the amphibian expert and the bird expert how to record vocal observations on tape. We showed interested villagers and fishers how and why we collected water quality data; we showed them how we identified fish. We presented the results to each village, and in the process, helped build a sense of pride in the river's extraordinary biodiversity.

Capacity building efforts are only just beginning for local residents. *CREDP will have made a significant input in building capacity if local stakeholders develop appropriate indicators for monitoring, and begin monitoring of their riverine ecosystem.*

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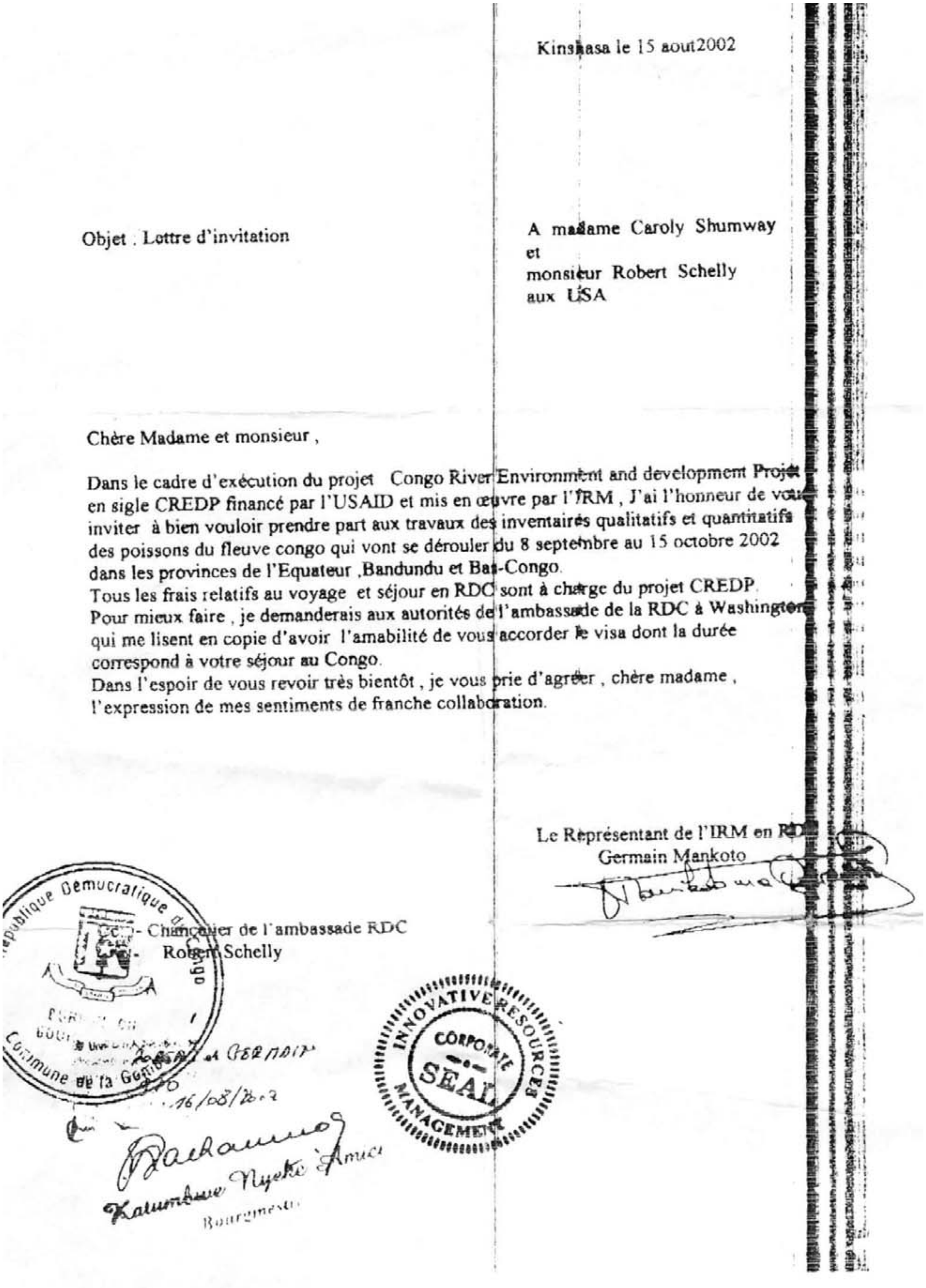
11. APPENDIX

a. LETTER OF INVITATION



Kinshasa le 15 aout2002

Objet . Lettre d'invitation

A madame Caroly Shumway
et
monsieur Robert Schelly
aux USA

Chère Madame et monsieur ,

Dans le cadre d'exécution du projet Congo River Environment and development Projet en sigle CREDP financé par l'USAID et mis en œuvre par l'IRM , J'ai l'honneur de vou inviter à bien vouloir prendre part aux travaux des inventaires qualitatifs et quantitatifs des poissons du fleuve congo qui vont se dérouler du 8 septembre au 15 octobre 2002 dans les provinces de l'Equateur ,Bandundu et Bas-Congo.
Tous les frais relatifs au voyage et séjour en RDC sont à charge du projet CREDP.
Pour mieux faire , je demanderais aux autorités de l'ambassade de la RDC à Washington qui me lisent en copie d'avoir l'amabilité de vous accorder le visa dont la durée correspond à votre séjour au Congo.
Dans l'espoir de vous revoir très bientôt , je vous prie d'agréer , chère madame , l'expression de mes sentiments de franche collaboration.

Le Représentant de l'IRM en RD
Germain Mankoto

CC : - Chancelier de l'ambassade RDC
- Robert Schelly

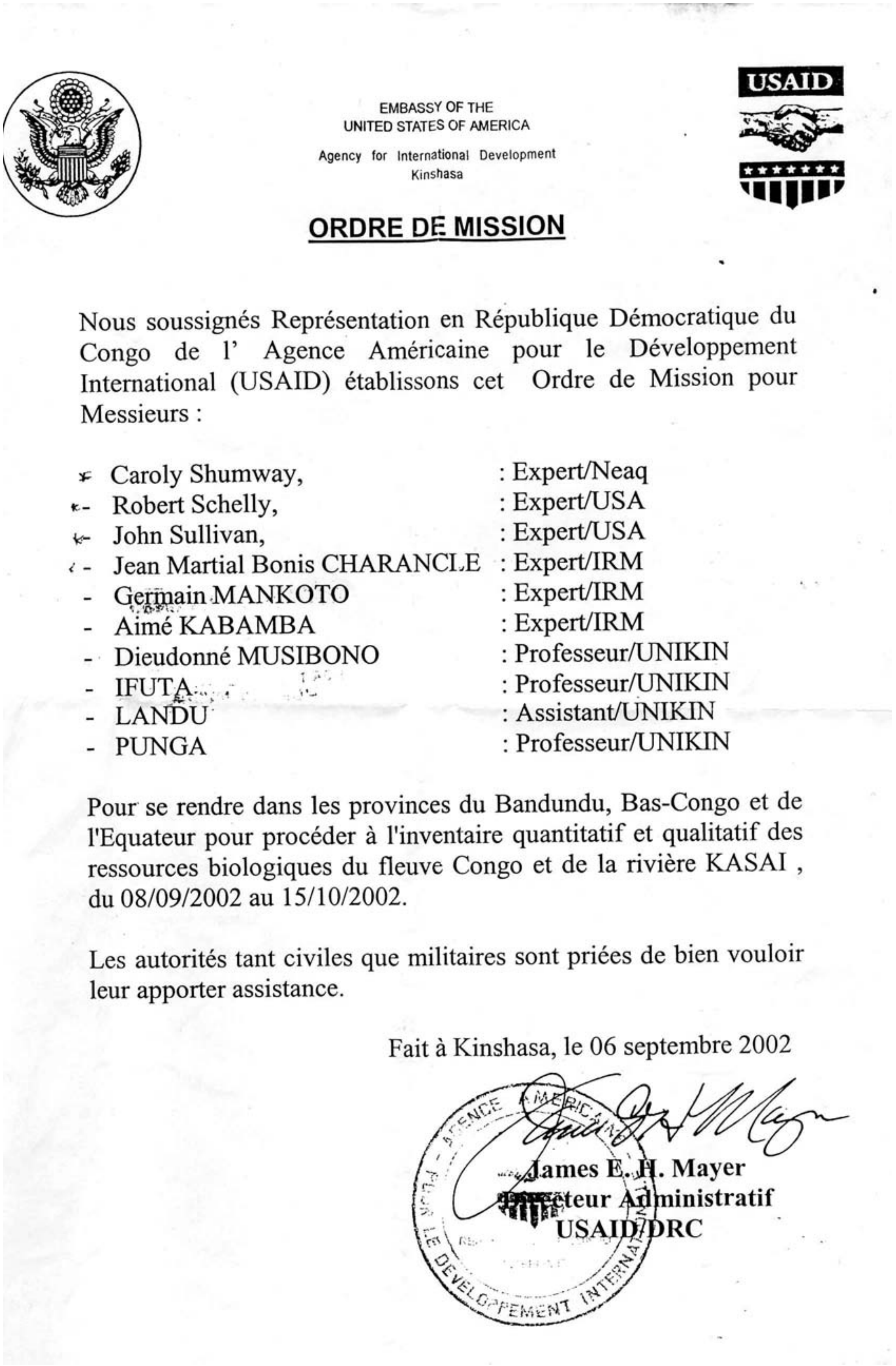
et GERMAIN

16/08/2002

Kalumbwe Nyeke Amici
Bourgmestre

INNOVATIVE RESOURCES MANAGEMENT
CORPORATE SEAL

b. ORDER OF MISSION



EMBASSY OF THE
UNITED STATES OF AMERICA
Agency for International Development
Kinshasa

USAID

ORDRE DE MISSION

Nous soussignés Représentation en République Démocratique du Congo de l' Agence Américaine pour le Développement International (USAID) établissons cet Ordre de Mission pour Messieurs :

- Caroly Shumway, : Expert/Neaq
- Robert Schelly, : Expert/USA
- John Sullivan, : Expert/USA
- Jean Martial Bonis CHARANCLE : Expert/IRM
- Germain MANKOTO : Expert/IRM
- Aimé KABAMBA : Expert/IRM
- Dieudonné MUSIBONO : Professeur/UNIKIN
- IFUTA : Professeur/UNIKIN
- LANDU : Assistant/UNIKIN
- PUNGA : Professeur/UNIKIN

Pour se rendre dans les provinces du Bandundu, Bas-Congo et de l'Equateur pour procéder à l'inventaire quantitatif et qualitatif des ressources biologiques du fleuve Congo et de la rivière KASAI , du 08/09/2002 au 15/10/2002.

Les autorités tant civiles que militaires sont priées de bien vouloir leur apporter assistance.

Fait à Kinshasa, le 06 septembre 2002

James E. H. Mayer
Directeur Administratif
USAID/DRC

c. TRIP ITINERARY

Sunday, Sept. 8 - Caroly (NEAq), Bob Schelly (AMNH) left for Kinshasa; arrived Sept. 9. Met at airport by Germain Mankoto, facilitator of IRM.

M-Wed. Sept. 10-14 - Prepared for survey, buying research and camping supplies, and meeting with our partners, researchers from the University of Kinshasa (3 days).

Wed. Sept. 11 - Dr. John Sullivan arrived from Gabon, via Air Gabon at 4:15 pm, flight #170. Met at airport by Germain Mankoto.

Thurs. Sept. 12 – Bought food, changed money, packed for first trip.

TRIP 1: Bandundu

Fri. Sept. 13 – Flew to **Bandundu** (on Kasai river). Obtained permits. Met with Governor of the province, and are interviewed on national television. The Governor is very enthusiastic about the project. He would like to see staff in the Department of Rural Development trained in survey techniques. *Overnight in Bandundu.*Briefly visited fish market; briefly met with NGO called PERILAC.

Sat. Sept. 14 - Boat to Mushie (time: 3 hours by motorized pirogue)**,** took some water quality measurements on the way. Stopped in Bokoni and briefly met with chief of the fishing village. Based in Mushie *(at the mission)*, organized team and process for the next two days.

Sun. Sept. 15 - Met with Roger Iziza Pembe (aka Coko), President of the NGO called COPADEM. Great potential partner. Surveyed. Set two gill nets in front of the town, on the other side of the bank. Took water quality samples at 4 sites on river; 2 sandy wetland areas, one in the center of the Fimi River, one by the banks of the town Mushie. Set macroinvertebrate nets. Obtained fish from fishermen.

Mon. Sept. 16 - Gill net stolen. Obtained fish from fishermen. Reported to Mushie fishermen on results. Boat to Bokoni. Surveyed along the way. Based in Bokoni *(camping).*

Tues. Sept. 17 - Met with fishermen and chief. Began survey, setting two gill nets next to wetland island. Two fishermen from Bokoni helped us. Bought fish from fishermen in Lome fishing village. Returned to Lome with seine and cast nets. Water quality measurements taken at 4 sites. Mist net set up for birds on one side of town.

Wed. Sept. 18 - Surveyed. Fish team went with fishermen to use cast nets by Bokoni, also used cast nets by wetland island. I and Seraphin talked with an old fishermen and the chief of the fishing village to get the names of fish in Lingala and Kokongo. Germain talked with indigenous chief of the land about the project. In the afternoon, we went back to Lome village, and went with a fisherman to see gill nets in the water. The size of the gill nets are illegal. Mist net repositioned to forest on other side of Bokoni.

Thurs. Sept. 19 - Surveyed. Reported to Bokoni fishermen and villagers on results. Packed supplies and samples. Boat from Bokoni back to Bandundu. (Time: 1 ½ hours). Overnight in Bandundu. Met with governor of province again.

Fri., Sept. 20- Flight did not show up. Stranded one extra day in Bandundu. Team summarized results. Met with the NGO SAQUA and PERILAC (same people). SAQUA brought diverse fish, several of interest for the pet trade for us to see. We bought some fish samples.

Sat., Sept. 21- Flew (return) to **Kinshasa (one hour)**. *Overnight in Kinshasa.*

Sun. Sept. 22- Overnight in Kinshasa.

TRIP 2: Bas-Congo

Mon. Sept. 23 - Flew to **Matadi, Bas Congo (one hour).** We were greeted by two of our partners here, Mr. Auguste of the NGO called CNVT (Comite National des Volontaires au Travail), and the Director of Agriculture, Fisheries, and Aquaculture. Together, we met the vice-governor of the province, Mr. Maboti. Rented 2 cars, and drove to Inga (45 minutes). Based in Inga *at SNEL houses.*

Tues. Sept. 24 - Met with 8 fishermen of the fisheries association. Determined sites to visit. Began survey, starting at Inga #1, aka Tank (reservoir). Visited fish market; saw synodontids, schilbeids, campylomormyrus. Surveyed Nziya.

Wed. Sept. 25- Surveyed. At 6 am, went to Inga #1 to meet fishermen. Surveyed Shongo (rapids).

Surveyed Fwamalo. Returned to Shongo to get water quality data.

Thurs., Sept. 26- Surveyed Point 50. Seraphin met with the fishermen to add Lingala and Kikongo names to the fish guide. In afternoon, I viewed two potential agricultural projects with Aime and Sylvain (SNEL). I visit two agricultural sites with Aime

and Sylvain, who works for SNEL. These are SNEL projects. One is an existing small garden, with tomatoes, lettuce, parsely, onion, and other vegetables. The other is a 60 hectare area of land that Sylvain envisions could be used for agriculture.
We had dinner with the Chief of SNEL.
Fri., Sept. 27- I and Bob went with President of Fishing Association back to Nziya; John went to fish market; Julien retrieved macroinvertebrate nets; rest worked on report. We reported to the fishermen and villagers on our results. We also presented our results to the Chief of the city and chief of SNEL. Drove to Matadi. *Overnight in Matadi.*Part of team met with the Governor of the Province.
Sat., Sept. 28- All of the team met with the Governor of the Province, presented our results, are interviewed on national television. Flew to Kinshasa. *Overnight in Kinshasa.*
Sun., Sept. 29- Overnight in Kinshasa. Bought supplies, worked on report.
Mon., Sept. 30- Overnight in Kinshasa. Bought supplies, worked on report.
Tues., Oct. 1- Overnight in Kinshasa. Worked on report.
Wed. Oct. 2 – Overnight in Kinshasa. Worked on trip expenses, budget, and report.
Thurs. Oct. 3 – Overnight in Kinshasa. Worked on report. Bob and John went to the Univ. of Kinshasa to process fish. Visited cultural market; saw tens of cages of African gray parrots for sale.
Friday Oct. 4 – Overnight in Kinshasa. Bought supplies, worked on report. Made copy of Poll and Gosse book for Univ. of Kinshasa.

TRIP 3: Equateur
Sat. Oct. 5 - Flew to **Mbandaka, Equateur.** Drove to Mission. Walked to town to: 1) begin immigration formalities and 2) meet with MONUC's Eve Gillian to check on details for MONUC flight; and 3) arrange rental of motorized pirogues for trip to Gombe.
Sun. Oct. 6- Caroly, Jean-Martial and Germain meet with Governor. Germain and Jean-Martial pursue pirogues and continue immigration formalities. Rest of team works on report. Bob, John, and rest of team went to fish market. In the afternoon, rent car to sample water, fish, and other animals next to the village, Bodjia. Meet Fulgence Ndombe, chief of pecheurs. Report to fishermen and villagers on results. Boat back to Mbandaka. Base in Mbandaka (*hotel*).
Mon. Oct. 7- Leave Mbandaka in pirogues for Gombe, 5 hours away. Weather turns to rain, and we make an emergency stop at the village Oenji, 1 hour south of Mbandaka.
Tues. Oct. 8 – Continue to Gombe (100 kms away). Two immigration stops on the way. Visit fish market in the morning at Maita. See large dead monkey and 6 small dead monkeys (bushmeat) at the market. Also live, soft-shelled turtle. Boat to Gombe (5 hours). Base in Gombe at the Chef du Secteur's yard, in tents. Gear is in closed building. Meet with Chef du Secteur and fishermen to plan out following day.
Wed., Oct. 9 – Only 1 day in Gombe, so to be most efficient, team splits into 4 groups: 1) John and Seraphin take a pirogue to the confluence of the Ubangi and Congo River. Their boat breaks down en route, so they don't get completely to the confluence. 2) Water quality team take a pirogue to sample water at Irebu and the confluence. 3) Caroly and Bob take a pirogue to Irebu. 4) Jean-Martial and Germain meet with fishermen all day at Gombe to discuss goals, perspectives on their resources, and small grant. We try to leave by 8 am, but fishermen did not arrange motor or pirogues for all teams, so first team left at 10:30; last at 12:30.
Thurs. Oct. 10 - Report to fishermen and villagers on results. eave for Mbandaka. Take water quality samples en route, midway between Mbandaka and Gombe.Try to leave via MONUC, but it has not been arranged.
Friday, Oct. 11 – Jean-Martial, Germain and I try to visit the Governor to report on our trip, but he is not at work due to the rain. Work on small grant with Dieudonné and Jean-Martial. Jean-Martial and Germain try to meet with Action Contre la Faim. Rest of team visits small botanical garden.
Sat. Oct. 12 – Visit fish market in the morning. Fly back to Kinshasa. Pack. *Overnight in Kinshasa.*
Sun., Oct. 13- John Sullivan returns to Libreville. Caroly, Bob, Jean-Martial, and Victor Puemba process fish for transport at the Univ. of Kinshasa. Caroly (NEAq) and Bob Schelly (Cornell) return to U.S.
CREDP team in Kinshasa reports on results to Min. of Fisheries, Development, Conservation, and others.

d. SAMPLE OF WATER TEAM DATA SHEET

CREDP Biodiversity Survey-Water Team **New England Aquarium**

Field/Input Sheet –Collection Data **Partners: ERGS, AMNH, Cornell Univ.**

A. Collection Numbers **1. STATION/FIELD NO**. □□□□ **2. ACCESSION NO**. □□□ **3A. UPDATE** Δ **3B. DELETE** Δ

B. Geographical Data

4. PROVINCE ______________________ 5. COUNTY________________________

6. LOCALITY____

6A. WATER BODY 6B. LOCALITY DESCRIPTION

____

7. LATITUDE 7A. □□ □□ □□ N 7B. □□ □□ □□ W TO 7C. □□ □□ □□ N 7D. □□ □□ □□W
&LONGITUDE LAT. S LONG. E LAT. S LONG E

8E. ALTITUDE □□□ METERS **9. LOCATION ACCURACY**: (TICK ONE) ± 1. < 10 KM Δ 2. < 20 KM Δ 3. < 40 KM Δ 4. < 200 KM Δ 5. > 200 KM Δ 6. DATA UNCERTAIN Δ

C. Temporal Data **WEATHER**____________________________

10. DATE: □□ □□ □□□□ **11. TIME COLLECTION STARTED** □□□□ **12. DURATION** □□.□ HRS
Day Month Year (Military time)

D. Ecological Data

13. WATER QUALITY: (TICK 1-2) 1. CLEAR & COLORLESS Δ 2. CLEAR & BROWN TINGED Δ 3. BLACK Δ 4. CLOUDY Δ 5. MUDDY Δ 6. POLLUTED Δ 7. OTHER _________________ **14A. WATER DEPTH:** MAX: □□□□ CM / M **14B**. MIN: □□□□ CM / M OR N/A Δ

15. CURRENT (TICK 1-2) 1. STILL Δ 2. SLOW Δ 3. MED Δ 4.FAST Δ **16. SECCHI DISK READING** □□.□ M

17. WATER TEMPERATURE □□.□□ °C **18. CONDUCTIVITY** □□ **19. pH** □□.□ **20. DISSOLVED SOLIDS** □□□□ ppm **21. KH** □□□ **22. gH** □□□ **23. PO_4** □□□ **24. NO_3** □□□ **25. OXYGEN** □□.□ ML/L

26. STREAM/LAKE/POOL WIDTH □□□.□ M / KM **27. LAKE/POOL LENGTH** □□□.□ M / KM

28A. DISTANCE OFFSHORE: MIN □□□□ M / KM **28B**. MAX □□□□ M / KM

29. PLANT TYPE (TICK 1-3) 1. ENCRUSTING Δ 2. FOLIOSE Δ 3. SUBMERGENT Δ 4.FLOATING Δ 5. EMERGENT Δ 6. SHORE FORESTED Δ 7. SHORE BUSHY Δ 8. SHORE BARREN OR GRASSY Δ 9. NONE Δ

30. PLANT KIND (NAME 1-2 MAIN KINDS) ____

31. PLANT AMOUNT (TICK ONE) 1. NONE Δ 2. SOME Δ 3. MODERATE Δ 4. MUCH Δ

32. BOTTOM (TICK 1-2) 1. BEDROCK Δ 2. BOULDERS Δ 3. STONES Δ 4. GRAVEL Δ 5. PEBBLES Δ 6. SAND Δ 7. MUD Δ 8. CLAY Δ 9. DETRITUS Δ 10. LOGS/BRANCHES Δ 11. OTHER ______________________

33. BOTTOM COVER (TICK 1) 1. NONE Δ 2. SOME Δ 3. MODERATE Δ 4. MUCH Δ

E. Capture Data

34A. GEAR (TICK 1-2) 1. SEINE Δ 2. EXPER. GILL NET Δ 3. BOTTOM TRAWL Δ 4. CAST NET Δ 5. DIP NET Δ 6. BAITED HOOK & LINE Δ 7. LURE & LINE Δ 8. LARGE TRAP Δ 9. NIGHT LIGHT Δ 10. POISON Δ 11. DROP NET Δ 12. HESTER-DENDY SAMPLER Δ13. KICK NET Δ 14. OTHER ______________________________ **34B. CLOSING** (TICK 1) 1. NON-CLOSING Δ 2. CLOSING Δ

35. SIZE OF NET OR OF MOUTH OF TRAWL/PLANKTON NET WIDTH □□.□ M LENGTH □□.□ M

36. NET MESH SIZE STRETCHED A. SMALLEST □□□MM B. LARGEST □□□MM

37. DEPTH CAPTURE MAX □□□□□ CM / M **37B.** MIN □□□□□ CM / M OR N/A Δ **38A. SPEED HAULED** □□.□ KNOTS

38B. DISTANCE HAULED □□□□M / KM **39. SELECTIVITY OF SAMPLE** (TICK 1) 1. ALL KEPT Δ 2. SAMPLE SELECTED Δ

40. VESSEL TYPE ________________ **41A. PRINCIPAL COLLECTOR** INITIALS □□ SURNAME _____________
41B. OTHER _________________________________ COLLECTORS/INSTITUTION

F. Additional Data

e. SAMPLE OF LAND TEAM DATA SHEET

CREDP Biodiversity Survey-LAND Team **New England Aquarium**
Field/Input Sheet –Collection Data **Partners: ERGS, AMNH, Cornell Univ.**

A. Collection Numbers **1. STATION/FIELD NO**. □□□□□□□ **2. ACCESSION NO.**□□ □□□ **3A. UPDATE** Δ **3B. DELETE** Δ

B. Geographical Data

4. PROVINCE ______________________ 5. COUNTY_________________________
6. LOCALITY____
6A. WATER BODY 6B. LOCALITY DESCRIPTION

7. LATITUDE 7A. □□ □□ □□ N 7B. □□ □□ □□ W TO 7C. □□ □□ □□ N 7D. □□ □□ □□W
&LONGITUDE LAT. S LONG. E LAT. S LONG E

8E. ALTITUDE □□□□ METERS **9. LOCATION ACCURACY**: (TICK ONE) ± 1. < 10 KM Δ 2. < 20 KM Δ 3. < 40 KM Δ 4. < 200 KM Δ 5. > 200 KM Δ 6. DATA UNCERTAIN Δ

C. Temporal Data **WEATHER**_____________________________

10. DATE: □□ □□ □□□□ **11. TIME COLLECTION STARTED** □□□□ **12. DURATION** □□.□ HRS
Day Month Year (Military time)

D. Ecological Data

13. TYPE OF HABITAT

A. FIELD Δ B. NEW OR OLD FALLOW Δ C. SECONDARY FOREST Δ D. PRIMARY FOREST Δ E. MARSHY FOREST Δ

F. HERBACEOUS SAVANNAH Δ G. WOOD SAVANNAH Δ H. SHRUB SAVANNAH Δ

14. TOPOGRAPHIC DATA

A. PLAIN Δ B. HILL Δ C. SLOPE Δ D. SWAMP Δ E. SAND Δ

15. TYPE OF SOIL

A. SANDY Δ B. MARSHY Δ C. CLAY Δ

16. VEGETATION

A. PLANT KIND (NAME 1-2 MAIN KINDS) ____

B. PLANT AMOUNT (TICK ONE) 1. NONE Δ 2. SOME Δ 3. MODERATE Δ 4. MUCH Δ

C. SAMPLE COLLECTED Δ Y Δ N

E. CAPTURE DATA

1. AMPHIBIANS TAPE RECORDING Δ Y Δ N #

2. REPTILES

3. BIRDS: 1. MIST NET Δ 2. RELEASE Δ Y Δ N SAMPLE # ___________________ TAPE RECORDING Δ Y Δ N #

4. MAMMALS

F. FAUNA

____

____

40. VESSEL TYPE _______________ **41A. PRINCIPAL COLLECTOR** SURNAME _____________
41B. OTHER _______________________________ COLLECTORS/INSTITUTION

f. LIST OF EQUIPMENT FOR BIODIVERSITY SURVEY

<u>Nets, collecting equipment</u>.
FISH
2 6 ft. cast nets
5 dip nets
2 seine nets, 4 X 6
1 seine net, 8X6
1 seine net, 20X6
2 seines, 30 X 6
1 trawl, 8 ft.
mesh bag liner for trawl
2 small gill nets
1 experimental gill net (100 ft.), 1, 1 ½, 2, 2 ½, 3)
1 experimental gill net (100 ft.) 3/8, ½, ¾, 1, 1 7/8
1 experimental gill net (100 ft.) 2, 2 ½, 3, 3 ½, 4
1 experimental gill net (100 ft.) ½, ¾, 1, 1 ½
conductivity meter
pH test paper
butterfly net
cast net

HERPS
1 mini-disc Sony player with microphone
5 mini-discs

BIRDS
1 mist net

INSECTS
1 insect net, kill jar and pins
1 observation container

MACROINVERTEBRATES
Magnifying glasses (2)
Loupe
1 dip net
Hester-Dendy invertebrate sampler
1 drop net
1 kick net

<u>Water testing equipment</u>
Secchi disk
2 Field thermometers
Water quality testing kit (Hagen Master Test Kit)
Depth meter

pH meter, and buffer standards
Refractometer
Dissolved O2 meter (YSI Environmental)

2 Conductivity meters
Spectrophotometer (HACH DR/2000)

Fish processing
Nalgene jars
Weighing scales (2, one at 4 pounds, one for 50 pounds)
KOH pellets (500 gm)
Paraformaldehyde (500 gm)
Formalin (20 liter; bought in Kinshasa)
Ethanol (1 liter, bought in Kinshasa)
Masks for fish processing (10)
2 buckets (bought in Kinshasa)
Field guides
Field notebooks
5 gallon containers for making up fix
Fixing tray
MS222 powder
Vials for fish tissue
Aquarium fish nets
Large syringes/lines/needles
Scalpel blades
Towel
Fishing rod & reel
Small tackle box
Nylon monofilament fishing line
2 Penpals (lg. plexiglass aquarium)
Tarp for sorting supplies
Gloves
Syringes
Cable ties
Battery-operated air bubblers/air stones/air lines
Loupe
Digital calipers
Dissecting equipment
Duct tape
Ruler, Tape Measure
Cheesecloth – 1 bolt of 60 yds.
Plastic bags
Syringes
Rotonene
Fish tagging supplies
Vials, ethanol for molecular samples

Photo
Cameras, lens, flash, film, video camera + 5 miniDV tapes

Electronics
Chargers
Batteries: 9V, C, D, AA, AAA, watch

Speaker
Equipment for detecting electric fish (amplifiers, speakers, oscilloscope)
2 GPS

Camping
Water filters
9 sleeping bags
9 mattresses
5 tents
3 tarps
Lantern
Flashlights
Stove
Head lamps

g. LIST OF FIELD EQUIPMENT PROVIDED BY SUPPORTING INSTITUTIONS

New England Aquarium
Digital camera, lens, flash, film
Digital video camera
Collecting jars
MS222 powder
Duct tape
Fishing rod and reel
Nylon monofilament fishing line
Small tackel box
Fixing tray
Vials for fish tissue
Aquarium fish nets
Large syringe
Scalpel blades
Towel
Tools (knife, pliers, mini hack-saw, screwdrivers, elec. tape)
2 penpals (lg. plexiglass aquarium)
Battery-operated air bubblers
Refractometer
Loupe
Digital calipers
Dissecting equipment
Ruler, tape measure
Rope
Surgical gloves
Tarps for fish sorting
Speaker
Tape recorder for recording frog and bird calls
Stopwatch
Dissolved oxygen meter
Depth meter
Field pH meter, buffer standards, acid and base
Camping supplies: 2 sleeping bags, mattresses, 1 3-person tent, lantern, flashlight, stove, head lamp

Cornell University
Camera, lens, flash, film
Fish tagging supplies
Methanol
Small gill nets (2)
Dip nets (2)
Plastic bags
All necessary electronic equipment to identify electric fish (scope,electrode, speakers)
Conductivity meter

pH test paper

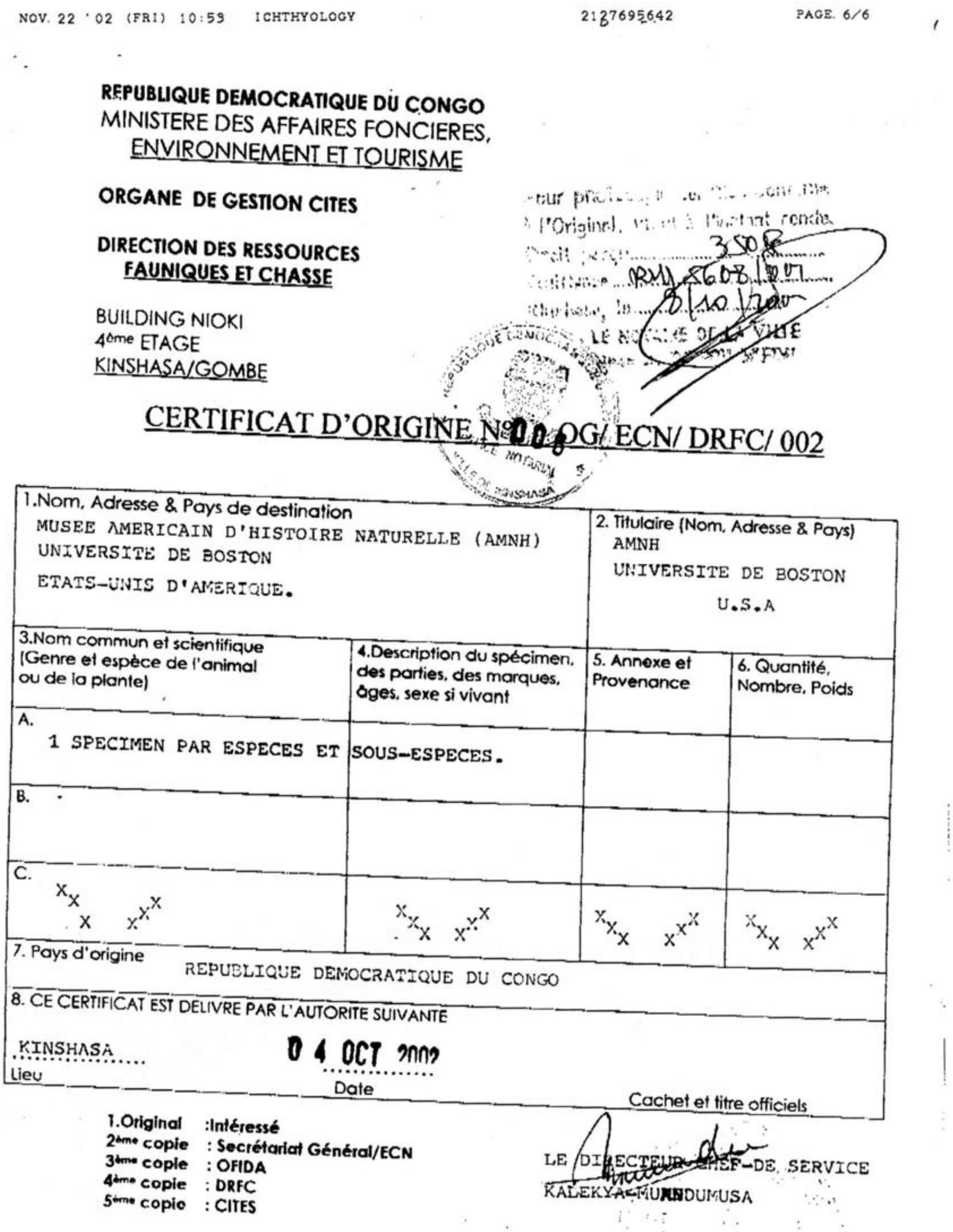
American Museum of Natural History
Camera, lens, flash, film
Plastic bags – different sizes
Whirl paks
Rubber bands
Powdered rotenone
Latex gloves
Needles and syringes (for injecting formalin)
Cheesecloth – 1 bolt
Plastic vials for tissues
Field notebooks
Field thermometers (2)
Liquipak Drums (1 gallon)
4 barrels
4 1 gal nalgene jars
Forceps
10x6 seine
30x6 seine
50x6 seine
Several 6 foot seines
Several bag seines
1 gill net
Cast net
Dip nets (1 small and 2 large)
Butterfly net
5 gallon plastic barrels
GPS device
Camping supplies: 1 sleeping bag, 1 2-person tent, head lamp

Environmental Resources Management and Global Security
Spectrophotometer (HACH DR/2000)
Conductivity meter

h. LIST OF EQUIPMENT DONATED TO UNIVERSITY OF KINSHASA by AMNH and NEAq

Fish guide to Fishes of West Africa, “Genera des Poissons d’eau douce de l’Afrique”, M. Poll and J.P. Gosse, authors.
Rotonene
Paraformaldehyde
Formalin
Surgical gloves
Plastic bags
Cheesecloth
Ethanol
Masks for fish processing
Water quality bottles

i. EXPORT PERMIT FROM DRC



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REPUBLIQUE DEMOCRATIQUE DU CONGO
MINISTERE DES AFFAIRES FONCIERES,
ENVIRONNEMENT ET TOURISME

ORGANE DE GESTION CITES

DIRECTION DES RESSOURCES
FAUNIQUES ET CHASSE

BUILDING NIOKI
4ème ETAGE
KINSHASA/GOMBE

[illegible] l'Original, [illegible] rendu
[illegible] 350 $
[illegible] (RM) 5608/2002
[illegible], le 8/10/2002
LE NOTAIRE DE LA VILLE

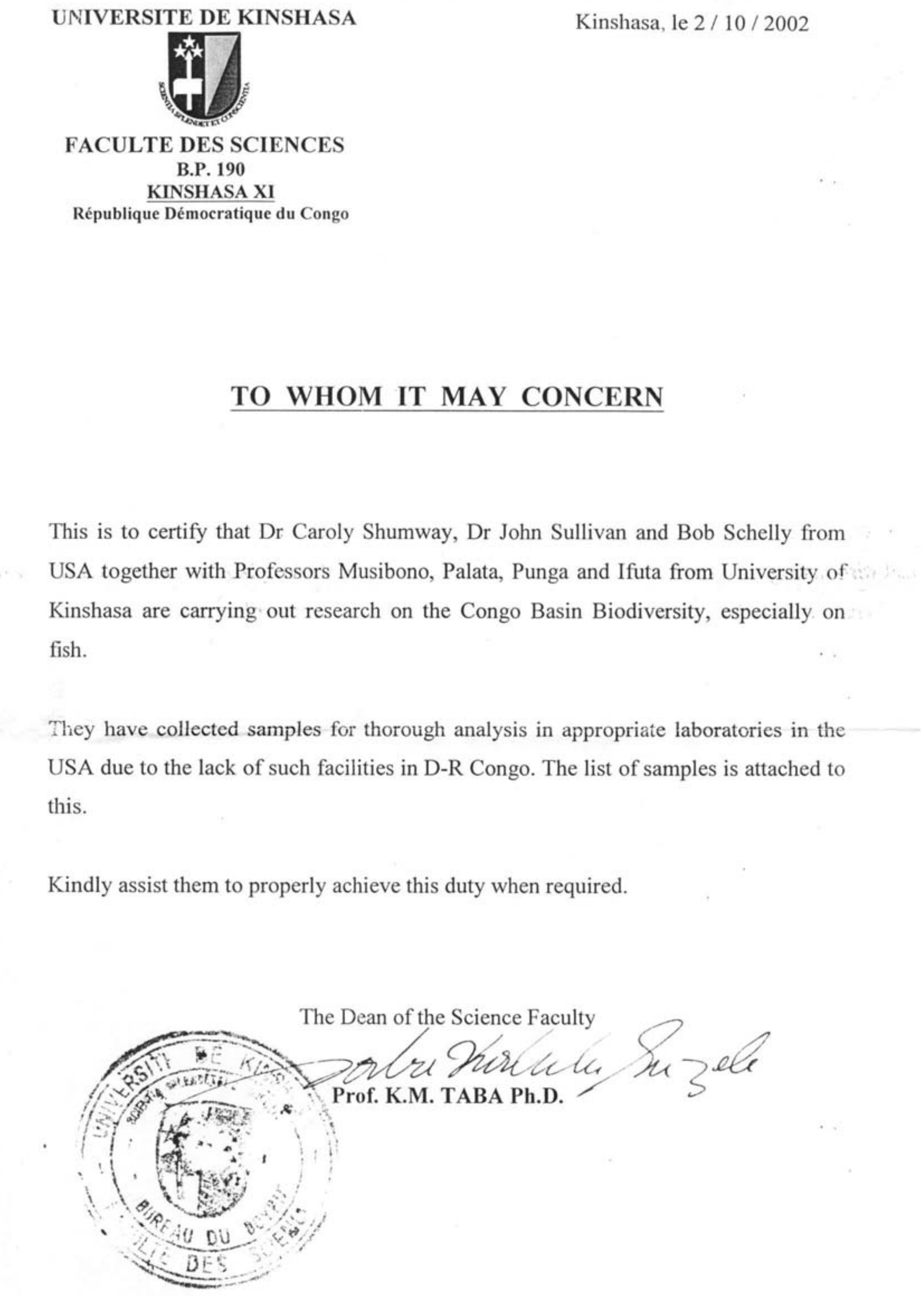
CERTIFICAT D'ORIGINE N°006 OG/ ECN/ DRFC/ 002

1.Nom, Adresse & Pays de destination MUSEE AMERICAIN D'HISTOIRE NATURELLE (AMNH) UNIVERSITE DE BOSTON ETATS-UNIS D'AMERIQUE.		2. Titulaire (Nom, Adresse & Pays) AMNH UNIVERSITE DE BOSTON U.S.A	
3.Nom commun et scientifique (Genre et espèce de l'animal ou de la plante)	4.Description du spécimen, des parties, des marques, âges, sexe si vivant	5. Annexe et Provenance	6. Quantité, Nombre, Poids
A. 1 SPECIMEN PAR ESPECES ET	SOUS-ESPECES.		
B.			
C. xx x xxx	xxx xxx	xxx xxx	xxx xxx
7. Pays d'origine REPUBLIQUE DEMOCRATIQUE DU CONGO			
8. CE CERTIFICAT EST DELIVRE PAR L'AUTORITE SUIVANTE			
KINSHASA Lieu	04 OCT 2002 Date	Cachet et titre officiels	

1.Original :**Intéressé**
2ème copie : **Secrétariat Général/ECN**
3ème copie : **OFIDA**
4ème copie : **DRFC**
5ème copie : **CITES**

LE DIRECTEUR CHEF DE SERVICE
KALEKYA-MUANDUMUSA

j. LETTER OF SUPPORT FROM UNIVERSITY OF KINSHASA



UNIVERSITE DE KINSHASA

FACULTE DES SCIENCES
B.P. 190
KINSHASA XI
République Démocratique du Congo

Kinshasa, le 2 / 10 / 2002

TO WHOM IT MAY CONCERN

This is to certify that Dr Caroly Shumway, Dr John Sullivan and Bob Schelly from USA together with Professors Musibono, Palata, Punga and Ifuta from University of Kinshasa are carrying out research on the Congo Basin Biodiversity, especially on fish.

They have collected samples for thorough analysis in appropriate laboratories in the USA due to the lack of such facilities in D-R Congo. The list of samples is attached to this.

Kindly assist them to properly achieve this duty when required.

The Dean of the Science Faculty

Prof. K.M. TABA Ph.D.

k. AMERICAN MUSEUM OF NATURAL HISTORY REGISTER OF FISH SPECIMENS

Summary of Fishes
RCS-02 Congo Collection

Field No.	Family	No. Spec.	Genus (if known)	generic name	other
RCS-02-015	Mormyridae	5			
	Cichlidae	1			
	Cyprinidae	1			
RCS-02-006	Characidae	20			
	Citharinidae	4			
	Cyprinidae	3			
	Polypteridae	1			
	Citharinidae	1			Distichodonitinae
	Cichlidae	4			
	Anabantidae	1	Ctenopoma		
RCS-02-013		2		Catfish	
	Mormyridae	2			
RCS-02-016	Cichlidae	7			
	Cyprinidae	2			
	Characidae	1			
RCS-02-005	Mormyridae	1			
	Mormyridae	1			
RCS-02-008	Cichlidae	1			
RCS-02-007	Cichlidae	2			
	Mormyridae	1			
RCS-02-010	Bagridae	2	Chrysichthys		
	Schilbeidae	3			
	Mochokidae	13			
	Mastacembelidae	2			
	Polypteridae	2			
	Citharinidae	1			
	Mormyridae	8			
	Cyprinidae	6			
	Cyprinidae	1	Labeo		
	Cichlidae	3			
	Polypteridae	1			
	Citharinidae	1			
	Citharinidae	1	Phago		
	Anabantidae	1	Ctenopoma		
RCS-02-005	Clupeidae	2			
	Characidae	3			
	Mormyridae	11			
	Schilbeidae	7			
	Clariidae	2			

Summary of Fishes
RCS-02 Congo Collection

	Anabantidae	2			
	Bagridae	3			
	Synodontidae	3			
RCS-02-004	Clupeidae	1			
	Citharinidae	1			
	Cyprinidae	2			
	Alestiidae	2	Hydrocynus		
	Bagridae	4			
RCS-02-002	Mormyridae	2			
	Cichlidae	1			
	Citharinidae	3			Distichodontinae
	Polypteridae	1			
	Protopteridae	1	Protopterus		
	Alestiidae	1	Hydrocynus		
	Synodontidae	1			
RCS-02-001	Polypteridae	1	Polypterus		
	Synodontidae	5			
	Schilbeidae	7			
	Bagridae	2			
	Characidae	6			
	Mormyridae	19			
	Cichlidae	2			
	Citharinidae	2			Distichodontinae
	Notopteridae	1			
RCS-02-014	Schilbeidae	2			
	Mormyridae	4			
	Cyprinidae	2			
	Bagridae	1	Chrysichthys		
	Mochokidae	1			
RCS-02-008	Citharinidae	6			Distichodontinae
	Cichlidae	6			
	Characidae	5			
		22		unknown	
	Cyprinidae	1			
	Mastacembelidae	1			
	Synodontidae	9			
RCS-02-021	Cichlidae	2			
	Mormyridae	4			
RCS-02-022	Mormyridae	14			
	Cichlidae	4			

Summary of Fishes
RCS-02 Congo Collection

	Clariidae	1			
	Mochokidae	5			
RCS-02-020	Cichlidae	11			
	Bagridae	1			
		41			Cyprinodontiformes
	Characidae	72			
	Cyprinidae	32			
RCS-02-025	Mormyridae	7			
RCS-02-026	Mormyridae	3			
	Characidae	26			
	Clupeidae	2			
	Citharinidae	2			Distichodontinae
	Cichlidae	1			
	Schilbeidae	16			
	Bagridae	2			
RCS-02-017	Bagridae	1			
RCS-02-007=9	Mormyridae	14			
	Cichlidae	9			
	Citharinidae	27			Distichodontinae
	Channidae	1			
	Anabantidae	6			
	Notopteridae	1			
	Mochokidae	17			
	Bagridae	1			
	Auchenoglanidae	2			
	Cyprinidae	4			
	Characidae	2			
RCS-02-018	Cichlidae	3			
RCS-02-016	Amphiliidae	1			
	Cichlidae	2			
	Clupeidae	1			
RCS-02-025	Cyprinidae	1			
	Citharinidae	1			Distichodontinae
	Anabantidae	1			
	Cichlidae	29			
RCS-02-012	Mochokidae	2			
	Cichlidae	4			
	Citharinidae	1			Distichodontinae
	Characidae	9			
RCS-02-017	Cichlidae	48			

Summary of Fishes
RCS-02 Congo Collection

	Cyprinidae	15			
	Characidae	41			
RCS-02-026	Mormyridae	4			
	Bagridae	2			
RCS-02-011	Mormyridae	1			
	Bagridae	2			
RCS-02-006	Mochokidae	9			
	Auchenoglanidae	1			
	Bagridae	1			
	Schilbeidae	2			
	Notopteridae	1			
	Citharinidae	24			Distichodontinae
	Tetraodontidae	2			
	Alestiidae	2	Hydrocynus		
	Mormyridae	17			
	Cichlidae	13			
	Channidae	4			
	Anabantidae	5			
	Characidae	62			
	Cyprinidae	54			
RCS-02-023	Mormyridae	27			
	Mochokidae	4			
	Bagridae	2			
RCS-02-027	Osteoglossidae	37			
	Mormyridae	13			
	Characidae	9			
	Cyprinidae	1			
	Mochokidae	4			
	Schilbeidae	1			
	Bagridae	4			
RCS-02-024	Cichlidae	20			
	Citharinidae	2			Distichodontinae
	Anabantidae	1	Ctenopoma		
	Characidae	105			

l. LIST OF BIOLOGICAL SAMPLING SITES.

Bandundu

1. Mushi, on Kwa River. Wetlands. 3°1.74 S, 16° 5.37E.
2. Between Mushi/Bokoni.
    center of Fimi River 3 °1.0 S 16°56.68E
    on Kwa river 3 ° 0.51S, 16°58.44E
    transition of grass to trees along banks. 3 ° 3.81S, 17°09.73E
    by lowland forest 3 ° 5.34S, 17°6.87E
3. Bokoni. Island wetlands, beaches. 3 ° 09.46S, 17°09.73E
4. Bandundu. Market. No GPS reading taken.

Bas-Congo

5. Fwamalo. Canal. 5°28.13S, 13°35.01E
6. Inga. Reservoir. 5°31.01S, 13°37.17E
7. Point 50. Rapids. 5°31.69S, 13°36.47E
8. Shongho. Rapids. 5°31.43S, 13°37.76E
9. Nziya. River . 5°32.25S, 13°33.61E

Equateur

10. Bodjia. Marginal waters. 0°2. 34S, 18° 10.94E
11. Gombe. No GPS reading taken.
12. Irebu. Wetlands. 0° 35.84 S, 17°46.96E
13. Ubangi confluence. Main part of river, near flooded forest. 0°30.75S, 17°43.16E
14. Midway between Gombe and Mbandaka. Main part of river. 0°16.84S, 17°59.03E

12. FIGURES

a. LIST OF PHOTOS.

Note: Species identifications are provisional at this time.

Credits:
John Sullivan – Figures # 39,40, 83-86, 90-91, 123-124
Robert Schelly – Figures # 1-2, 7-8, 17, 24-38, 41-42, 44,49,54,64, 66,68,73-76,79,81-82, 87-89, 92-97, 99-100, 107, 111-112, 114, 122, 128-129, 133-134, 136-137, 139, 141
Caroly Shumway – Figures # 3-6, 9-16, 18-23, 43, 45-48, 50-53, 55-63, 65, 67, 69-72,77-78, 80,101-106, 108-110, 113,115-121, 125-127, 130-132, 135, 138, 140

b. METHODS

Fig. 1. Epervier (cast net).
Fig. 2. Throwing the cast net.
Fig. 3. Dip nets used in the rapids of Shongho.
Fig. 4. Dip- netting in a forest stream.
Fig. 5. Experimental gill net.
Fig. 6. Collecting tissue for molecular analysis.
Fig. 7. Preparing to sample fish, Bandundu.
Fig. 8. Bandundu.
Fig. 9. CREDP Biodiversity team.
Fig. 10. CREDP Biodiversity team.
Fig. 11. CREDP Biodiversity team.
Fig. 12. Research pirogue.
Fig. 13. Observing artisinal fishing.
Fig. 14. Mist-netting birds.
Fig. 15. CREDP team, with one of our partners, the Bas-Congo Fishing Association.
Fig. 16. The Bas-Congo Fishing Association.

c. FISHING TECHNIQUES

Fig. 17. Construction of an artisinal fish trap, Bandundu.
Fig. 18. Hundred meter gill net, used in the wetlands by Lome fishing village.
Fig. 19. Innertube used in artisinal rapids fishing.
Fig. 20. Handlines for rapids fishing.
Fig. 21. Rapids fishing.
Fig. 22. Artisinal dynamic gillnet fishing, Equateur.
Fig. 23. Artisinal dynamic gillnet fishing, Equateur.

d. BANDUNDU-FISHES

Fig. 24. Representative fishes collected at Bandundu.
Fig. 25. *Campylomormyrus tamandua*.
Fig. 26. Large *Campylomormyrus sp.*
Fig. 27. *Genyomyrus donnyi*.
Fig. 28. *Mormyrops anguilloides.*

e. BANDUNDU – OTHER SPECIES

f. BANDUNDU HABITATS

Fig. 68. Swamp forest (front); lowland gallery forest (back).

g. BANDUNDU PEOPLE

Fig. 69. Returning to the Bokoni fishing village after sampling.
Fig. 70. The town of Mushi.
Fig. 71. Director and members of the NGO, PERILAC.
Fig. 72. Director and members of the NGO, SAQUA.
Fig. 73. The fishing village of Bokoni.
Fig. 74. Fishes captured at Lome fishing village.
Fig. 75. Residents of the Lome fishing village.
Fig. 76. The market at Bandundu.
Fig. 77. Fish at the Bandundu market.
Fig. 78. Fish at the Bandundu market.
Fig. 79. Fish at the Banundu market.
Fig. 80. Young fishers.
Fig. 81. Children of the Lome fishing village.

h. BAS-CONGO FISHES

Fig. 82. Representative fishes observed at the Inga market.
Fig. 83. *Campylomormyrus rhyncophorus*; *Mormyrus caballus bumbanus.*
Fig. 84. *Rheoglanis dendrophorus.*
Fig. 85. *Euchilichthys sp.*
Fig. 86. *Euchilichthys sp.*
Fig. 87. *Labeo sorex.*
Fig. 88. *Labeo sorex*, same specimen as in Fig. 87.
Fig. 89. *Labeo sorex,* same specimen as in Figs. 87 and 88.
Fig. 90. *Labeo nasus.*
Fig. 91. *Labeo nasus,* same specimen as in Fig. 90.
Fig. 92. *Labeo macrostoma.*
Fig. 93. *Labeo nasus.*
Fig. 94. Diverse Labeo species collected at Point 50.

i. BAS-CONGO HABITAT

Fig. 95. Savannah on the cliff bordering Nziya.
Fig. 96. Nziya.
Fig. 97. Nziya.
Fig. 98. Fwamalo.
Fig. 99. Aerial shot of Bas-Congo.
Fig. 100. Matadi.
Fig. 101. Savannah on the cliff bordering Shongho.
Fig. 102. Shongho.
Fig. 103. Boulders along the Shongho bank.
Fig. 104. Boulders along the Shongho bank.

EQUATEUR – PEOPLE

Fig. 137. The Gombe Fishing Association.
Fig. 138. The Chef de Cité and his wife, Gombe.
Fig. 139. The market at Mbandaka.
Fig. 140. Artisinal gill net fishing by the village of Irebu.
Fig. 141. The market at Mbandaka.