



THE STATUS AND DISTRIBUTION OF FRESHWATER BIODIVERSITY IN CENTRAL AFRICA

Brooks, E.G.E., Allen, D.J. and Darwall, W.R.T.



CENTRAL AFRICA



The IUCN Red List of Threatened Species™ Regional Assessment

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Executive Summary

Central Africa supports an incredible biodiversity, and its inland waters are no exception. The Congo River has the highest species diversity of any freshwater system in Africa, and is second in species richness globally, after the Amazon. This diversity provides benefits to humans both directly, such as through livelihoods from fisheries, and indirectly through services such as the purification of water for drinking. Currently, central Africa is not heavily developed, but this is likely to change dramatically in the next few decades, in particular should long-term political stability come to the region. Development activities are, however, not always compatible with conservation objectives which are, in most cases, poorly represented within the development planning process. One of the main reasons cited for inadequate representation of biodiversity in the development processes is a lack of readily available information on inland water taxa. In response to this need for basic information on species, the IUCN Species Programme conducted a regional assessment of the status and distribution of 2,261 taxa of freshwater fishes, molluscs, odonates, crabs and selected families of aquatic plants from throughout central Africa. This study is based on the collation and analysis of existing information, and the knowledge of regional experts. All species are assessed through application of the IUCN Red List Categories and Criteria to assess species risk of extinction, and distribution ranges have been mapped for the majority of species, thereby providing a tool for application to the conservation and development planning processes. The full dataset, including all species distribution maps (GIS shapefiles), is freely available in the DVD accompanying the report and through the IUCN Red List of Threatened Species™ website (www.iucnredlist.org).

The richest area of species diversity is clearly defined by the channel of the Congo River and its tributaries the Ubangi River and the Kasai River. Another extremely diverse area is the highlands of south-western Cameroon. Particularly high numbers of species from all taxonomic groups are found in the Upper Congo Rapids, and at Malebo Pool, also on the mainstream Congo River. Approximately one half of all species are endemic to the region, including an exceptional 74% of all fish species.

Fifteen per cent of the freshwater species of central Africa are threatened with extinction according to the IUCN Red List Categories and Criteria. If all Data Deficient species were also found to be threatened, this could rise to as much as 36%. This level of threat is predicted to increase dramatically in response to growing levels of development, unless the ecological requirements of freshwater species are given much greater consideration in future planning. By far the biggest threat in the region is habitat loss due to agriculture and deforestation, as well as infrastructure development, and water pollution (in particular by sedimentation). The highest concentrations of threatened species are found in the Lower Congo Rapids, just downstream from

the two capitals of Brazzaville and Kinshasha, and in the highly vulnerable Western Equatorial Crater Lakes.

A network of river and lake basins are identified as potential Key Biodiversity Areas (KBAs) most important for the protection of threatened and restricted range species. Future efforts in managing inland waters must take account of the upstream and downstream connectivity in freshwater ecosystems. For example, it is recommended that conservation efforts focus on the protection of upper catchment areas, provision of environmental flows, and the inclusion of rivers and lakes as specified conservation targets within protected areas rather than as boundary markers for protected areas. Integrated Water Resource Management is recommended along with the initiation of additional river/lake basin authorities, and increased capacity to manage protected areas.

The results of this assessment are to be merged with similar studies that have been conducted for all other regions of Africa, in order to provide a baseline of the status and distribution of freshwater biodiversity throughout all of continental mainland Africa. This information source, which will be made freely and widely available, will provide essential information currently lacking in many places, to help conservation and development planning proceed in a manner that takes full account of the requirements of freshwater species.

Finally, it is most important that the findings and the data compiled here, are made available to the relevant decision makers and stakeholders in a format that can be easily understood and readily integrated within the decision making process.

The key messages from this assessment are:

- The inland waters of central Africa support an exceptionally high diversity of aquatic species, with high levels of endemism. Many of these species provide direct (e.g. fisheries) or indirect (e.g. water purification) benefits to people. The conservation of these species is most important to the livelihoods and economies of the regions' people.
- More than 15% of species across the region are currently threatened and future levels of threat are expected to rise significantly due to increasing development throughout the region, and an associated higher demand for natural resources.
- Data on the distribution, conservation status, and ecology of 1,207 species of fish, 166 molluscs, 458 odonates, 38 crabs and 392 selected aquatic plants are now freely available through this project and the IUCN Red List website (www.iucnredlist.org/initiatives/freshwater/centralafrica).
- The data made available through this assessment must be integrated within the decision-making processes in planning for the conservation and development of inland water resources. Lack of available information should no longer be

- given as a reason for inadequate consideration for development impacts to freshwater species.
- Species information remains very limited for many species within the region, with 21% of known species classified as Data Deficient. Regions in the Democratic Republic of Congo
- in particular are identified as a priority for future surveys. All taxonomic groups lack vital data on species distributions and threats, but spatial information on aquatic plants in particular needs to be greatly improved throughout the region.

Résumé Exécutif

L'Afrique Centrale abrite une biodiversité incroyable, et ses eaux douces ne font pas exception. Le fleuve Congo a la plus grande diversité d'espèces de tous les systèmes d'eau douce d'Afrique, et la seconde au monde après l'Amazone. Cette diversité profite aux humains à la fois directement, à l'exemple des moyens de subsistance tels que la pêche, et indirectement à travers des services tels que la purification de l'eau potable. Actuellement, l'Afrique Centrale n'est pas très développée, mais cela pourrait changer radicalement dans les prochaines décennies, en particulier si la région connaissait une longue période de stabilité politique. Pourtant, les activités de développement ne sont pas toujours compatibles avec les objectifs de conservation qui sont le plus souvent mal intégrés dans les processus de planification du développement. L'une des principales raisons invoquées pour le manque de prise en compte de la biodiversité dans les processus de développement est le manque d'information aisément accessible sur les espèces d'eaux douce. En réponse à ce besoin d'information fondamental, le Programme Espèces de l'IUCN a conduit une étude régionale sur le statut et la distribution de 2 261 taxons de poissons, mollusques, libellules, crabes et de certaines familles de plantes aquatiques des eaux intérieures de l'Afrique Centrale. Cette étude repose sur la collecte et l'analyse des informations existantes et sur les connaissances des experts régionaux. Toutes les espèces ont été évaluées grâce aux Catégories et Critères de la Liste Rouge de l'IUCN de façon à estimer leur risque d'extinction, et les aires de distribution ont été cartographiées pour la majorité des espèces, fournissant ainsi un outil à utiliser dans les processus de planification de la conservation et du développement. Le jeu complet de données, ainsi que toutes les cartes de distribution des espèces (fichiers SIG), sont accessibles sans frais sur le DVD accompagnant le rapport et à travers le site de la Liste Rouge de l'IUCN des Espèces MenacéesTM (www.iucnredlist.org).

La zone la plus riche en termes de diversité d'espèces est clairement définie par l'axe du fleuve Congo et de ses affluents, les rivières Oubangui et Kasaï. Les hauts plateaux du sud-ouest du Cameroun constituent une autre aire d'extrême diversité. On trouve dans les rapides du Haut-Congo et au Pool Malebo, ainsi que sur le cours principal du fleuve Congo un nombre d'espèces particulièrement élevé dans tous les groupes taxonomiques. Environ la moitié de toutes les espèces est endémique de la région, y compris un taux exceptionnel de 74% des espèces de poissons.

Quinze pour cent des espèces d'eau douce d'Afrique Centrale sont menacées d'extinction selon les Catégories et Critères de la Liste Rouge de l'IUCN. Si toutes les espèces pour lesquelles les données sont insuffisantes se trouvaient être également menacées, ce chiffre pourrait atteindre 36%. Ce niveau de menace devrait augmenter de façon spectaculaire avec la progression du niveau de développement, à moins que les exigences écologiques des espèces d'eau douce ne soient mieux prises en considération

dans les planifications futures. La plus grande menace sur la biodiversité aquatique de la région est de loin la perte d'habitat due à l'agriculture et à la déforestation, au développement des infrastructures, ainsi qu'à la pollution des eaux (en particulier par sédimentation). Les plus fortes concentrations d'espèces menacées se trouvent dans les chutes du Bas-Congo, juste en aval des deux capitales de Brazzaville et Kinshasa, et dans les très vulnérables lacs de cratères de l'Ouest-Equatorial.

L'étude identifie un réseau de bassins fluviaux et lacustres comme étant potentiellement les plus importantes Zones Clés pour la Biodiversité, en vue de la protection des espèces menacées ou dont l'aire de distribution est réduite. Les efforts dans la gestion des eaux intérieures doivent à l'avenir tenir compte de la connectivité de l'amont et de l'aval des écosystèmes d'eau douce. Par exemple, il est recommandé que les efforts de conservation soient concentrés sur la protection de l'amont des bassins versants, la sécurisation des débits environnementaux et l'intégration des rivières et des lacs comme des cibles spécifiques de conservation à l'intérieur des aires protégées, plutôt que comme limites des aires protégées. L'étude recommande la Gestion Intégrée des Ressources en Eau (GIRE), de même que la mise en place de nouvelles autorités de rivières et de lacs, et le renforcement des capacités de gestion des aires protégées.

Les résultats de cette évaluation vont maintenant rejoindre ceux des études similaires menées dans d'autres régions de l'Afrique, de façon à fournir une base de l'état et de la distribution de la biodiversité des eaux douces sur l'ensemble du continent africain. Cette source d'information, qui sera disponible gratuitement et largement accessible, fournira des informations essentielles qui font actuellement défaut dans de nombreux endroits, pour aider les processus de planification de la conservation et du développement, afin qu'elles tiennent pleinement compte des besoins des espèces d'eau douce.

Enfin, il est très important que les conclusions et les données compilées ici, soient mises à la disposition des décideurs politiques et des parties prenantes sous un format aisément compréhensible et facile à intégrer dans les processus de prise de décision.

Les messages clés de cette étude sont les suivants :

- Les eaux intérieures d'Afrique Centrale sont le support d'une diversité exceptionnelle d'espèces aquatiques, avec des niveaux élevés d'endémisme. Beaucoup de ces espèces procurent des bénéfices directs (comme la pêche) ou indirects (comme la purification de l'eau) aux populations. La conservation de ces espèces est par conséquent des plus importantes pour la subsistance et l'économie des populations de la région.
- Plus de 15% des espèces de la région sont actuellement menacées et on peut s'attendre à une augmentation significative des

niveaux de menace en raison du développement croissant dans toute la région, associé à une demande plus élevée en ressources naturelles.

- Les données sur la distribution, l'état de conservation et l'écologie de 1 207 espèces de poissons, 166 espèces de mollusques, 458 espèces d'libellules, 38 espèces de crabes et d'une sélection de 392 espèces de plantes aquatiques sont maintenant disponibles gratuitement grâce à ce projet et via le site Web de la Liste Rouge de l'IUCN (www.iucnredlist.org/initiatives/freshwater/centralafrica).
- Les données rendues disponibles par cette évaluation doivent être intégrées dans les processus décisionnels de planification de la conservation et du développement des ressources en eaux intérieures. Le manque d'information disponible ne

devrait plus être invoqué pour justifier une prise en compte insuffisante des impacts du développement sur les espèces d'eau douce.

- Les informations sur de nombreuses espèces de la région restent très limitées, 21% des espèces connues étant classés comme espèces à «données insuffisantes». Des régions, en République Démocratique du Congo en particulier, sont identifiées comme prioritaires pour de futures recherches. Des données essentielles sur la répartition des espèces et sur les menaces manquent dans tous les groupes taxonomiques, mais les informations sur la distribution spatiale des plantes aquatiques en particulier, doivent être considérablement améliorées dans la région.

Chapter 1. Background

Brummett, R.¹, Stiassny, M.² and Harrison, I.³

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Healthy freshwater ecosystems are essential to the rich biodiversity they support and to the landscapes and seascapes that they traverse and ultimately flow into. Healthy freshwaters are also essential to support human health and livelihoods (Emerton and Bos 2004; Emerton 2005). Humans rely directly on freshwater for drinking, washing, agriculture, transportation, and industrial processes, including the generation of electrical energy (MEA 2005a; Farrell *et al.* 2010). Freshwater ecosystems also provide humans with diverse fisheries of fishes, turtles, frogs, snails, and crayfishes (Revenga and Kura 2003; Bogan 2008; Strong *et al.* 2008), as well as various types of plants that are harvested for food and building materials (Li *et al.* 2000). Fisheries and aquaculture of fishes are an essential part of the economy of many countries and are a major source of protein for a billion people worldwide (Finlayson *et al.* 2006; Dugan *et al.* 2007; LePrieur *et al.* 2008; Neiland and Béné 2008). Tropical inland fisheries production is estimated at 5.46 million tonnes with a gross market value of USD 5.58 billion (Neiland and Béné 2008). This is equivalent to 19% of the current value of total annual fish exports from developing countries (USD 29 billion). As part of the ornamental trade more than 750 species of freshwater fishes are traded internationally each year. Other, indirect, yet critical services provided by freshwater ecosystems are flood control, water purification, delivery of nutrient-rich sediments to floodplains and estuaries, and carbon sequestration (MEA 2005b; Emerton 2005; Farrell *et al.* 2010). The proper functioning of freshwater ecosystems is highly dependent on their interrelationships with the terrestrial systems through which they flow (Baron *et al.* 2002). For example, forest regions within watersheds play an important role in water recharge

and can reduce the magnitude of peak flooding and moderate flow (Farrell *et al.* 2010). Sheil and Mudiyarso (2009) indicated that intact forest cover in the Congo basin contributes to the high rainfall there. Properly functioning freshwater ecosystems also moderate the regional impacts of climate change (Kamden-Toham *et al.* 2006) and provide important buffers against sea level rise and increased storm surges.

One estimate gave a global value for all freshwater services at USD 7 trillion a year (in 2009 dollars), approximately 15% of the total estimated value of all the world's ecosystem services combined (Costanza *et al.* 1997). This study estimated the value of freshwater ecosystems to be between USD 12,227 to USD 28,173 per hectare, depending on ecosystem type (in 2009 dollars). However, the high value of freshwater ecosystems and their services is often underestimated in regional planning and development. Consequently, freshwaters and freshwater habitats are often degraded by human societies, under a misguided perspective that their exploitation is economically productive and cost effective (Postel and Carpenter 1997; Postel 2003; Wallace *et al.* 2003). It has been suggested that nearly half the world's wetlands have been degraded (WMO 1997; Postel and Richter 2003; MEA 2005). From an economic standpoint, it is more far more cost-effective to maintain well-functioning freshwater ecosystems than to have to develop often costly mechanisms to restore them to a condition where they once again support a rich diversity of species and ecosystems services (Jackson *et al.* 2001; Balmford *et al.* 2002; Postel 2003; Emerton and Bos 2004).

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³ Conservation International, 2011 Crystal Drive, Suite 500, Arlington, VA 22202, USA.

In Africa there is a strong focus on development projects to secure safe drinking water, improved sanitation, irrigation for agriculture, and hydropower, as identified in the Africa Water Vision 2025 presented in the African Regional Paper of the Fifth World Water Forum (African Development Bank Group 2009). It will be critical to achieve these development goals in order to sustain the livelihoods and well-being of Africa's human population that is expected to rise by 36% between 2010 and 2025 (UN 2009; <http://esa.un.org/unpp/>). The Africa Water Vision 2025 indicates the need for at least USD 20 billion per annum to meet these uses of water as well as for "environmental uses." An integrated approach to development is required in order to ensure people have water for domestic and industrial use, while still retaining water of sufficient quantity and quality in the freshwater ecosystems to maintain biodiversity and provide the myriad of other services that support human livelihoods and well-being (Emerton 2005; Forslund *et al.* 2009). This integrated approach must also take account of the affects of climate change over the coming decades. A necessary first step in achieving such an integrated approach is to assimilate a baseline of data for freshwater biodiversity and threats for integration into planning and management processes. This project, therefore, provides the critical first step of data assimilation for central Africa, which is especially important because our knowledge of the biodiversity of this region has been incomplete for many years (see section 1.2).

Here we summarize the results of assessments of the distribution, ecology, and conservation status of freshwater biodiversity in central Africa. This work complements the existing reports on the status of freshwater biodiversity in eastern, southern, western and northern Africa (Darwall *et al.* 2005, 2009; Smith *et al.* 2009; García *et al.* 2010). The results of all regional studies will be combined into a comprehensive, continental-scale analysis

of African freshwater biodiversity, closely linked to the existing scheme of African freshwater ecoregions described by Thieme *et al.* (2005).

1.1 Global status of freshwater biodiversity

1.1.1 Species diversity

Freshwater animals comprise those species that live in or on fresh water for at least a part of their life cycle, or are dependent on freshwater ecosystems for some aspect of their ecology (Balian *et al.* 2008a). These latter, fresh water dependent species, do not necessarily live in fresh water but may be dependent on the system for food (e.g., waterfowl and mammals that feed on fish and amphibians), or for some other resource (such as mud and water for building nests, in the case of many birds and insects). The current estimate of the numbers of freshwater animal species is about 126,000 (Balian *et al.* 2008b), although higher numbers have also been proposed (Abramovitz 1996; Balian *et al.* 2010). Over 60% of the recorded species of freshwater animals are insects (Balian *et al.* 2008b). Approximately 45% (between 12,740 and 15,062 species) of known fish species inhabit freshwater (Leveque *et al.* 2008), representing almost 25% of the world's known vertebrates. When amphibians, aquatic reptiles and mammals are added to this total, it becomes clear that about 38% of all vertebrate species are confined to freshwater (Balian *et al.* 2008, 2010). The true number will be much higher than this as, for example, between 1976 and 1994, an average of 309 new fish species, approximately 1% of known fishes, are formally described or resurrected from synonymy each year (Stiassny 1999) and this trend has continued (Lundberg *et al.* 2000). Similarly, the number of recognized species of amphibians increased about 48% between 1985 and 2006 (Frost *et al.* 2006).

Riverside market, Kisangani, DRC. Photo: © K.-D. Dijkstra.



Freshwater plants or hydrophytes are generally considered as, “all plants that tolerate or require flooding for a minimum duration of saturation/inundation” (Gopal and Junk 2000). According to Chambers *et al.* (2008), there are an estimated 2,614 aquatic vascular macrophyte species within the two better-known plant divisions Pteridophyta and Spermatophyta. About 39% of the c. 412 genera containing aquatic vascular macrophytes are endemic to a single biogeographic region, with 61–64% of all aquatic vascular plant species found in the Afrotropics and Neotropics being endemic to those regions.

Surface fresh waters cover about 0.8% of the Earth’s surface and are less than 0.008% of the total volume of water on earth (i.e., including sea water, snow, ice, and deep groundwater systems). Therefore, the great diversity of freshwater species is confined to a relatively small extent of habitats (Gleick 1996; Dudgeon *et al.* 2006). Terrestrial and marine ecosystems may have a greater percentage of known species but fresh waters are considered to have a far greater spatial richness of species.

1.1.2 Major threats to freshwater species

Worldwide freshwater biodiversity and habitats are seriously threatened (Revenga and Kura 2003; Leveque *et al.* 2005; Dudgeon *et al.* 2006; Thieme *et al.* 2010a), to a level that exceeds that of terrestrial or marine ecosystems. The Living Planet Index (Hails 2008) shows that populations of 458 freshwater species declined by an average of 35%, compared to an average of 33% decline in 887 terrestrial species, and a 14% decline in 341 marine species between 1970 and 2005. These estimated declines for freshwater species are likely to be underestimates, due to the lack of comprehensive surveys for many regions, and the lack of knowledge on the taxonomy for many groups (especially invertebrates). The main threats to freshwater biodiversity are habitat degradation caused by infrastructure development and land conversion, water pollution, flow modification, introduction of invasive alien species, overharvesting and overexploitation (MEA 2005; Dudgeon *et al.* 2006; Thieme *et al.* 2010a). Increasing human population growth and economic development are recognized as the indirect drivers behind many of these threats.

In many cases the decline of species is not caused by a single threat, but instead by two or more different threats working together, or by a sequence of threats (Harrison and Stiassny 1999). In these cases, the synergistic threats may have a much more significant impact on the species than any one threat on its own, as described by Roberts (1993) for threats to south-east Asian fishes. For example, there are several cases where lacustrine species have been first reduced by overfishing and, in this weakened condition, species and whole communities have been significantly impacted by subsequent competition from introduced species or from pollution (Harrison and Stiassny 1999). Several environmental changes, occurring globally, are also being superimposed on the threats noted above; for example, increased nitrogen deposition, changes in climate, shifts in precipitation and runoff patterns (Rabelais 2002; Dudgeon *et al.* 2006; Rockström *et al.* 2009;

Thieme *et al.* 2010a; Baron *et al.* 2011). The effects of global climate change will not be trivial, altering water temperatures, and the timing and quantity of precipitation which will affect the quantity of flows through freshwater ecosystems. Many freshwater species are highly dependent on water temperature, but also rely on specific rates of water flow, and specific cues from seasonal changes in those flows for breeding and feeding cycles and migrations.

1.1.3 Species threatened status

Change in status of threatened species is accepted as one of the best indicators for assessing the condition of ecosystems and their biodiversity. The Convention on Biological Diversity (CBD) used measurements of change in the status of threatened species as indicators for monitoring progress towards the 2010 target for reduction of biodiversity loss. Those measurements have shown that the rate of biodiversity loss is not slowing and the 2010 target has not been met (Butchart *et al.* 2010). The IUCN Red List of Threatened Species™ (IUCN 2010) (hereafter cited as the IUCN Red List) is recognized as the best source of information, at the global level, on the threatened status of plants and animals (Vié *et al.* 2009). It provides information on the taxonomy, distribution, ecology, utilisation, livelihoods, values, threats, conservation measures (in place and/or needed), and risk of extinction as assessed using the IUCN Red List Categories and Criteria: Version 3.1 (IUCN 2001). This system has now been applied to all known species of mammals, birds, amphibians, freshwater crabs, reef-building corals, cycads, and conifers. The results highlight the species that are facing a higher risk of global extinction (i.e., those listed as Critically Endangered, Endangered or Vulnerable). Stuart *et al.* (2010) have proposed that the IUCN Red List should be used as the platform for a global project, the “Barometer of Life,” to unite taxonomists, biogeographers, ecologists, conservationists, and amateur naturalists in a coordinated exploration of global biodiversity, with an emphasis on identifying threatened species. This project would complement the Encyclopedia of Life, a powerful initiative to document every known species (Wilson 2003; EOL 2010).

Inland freshwater species are incompletely covered in the IUCN Red List but, for those taxonomic groups that have been completely assessed, globally, the results show a high percentage of threatened or extinct species. For example, 46% of freshwater mammals, 35% of amphibians, 38% of freshwater turtles, and 32% of freshwater crabs that are not Data Deficient are considered threatened or Extinct (Stuart *et al.* 2004, 2008; Schipper *et al.* 2008; Cumberlidge *et al.* 2009; Buhmann *et al.* 2009; Turtle Taxonomy Working Group 2009; IUCN 2010). In Europe, 38% of freshwater fishes (200 species) are listed as globally threatened and an additional 2% (13 species) as Extinct (Kottelat and Freyhof 2007). A regional assessment of the Mediterranean inland waters, found that the majority, 56%, of endemic freshwater fish species are threatened (Smith and Darwall 2006). Assessments of freshwater fishes in northern, western, eastern and southern Africa show between 11% and 27% to be regionally threatened

(Darwall *et al.* 2005, 2009; Smith *et al.* 2009; García *et al.* 2010). Clearly global and regional level threats to freshwater species are a significant concern.

1.2 Situation analysis for central Africa

1.2.1 Geographic extent

Central Africa, as defined in this regional assessment, is a generally forested region (although parts have been impacted by human activities), which includes the Congo and Lower Guinea rainforests that together occupy some 4.2 million km². The central Africa assessment region is bordered to the north by the more typically savannah regions of the Niger-Benue, Chad, and Upper Nile drainage systems; to the east by the central African highlands and Rift valley (see Darwall *et al.* 2005); to the south by the central African plateau and southern African highlands, covering Zambia and Angola and countries to the south of these (see Darwall *et al.* 2009); and to the west by the Atlantic Ocean (Figure 1.1). Thus, the central African assessment region includes the drainages of southern Cameroon from the Cross River (adjacent to the Nigerian border) and extends south to the mouth of the Congo, including all river drainages in Equatorial

Guinea, Gabon, the Republic of Congo, and Cabinda. The region also includes all the rivers of the Democratic Republic of Congo (DRC) that flow into the main channel of the Congo River (see below). This includes a few tributaries of the Congo basin that have their upper reaches in northern Angola and north-eastern Zambia. The northern part of the central African assessment area also includes rivers in the southern half of the Central African Republic that flow to the Sangha and Ubangi rivers (both of which are large affluent tributaries of the Congo River).

The assessment area comprises two biogeographic ‘provinces’ that are based on their characteristic fish faunas (Roberts 1975; Lévéque 1997); the Lower Guinean Province, and the Congo (Zaire) basin Province (Figure 1.2). The Lower Guinean province drains some 680,000 km² along the western coast of central Africa, is delimited to the north by the Cross river basin located at the border of Cameroon and Nigeria, and extends south to the Chiloango river basin in Cabinda and the Republic of Congo. The Congo Province is much larger draining about 3,600,000 km² of central Africa, and comprising the entire Congo River and associated tributaries (such as the Kasai, Sangha, Ubangi and Uele rivers), and Lake Tanganyika (although the lake was covered in the eastern Africa assessment (Darwall *et al.* 2005) and so is not included here). The Congo basin is the largest in Africa, including

Figure 1.1 The central Africa assessment region and major waterways, mapped to river sub-catchments.



portions of 10 countries. The high rainfall and low evaporation in the Congo basin mean that the Congo River and its tributaries carry about 30% of Africa's surface flow (Thieme *et al.* 2010a).

A method of defining the biogeographic regions of Africa, based on 'freshwater ecoregions', was developed by Thieme *et al.* (2005) and slightly revised by Abell *et al.* (2008). These ecoregions are defined by a combination of physical and biological characteristics, including the hydrological features of the region, and the communities of aquatic species present. They divided continental Africa into 79 freshwater ecoregions; 18 of these are entirely within the boundaries of the central Africa assessment region, and include some of the world's largest wetland systems and last remaining tracts of moist tropical lowland forest. Segments of another three also fall within the region. In this review of the conservation status of freshwater biodiversity in central Africa we will examine patterns of species distributions and threats relative to the larger Lower Guinean and Congo ichthyofaunal provinces as well as many of the smaller freshwater ecoregions.

1.2.1.1 Congo Basin Province (excluding Lake Tanganyika)
The characteristic patterns of mollusc species distributions also fit this Lower Guinean province (Van Damme 1984). It seems

likely that a more broadly distributed group of archaic taxa, related to the modern species in both the Lower Guinean and Upper Guinean provinces (the latter extends from Guinea through Sierra Leone and Liberia; Lévéque 1997) were repeatedly and/or progressively isolated during the several dry phases that reduced the extent of rainforest between 70,000 years ago and the present day. That the fish fauna of what are now savannah-type rivers to the north and west of the Lower Guinean province are similar to those in present rainforest areas supports the idea that current rainforest extent is not the same as the historical distribution (Lévéque 1997).

The Lower Guinean Province comprises a total of five freshwater ecoregions. The north of the Province has segments of two of these ecoregions. One is the **Northern Gulf of Guinea Drainages** ecoregion (as named by Abell *et al.* 2008; previously named the northern west coastal equatorial ecoregion, by Thieme *et al.* 2005), which is represented in northern Cameroon mainly by the Wouri River basin; the other is the **Lower Niger-Benue** ecoregion (represented by the upper section of the Sanaga river and its headwaters). These two ecoregions also extend north and west into the Nilo-Sudanic regions of West Africa. The small, yet highly distinctive, **Western Equatorial Crater lakes** ecoregion is in the highlands north of the Wouri river, adjacent to the south-western

Figure 1.2 Delineation of freshwater ecoregions within the central Africa region (adapted from Thieme *et al.* 2005), and the two major ichthyofaunal provinces of Lower Guinea and Congo, mapped to river sub-catchments.



part of the Nigeria-Cameroon border. This is an important conservation area (see Chapter 3). The main part of the Lower Guinean province is formed by two large and rather homogenous ecoregions: the **Southern Gulf of Guinea Drainages** ecoregion (as named by Abell *et al.* 2008; previously named the central west coastal equatorial ecoregion, by Thieme *et al.* 2005) in Cameroon, Equatorial Guinea, northern Gabon, and a very small part of the Republic of Congo; and the **Ogowe-Nyanga-Kouilou-Niari** ecoregion (as named by Abell *et al.* 2008; previously named the southern west coastal equatorial ecoregion, by Thieme *et al.* 2005) in southern Gabon, south-western Republic of Congo, Cabinda, and a small part of the Democratic Republic of Congo bordering Cabinda. The latter two, larger ecoregions include numerous small, forested black-water coastal basins, as well as the larger river basins of the lower Sanaga, Ogowe, Nyanga, Kouilou-Niari, and Chiloango.

1.2.1.2 Congo Basin Province (excluding Lake Tanganyika)
 The Congo River, with a length of 4,374 km (Runge 2007) is usually divided into three main sections, the upper (Lualaba), middle, and lower Congo. The headwaters of the main channel of the Congo arise in the savannahs of the Shaba highlands, in the south-eastern Democratic Republic of Congo, at an altitude of 1,400–1,500 m (Runge 2007). The Lualaba flows north, passing a series of falls and rapids, and is joined by the Luapula/Luvua system that drains Lake Mweru, as well as several rivers draining from the highlands of the central African Rift valley to the east. This upper section of the Congo ends at Boyoma Falls, just upstream of the town of Kisangani. There are five freshwater ecoregions associated with the upper Congo drainage. The upper Lualaba river and its major tributary, the Lufira River, form the **Upper Lualaba** ecoregion. The Luapula River, which drains from Lake Bangweulu to Lake Mweru, forms the **Bangweulu-Mweru** ecoregion. Downstream from the **Upper Lualaba** and **Bangweulu-Mweru** ecoregions is the **Upper Congo** ecoregion,

which comprises the Luvua (from where it exits Lake Mweru to its junction with the Lualaba), the Lualaba and its tributaries from the confluence with the Luvua to Boyoma Falls, and most of the course of the Lomami river running parallel to the Lualaba and slightly to the west of it (joining the Congo downstream from Kisangani, at Yangambi). Rivers draining to the Lualaba from the high elevations of the central African Rift valley to the east of the **Upper Congo** ecoregion comprise the **Albertine Highlands** ecoregion. The **Upper Congo Rapids** ecoregion, upstream from Kisangani, forms a boundary between the upper and middle sections of the Congo River.

The middle section of the Congo, starting at Boyoma Falls, turns west at Kisangani, then south-west following a large arc. This middle section is joined by several other large rivers that are themselves part of the huge Congo basin. The Aruwimi, Itimbiri, Mongala, Ubangi, and Sangha rivers drain from the north; and Lomami, Lulonga, Ruki/Lomela, and Kasai/Lukenie rivers drain from the central and southern parts of the basin. The middle part of the Congo River is not interrupted by rapids and forms wide, anastomosing channels (Runge 2007). It ends at **Malebo Pool**, where the river expands up to 28 km across, with several islands, and the waters slow down considerably.

Most of the middle section of the Congo lies within the large **Cuvette Centrale** ecoregion. However, some of the large tributaries and associated wetlands that drain into the middle Congo are recognized as discrete freshwater ecoregions. The Ubangi River, which joins the middle Congo from the north near the large settlement of Mbandaka (formerly Coquilhatville), comprises the **Sudanic Congo-Ubangi** ecoregion. This ecoregion covers much of the northern section of the Congo ichthyological Province. Upstream from Moboya, at Yakoma, the Ubangi splits into the Mbomou River, running to the north along the border between the Central African Republic and the Democratic

Family life at the edge of the river. Lower Lomami, DRC. Photo: © K.-D. Dijkstra.



Republic of Congo, and the Uele River to the south. The Uele, with its tributaries, form most of the **Uele** ecoregion in the north-east of the Democratic Republic of Congo.

The **Sangha** ecoregion, comprising the Sangha River and its tributaries, is adjacent to the **Ubangi** ecoregion to the north of the middle Congo. The **Lake Tumba** ecoregion, comprising the lake and associated wetlands which drain from the east into the middle Congo, is on the south-east bank of the Congo, near the confluence with the Ubangi. Further south, the Kasai River and its tributaries form the very large **Kasai** ecoregion. The major tributaries of the Kasai are the Kwango, Inzia, Kwilu, Kwenge, Loange, and Lulua rivers, joining the Kasai from the south and draining a large part of the southern and south-western Democratic Republic of Congo and northern Angola; the Sankuru that joins from the east; and the Fimi/Lukenie system which runs parallel to and just north of the main Kasai River. Waters draining from the **Mai Ndombe** ecoregion also connect to the Lukenie. The last ca. 80 km of the Kasai system, from the confluence of the Fimi to the main channel of the Congo, is named the Kwa. Malebo Pool (formerly Stanley Pool), which forms the junction between the middle and lower sections of the Congo, is also recognized as the discrete **Malebo Pool** ecoregion.

The outflow of Malebo Pool marks the start of the lower section of the Congo, and is bordered on each side of the river by the capital cities of Kinshasa (Democratic Republic of Congo) and Brazzaville (Republic of Congo). Between Kinshasa and Matadi, the river descends 280 m (over a length of 498 km) through at least 32 cataracts (Beadle 1981; Thieme *et al.* 2005) and perhaps as many as 66 (Roberts 1946), the most well known of which are the Inga rapids. The River reaches the Atlantic Ocean between Banana Point in the Democratic Republic of the Congo, and Sharks Point in Angola. The sediment-bearing plume of the river extends up to 20 km into the Atlantic, and the surface freshwater plume can be recognized up to 800 km from the mouth (Runge 2007). The short, lower section of the Congo includes two ecoregions; the **Lower Congo Rapids** ecoregion constituted by the main channel of the Congo (and bordered to the north by the **Ogowe-Nyanga-Kouilou-Niari** ecoregion of Lower Guinea), and the **Lower Congo** ecoregion that lies to the south of the main channel of the Congo.

1.2.2 Biophysical characteristics

The central African region includes an equatorial zone with tropical zones to the north and south. The highlands along the Rift valley at the eastern edge of central Africa also include some temperate zone habitats. However, the heart of the basin is within the equatorial climate zone where there is no real dry season. The rainfall in the equatorial region varies between 1,500 and 2,000 mm a year, with an average temperature of approximately 26°C. Average humidity is around 77.8% and evapotranspiration is 170 mm (Brummett *et al.* 2009a). The central African basin has annual renewable water resources of about 1.3 billion cubic

metres, and accounts for about 30% of the water resources in Africa (Brummett *et al.* 2009a).

Central Africa has thousands of kilometres of rivers, ranging from small coastal basins to the enormous Congo basin, and the basins incorporate savannah and rainforest. The rivers include low gradient ones such as the floodplain sections of Ogowe River, and some high gradient rivers such as those running off the highlands of the Cameroon/Nigerian border, or off the Albertine highlands at the central African Rift. There are some whitewater rivers (high in sediment) in central Africa, such as the Sanaga, Cross, Mungo, and Wouri rivers that flow through savannah in the **Northern Gulf of Guinea** and **Lower Niger-Benue** ecoregions of northern Lower Guinea (Stiassny and Hopkins 2007). There are also a few clearwater streams in the Mount Cameroun area. However, most rivers flowing through the rain forests of the southern part of the Lower Guinea province and the Congo province are “blackwater” (Thieme *et al.* 2005; Stiassny *et al.* 2007), with a hydrological regime and water temperature directly influenced by the presence of the forest. These rivers have mean pH values between five and six, and electrical conductivity between 20 and 30 µS/cm (Brummett and Teugels 2004). Water temperature is always between 20 and 30° C. The water in these rivers is tea-coloured as a result of tannins and the low dissolved nutrient concentration, low light (due to narrowness of valleys, extensive canopy cover, and often cloudy skies) and the large amount of allochthonous vegetative matter that falls or flushes into the water from the surrounding forest. The low dissolved mineral and nutrient concentration also means that these blackwater, rainforest rivers have low primary productivity, and the foodwebs are mostly based on the allochthonous plant materials from the forest. The large amounts of dead wood influence water depth and current velocity and provide shelter from predation, thus partitioning the stream and creating a large number of microhabitats.

Flooded swamp forest, either permanent or annual, is a typical feature of rainforest river headwaters. These contain very low dissolved oxygen and high carbon dioxide concentrations (pH is in the range of 4–5), but large quantities of allochthonous materials on a substrate of organic mud. Small, first order streams drain from these swamp forests or from other wetlands such as lakes or small springs. Welcomme (1976) estimated the total number of small, first order rainforest streams within central Africa at over 4 million, with a combined total length equal to half of all watercourses in Africa, making these the largest single riverine ecosystem on the continent. First order rainforest streams are typically less than 5 m wide, less than 50 cm deep, and are characterized by long stretches of shallow riffle interrupted by deeper, lower-velocity pools. Topographic relief in rainforests tends to be low, therefore current velocity in these rainforests seldom exceeds 0.5 m sec⁻¹. Canopy closure ranges between 25 and nearly 100%. Substrate is typically composed of leaf-covered sand or gravel. As one proceeds downstream, to medium sized streams there is a tendency for decreasing canopy closure, current velocity, allochthonous material and electrical conductivity, and

increasing depth, quantities of fine sediment and large boulders, dissolved oxygen and pH.

The Congo River itself contains many habitat types, including waterfalls at the edges of the Congo basin in the region of the **Uele** and **Albertine Highlands** ecoregions; gorges with powerful rapids in the main channel of the Congo downstream from Kinshasa (in the **Lower Congo Rapids** ecoregion), and upstream from Kisangani (in the **Upper Congo Rapids, Upper Congo, and Upper Lualaba** ecoregions); and large channels with islands and adjacent floodplains (in the **Cuvette Centrale** ecoregion). The large floodplain forests and swamps of the Cuvette Centrale, and the lakes of Mai Ndombe and Tumba are the remnants of a former, larger lake that existed during the Pliocene (ca. 5.3–2.6 million years ago). At this time the middle and upper sections of Congo were disconnected from the sea and drained into an endorheic basin in the region of the **Cuvette Centrale** ecoregion (Lévéque 1997; Kamdem *et al.* 2006; Thieme *et al.* 2008).

The modern day flow of the Congo River, which is influenced by several complex factors, has an average annual discharge (measured at Kinshasa) of $46,200 \text{ m}^3\text{s}^{-1}$ (Runge 2007; Brummett *et al.* 2009a). The range in discharge falls between the minimum and maximum values of $23,500 \text{ m}^3\text{s}^{-1}$ (in July and August) and $64,900 \text{ m}^3\text{s}^{-1}$ (in December) respectively. The major, northern drainages of the Ubangi and its tributaries have a single annual peak of high water and similarly one of low water. However, the drainages to the south, such as the Kasai, Lualaba, Luapula, and their tributaries, have two peaks each of high water and low water. The period of peak flow in the northern drainages occurs between September and November, which coincides with a period of minimum flow for the major, southern drainages. Similarly, one of the peak flows for the southern drainages, occurring in March and May, coincides with the minimum flow for the northern drainages. Because these minimum and maximum flows for northern and southern drainages occur concurrently, they tend to balance each other's effects and the seasonal variation in flow for the middle to lower parts of the Congo is not extremely large. By comparison, most of the large rivers of the Lower Guinea region have a more obviously bimodal discharge pattern (Mahé and Olivry 1999). In general, the magnitude of fluctuation is greater in the north (up to 8 m on the Lower Cross) and south (Peyrot 1991).

Besides its extensive river networks, central Africa has several lake systems. These are variable in size, origin and ecology. Among the smallest are the volcanic crater lakes that traverse the western edge along the Nigeria-Cameroon border, which are known for the high proportion of endemic species and their interesting geomorphology. One of these, Lake Nyos, is best known because of its sudden release of carbon dioxide from super-saturated deep waters, that killed over 5,000 people and livestock in 1986. In the Congo basin there are several shallow lakes that are characterised by extensive swamp forest, such as Lake Tele in the Republic of Congo, and the larger Lakes Tumba and Mai Ndombé in the Democratic Republic of Congo. The Congo basin also includes the Albertine

Rift lakes of Bangweulu (shallow, at 10 m depth) and Mweru (slightly deeper at 37 m depth) and their associated wetlands. Also, the Upemba Depression (also called the Kamolondo Depression), near the junction of the Lufira with the Lualaba River, includes a mosaic of lakes and wetlands that seasonally extend between 8,000 and 11,840 km² (in the flood season).

1.2.3 Aquatic biodiversity

In addition to some 77 million people, the central African rainforests (Lower Guinean and Congo forests combined) harbour the greatest biodiversity on the continent with approximately 1,000 fish species, 400 mammal species, 1,000 birds and over 10,000 vascular plants (CARPE 2001; African Development Bank 2006). However, even these are likely underestimates because taxonomic surveys are lacking for much of central Africa and new species are continually being discovered (e.g., Lévéque *et al.* 2005; Frost *et al.* 2006). Nonetheless several studies recognize freshwater biodiversity hotspots in the region (Groombridge and Jenkins 1998; Kamdem-Toham *et al.* 2003; Thieme *et al.* 2005). About 15 strictly aquatic mammals live in the waters of central Africa; including several that are endemic (e.g., the aquatic genet (*Osbornictis piscivora*), Ruwenzori otter shrew (*Micropotamogale ruwenzorii*), and giant otter shrew (*Potamogale velox*)). There are at least 73 Important Bird Areas in the central Africa region (perhaps as many as 123). The region also has a rich herpetofauna, with upwards of 280 aquatic frogs, and about 20 aquatic snakes, turtles and crocodiles are known (Brummett *et al.* 2009a). Most of the coastal sub-basins of Cameroon and Gabon each have more than 10 co-occurring species of turtle, as do the lower to middle sections of the Congo river and lower part of the Ubangi River (compared to the global maximum of 19 co-occurring species found in just two sub-basins in the world) (Buhlmann *et al.* 2009). The Democratic Republic of Congo is also one of only two countries in the Afrotropical realm with more than 200 scientifically recognized species of amphibians (the other country is Madagascar). If species that are still awaiting scientific description are included in the counts, then Cameroon also has more than 200 species of amphibians (Andreone *et al.* 2008; Amiet 2008). Diversity of freshwater crabs appears to be highest in the lower parts of the Congo Basin and the upper reaches, including those draining from Rwanda and Burundi (Groombridge and Jenkins 1998). South-east Nigeria, southern Cameroon, and Gabon also host three endemic genera and more than 10 endemic species of freshwater crabs (Cumberlidge 1998, 2008).

There are several factors that contribute to the high richness of freshwater species in the Lower Guinea, and more noticeably, Congo provinces. The geographic extent, dense hydrographic network, and diversity of river types and available habitats (see 1.2.1) are leading reasons. Hydrographic barriers between habitats also promote species diversity and richness; e.g., waterfalls at the edges of the Congo basin in the region of the **Uele** and **Albertine Highlands** ecoregions, and rapids in the main channel of the Congo (Thieme *et al.* 2005; Brummett *et al.* 2009a; and see discussion above). The region has remained environmentally stable



Wetland near Sanga river, Cameroon. Photo: © David Allen.

since at least the Pleistocene, about 12,000 years ago (Kamden *et al.* 2006; Thieme *et al.* 2008); the equatorial position and large amount of forest cover mean that much of the Congo Province region is climatically relatively stable, which also helps support species richness.

Some of the basins of Lower Guinea, especially the Ntem and Ogowe, share components of their freshwater flora and fauna with the Congo province. This is partly thought to be due to river captures that have occurred at the headwaters of the Lower Guinean rivers. It is probable, for example, that the upper reaches of some of the tributaries to the Congo, such as the Sangha, have captured headwaters of Lower Guinean rivers such as the Nyong and Ntem, resulting in a mixing of freshwater flora and fauna (as documented for fishes and molluscs; Stiassny *et al.* 2007).

The forested nature of the watershed is the major determinant of productivity and community structure in rainforest rivers. Stream width, depth, current velocity and substrate type have been identified as critical in determining the spatial distribution of most species (Lowe-McConnell 1975; Kamdem-Toham and Teugels 1997). These are all in one way or another, determined by the degree of canopy closure over the river from the surrounding forest. Species diversity and richness both increase as one moves downstream from headwater swamp, to first-order forest stream, to medium-sized tributary to the main channel (Géry 1965). The large quantities of allochthonous materials present on the mud substrates of swamp forests provide rich food resources; however, the low dissolved oxygen and high carbon dioxide concentrations

mean that these habitats are often restricted to species that are adapted to these anoxic conditions (e.g. fishes with accessory breathing organs).

The alternation between shallow riffle and deeper, slower-flowing pools in many first order streams provide a mix of habitats for different communities. The deeper pools also provide small patches of habitat where fishes and other aquatic species can shelter during dry periods when streams stop flowing. Medium-sized streams are transitional zones (Lévêque 1997) supplying different types of habitats from those found in the first order streams, and the main channels of rainforest rivers represent the most stable biotope and offer the greatest range of micro-habitats.

1.2.4 Regional threats

There are many different types of threats to African freshwaters, and their impacts are felt across the entire continent (see Getahun and Stiassny 1998; Thieme *et al.* 2005; Chapman *et al.* 2008; Darwall *et al.* 2009). Only in recent years has the Central African Program for the Environment (CARPE), based in Kinshasa, DRC, initiated efforts to gain a basic understanding of the fisheries ecology of these systems. A major threat to central African freshwater ecosystems is loss of riparian habitat through deforestation, and the reduction of water quality through pollution (e.g., from mining activities, human settlement, and runoff of agricultural fertilizers) and increased sediment loads (caused by erosion of deforested and farmed land) (Brummett *et al.* 2009).

Lower Itimbiri, DRC. Photo: © K.-D. Dijkstra.



1.2.4.1 Deforestation and impacts on water quality

Increasing population and poverty, coupled with false valuations of rainforest biodiversity have led to habitat destruction and over-exploitation of the forest resources (Stiassny 1996). Deforestation is driven by a variety of factors including commercial logging for timber, conversion for human habitation, mining, or agriculture, and production of firewood increasingly in the form of charcoal transported to population centres. The Congo Basin has already lost an estimated 46% of its rainforest to logging and conversion to agriculture, and continues to lose forested watershed at an average rate of 7% per year (Revenga *et al.* 1998). This loss of forest has major effects on ecosystem structure and function, and is perhaps the greatest threat to the freshwater ecosystems of central Africa. For example, water temperature and hydrological regime of rivers are affected by the forest (Brummett *et al.* 2009a). As noted above, the dead wood that accumulates in rivers and wetlands affects depth and current, provides multiple habitats for aquatic organisms, and is an essential source of nutrients for food webs in blackwater streams. Loss of riverside vegetation exposes aquatic species to levels of sunlight and temperature that are too high for many of them, and that may also promote the development of algal blooms that then cause eutrophication. This loss of cover also deprives many species, especially fishes, of shelter from predators such as birds and mammals.

Deforestation exposes delicate forest soils that are easily eroded, and washed into streams and rivers that become increasingly turbid. The sediment carried in the river can clog the gills of fishes and other gill-breathing organisms (Roberts 1993), can cover and suffocate eggs, and may reduce the available light to levels that are too low for many submerged aquatic plants. These plants are also killed when sediments coat their surfaces, blocking their stomata and preventing photosynthesis. Sediment which is deposited on submerged surfaces also reduces food supplies and habitats for many other species, as well as disrupting breeding sites. Also, given that watershed forests are controlling factors for rainfall and peak flow flooding events in freshwater systems, the loss of forest will contribute to disrupted flows, and increased likelihood of flooding, which also impacts freshwater biodiversity (Bradshaw *et al.* 2007, 2009; Brummett *et al.* 2009a; Farrell *et al.* 2010).

Commercial logging occurs in several of the larger river basins of Lower Guinea, including the Nyong (Cameroon), the Ogowe/Ivindo system (Gabon), and Kouilou/Niari systems (Republic of Congo). Deforestation, as noted above, either for firewood/charcoal, logging, or as part of land clearing for agriculture or mining, has also occurred in many parts of the Congo basin. The threats are relatively large in the **Upper Congo** ecoregion, with Kivu Province currently experiencing the highest levels of deforestation for the entire Democratic Republic of Congo (Thieme *et al.* 2005). In the **Kasai** ecoregion extensive deforestation had already occurred during the mid 20th century, though some areas of forest remain and are under threat, particularly for charcoal production to supply Kinshasa (Thieme *et al.* 2005). The impacts of logging, including the effects of increased accessibility to the region provided by logging roads (see below), are some of the major threats

to freshwaters of the **Sangha** ecoregion. Similarly, the impacts of logging threaten the Ubangi river and tributaries in the northern parts of the Republic of Congo.

The **Cuvette Centrale** ecoregion includes large areas of forest and associated seasonally flooded wetlands in the central Congo basin that are currently relatively inaccessible, hence they face relatively fewer threats and the forest is in closer to a pristine condition. However, according to Thieme *et al.* (2005), 37% of the total exploitable rainforest has been designated for timber concessions (80% in Cameroon), and this removal of riparian forest would severely affect the diversity of species of fishes in the rivers and wetlands and potentially undermine their ecological integrity (CARPE 2001). Deforestation is currently a problem in the north-eastern parts of the Cuvette Centrale, caused by illegal logging from Uganda and by refugees displaced by the civil unrest in neighbouring countries.

The central African forests are being harvested in a largely irresponsible manner that not only takes out the valuable timber and exacerbates runoff and siltation (as discussed above), but also crushes the understory, and creates more uniform stream courses with straighter channels, fewer riffles, and more pools. Mino-Kahozi and Mbantshi (1997), Kamdem-Toham and Teugels (1999), Bruijnzeel (2004) and Brauman *et al.* (2007) have described the changes that occur in and around rainforest rivers as a result of poorly managed logging operations. Road construction, saw mills and other infrastructure associated with logging attracts people into the forest, resulting in wholesale transformation of the ecosystem (Burns 1972; Garman and Moring 1993). A particular problem in some areas is that the cleared land and new roads increases the probability of mineral prospecting.

Comparisons of undisturbed and disturbed sites show that the changes in water quality can be quite severe. In undisturbed sites, water was clear brown with a mean temperature of 23.5°, dissolved oxygen between 2.5 and 4.2 mg/l (measured at noon) and electrical conductivity between 20 and 30 µS/cm. In sites affected by logging, the water was cloudy with a mean temperature of 34°, dissolved oxygen of <1.0 mg/l and average electrical conductivity of 48 µS/cm. Changes of this magnitude wreak havoc on aquatic life and may last for many years (Grown and Davis 1991) and in isolated systems where recolonization is limited, may be irreversible.

1.2.4.2 Land Conversion for plantations and agriculture, and impacts on water quality

Conversion of landcover to plantations has occurred in many regions. Habitat degradation from banana, rubber and oil palm plantations, including pollution and sedimentation, are particular problems in Southern Cameroon. Along the coast, approximately from the Ndian to the Kribi (Kienké) rivers some of the world's most biodiverse rainforest has been converted to oil palm plantations. Eucalyptus plantations (for firewood and building materials) occur along the coast of the Republic of Congo

and Cabinda. Parts of the **Upper Congo** ecoregion have also been converted to oil palm, and there are plans for development of additional oil palm plantations, with Chinese subsidization, around Lake Tumba.

Clearing of land for agriculture, often by slash and burn, are common, especially in parts of Lower Guinea. According to CARPE (2001), some 21,000 km² ha of rainforest are lost each year in the Lower Guinea region. Livestock are frequently placed on the cleared land, resulting in overgrazing. Unmanaged clearing the land and grazing usually result in soil erosion and increasing sedimentation in the freshwater ecosystems (as noted above). In addition, pesticides and fertilizers applied to agricultural lands wash into the freshwater systems, polluting them and promoting eutrophication. Slash and burn agriculture occurs around Lake Tumba, and is likely to impact the freshwater ecosystems of the region. Inogwabini *et al.* (2006) commented on the soil erosion and sedimentation of Lake Tumba caused by large numbers of villages at the shore. Thieme *et al.* (2005) note that clearing of seasonally inundated forests in the south-west part of Mai Ndombe, for rice cultivation, could have a significant impact on those freshwater ecosystems. Forest has also been cleared for agriculture in the **Upper Congo** ecoregion.

1.2.4.3 Mining and drilling, and impacts on water quality

Mining activities impact central African freshwater ecosystems because they cause pollution and increased sedimentation, as well as deforestation in the region of the mines. Mining for gold, diamonds, and several other mineral ores occurs in parts of Lower Guinea. (e.g. in the Ogooué system, and Kouilou/Niari and Chiloango basins), but is ubiquitous in the Congo basin. For example, logging in the **Sangha** ecoregion has increased the probability of mineral prospecting in that area. Thieme *et al.* (2005) note that industrial gold mining near the border between the Republic of Congo and Cameroon, and alluvial diamond mining in the upper reaches of the Sangha, in the Central African Republic, have caused increased sedimentation and pollution in these rivers. In the Ubangi drainage, diamond mining occurs upriver from Bangui towards the confluence with the Uele resulting in pollution and sedimentation. Sediment washed into the river from mining and from agricultural development (e.g., in the region of Mpoko, north of Bangui) has reduced the depth of the river downstream from Bangui and a lack of sufficient water in the river causes problems for shipping for four to five months most years (Brummett *et al.* 2009a). Some mining activities also occur in the eastern part of the **Uele** ecoregion although, for the most part, the inaccessibility of the ecoregion means that it is less significantly impacted.

In the **Cuvette Centrale** ecoregion, mining occurs along the middle Congo between the confluence with the Itimbiri and Kisangani. It also occurs especially along the eastern perimeter of the **Upper Congo** ecoregion and the north-eastern **Albertine Highlands**. The impacts of mining represents one of the greatest threats to freshwater ecosystems in the **Upper Lualaba** and **Kasai** ecoregions. In the **Upper Lualaba** ecoregion there is extensive

mining for several different minerals, including cobalt, copper, tin, and uranium. Diamond mining occurs in the upper parts of several of the river basins of the **Kasai** ecoregion. This diamond mining, although artisanal, is intense and causes major habitat modification as well as increased sedimentation from digging sand from the river bed and from clearing of riparian vegetation. Copper mining also occurs in the upper parts of the Kasai, though most commercial mining in the region has declined due to civil unrest centred in neighbouring Angola. The relatively large human population in the Kasai region, and the possible resumption of commercial mining following greater civil stability, are significant future threats for the region.

Oil exploration along the coast of Gabon, Cabinda, and the Republic of Congo impacts some of the coastal drainages. This occurs either directly from oil pollution, or from the impacts on coastal habitat caused by development of service industries supplying the oil companies. Shumway *et al.* (2003) note that presence of oil in the lower Kasai region may attract industrial exploration which would pose a threat in the future. Also, methane deposits discovered under Mai Ndombe are likely to be exploited, which will further threaten its freshwater ecosystems.

1.2.4.4 Dams

Dams and water extraction are less of a threat in central Africa than in other parts of Africa (especially compared to southern Africa; see Darwall *et al.* 2009). Nevertheless, dams, both in Lower Guinea and in the Congo basin pose local but very severe threats in several regions. Moreover, the potential for future development of hydropower projects is large. At the end of 1999, the total installed operational capacity of hydropower in the Congo Basin was reported at 5,751.5 MW, 43% (2,508 MW) of which is located in the Democratic Republic of Congo (Brummett *et al.* 2009a). Those authors found that inventories of currently operating power stations report a total operating power of over 4.4 million KW. However, this current operational capacity is only a small fraction of the estimated hydropower potential in the Congo Basin, which may be the most important region for future hydroelectric development throughout the entire African continent (Brummett *et al.* 2009a).

Altered flow and sediment load downstream from dams impacts many species and ecosystem functioning, and the impoundment of rivers and conversion of large sections of the rivers into lakes results in widespread loss of habitat. Several dams have been constructed on rivers in Lower Guinea, including some large dams (over 30 m) on the Sanaga, Mape (Cameroon), M'Bei (Gabon), and the largest is the Moukoukoulou dam (60 m) on the Bouenza River (Republic of Congo). There are fewer dams in the Congo basin province, with several of them concentrated in the **Lower Congo Rapids** ecoregion or the headwater regions of the **Upper Congo** and **Upper Lualaba** ecoregions. The largest dam project for central Africa is in the region of the rapids at Inga, where two dams are in operation (Inga I and II) although only at half their installed capacities of 358 and 1,424 MW respectively (Brummett *et al.* 2009a). A third dam (Inga III) of 4,500 MW has been proposed but development, due to start in 2010, has stalled. Finally a fourth, huge dam of

39,000 MW capacity (approximately twice the size of the Three Gorges Dam in China), termed 'Grand Inga' had been proposed for development by 2025. The compound effect of these dams would be severe, diverting part of the Congo River flow into a large reservoir and changing the downstream flow and ecology. In addition the industrial infrastructure, roads, and housing for workers, necessary for creating these dams and the power stations and extensive power distribution lines, would be very large and would likely add to the pollution and siltation of the river. Due to the devastating effects that would be caused by a reservoir of that size, plans for the Grand Inga Dam have now been replaced by Grand Inga Cascades, as a 'run of the river' structure designed not to disrupt the river flow (Showers 2009). Whilst this should massively reduce some of the impacts of the scheme, all the associated infrastructure impacts will still be prevalent. Other dams of the Lower Congo Rapids region that are likely to pose significant threats to the freshwater biodiversity include the 17 m Zongo dam on the Inkisi River (built to increase power capacity supplied to Kinshasa), and the 36 m Djoue dam on the Djoue river near Brazzaville.

Further upriver in the Congo basin, the 30 m Mobaye dam on the Ubangi is assumed to pose a threat to freshwater species. In the upper parts of the Congo several large dams have been built on the headwaters of the rivers, to supply power to support the mining industries in this region. Three large dams of over 70 m exist on the upper Lualaba, and smaller dams (less than 20 m) are on the Lufira.

1.2.4.5 Human settlement and civil unrest

Impacts of human settlement are not as extensive for central Africa as for much of the remainder of the continent, but there are some regions where water quality is compromised by urban pollution. There is relatively dense human settlement in northern Lower Guinea, near the border with Nigeria, though most of the impacts of this human settlement are from land clearing (especially for agriculture). There are some other large towns and cities in central Africa which lack adequate infrastructure to deal with inorganic chemical pollution and sewage. Large volumes of sewage are released either untreated or very poorly treated from the cities of Brazzaville and Kinshasa into Malebo Pool and the Congo River downstream. In addition, a large amount of lead and waste oil drains into the river, originating from industry and cars in the cities, or from boat traffic on the river. Even at Inga, about 300 km downstream from Kinshasa, the waters are significantly polluted by heavy metals, especially lead and cadmium (Shumway *et al.* 2003). The main channel of the Ubangi is impacted by pollution from the city of Bangui, and impacts of urbanisation are also large in the vicinity of Kisangani where up to 95% of industrial waste is dumped into rivers (UNEP 1999). However Thieme *et al.* (2005) note that subsequent to the civil unrest in the area it is not clear whether industrial activity is still as extensive as it once was. Much of the northern and north-eastern Congo basin is relatively isolated and minimally impacted by human settlement. However, some railway development has occurred

Artisanal fisherman's basket trap, at Yalala rapids, lower Congo, Democratic Republic of Congo Photo: © Robert Schelly.



in the **Uele** ecoregion, which may bring threats to the otherwise undeveloped eastern parts of this region.

While civil unrest might have reduced the scale of some of the industrial drivers of threats to freshwater ecosystems (e.g., logging and mining), it has exacerbated several other known drivers. In eastern parts of the **Upper Congo**, **Uele**, and especially in the **Albertine Highlands** ecoregions, war and civil unrest adjacent to the border of the Democratic Republic of Congo with Uganda and Rwanda have displaced local communities into previously undisturbed regions of the forest. Thieme *et al.* (2008) note that the displaced populations tend to resettle along waterways and depend upon the natural resources for their livelihoods. In many cases this results in increased riparian deforestation and habitat disturbance, which impacts the rivers and has compromised the safety of some National Parks and reserves. Further west, in the **Sangha** ecoregion in the Republic of Congo, refugees from civil unrest in the Democratic Republic of Congo have congregated near the confluences of the Sangha, Likouala and Ubangi rivers within the middle section of the Congo. It is likely that their presence will threaten the freshwater resources in this region.

1.2.4.6 Overharvesting

Threats from poorly managed fisheries and overharvesting are not commonly reported in the Lower Guinea and Congo basin provinces, but have been noted for some species, e.g., the goliath tigerfish, *Hydrocynus goliath*, in the lower and middle Congo River, and the freshwater prawn, *Macrobrachium vollenhovenii*, in the coastal rivers of southern Cameroon and overfishing is reported in Lake Tumba. Among the greatest problems associated with fisheries are the use of extremely fine mesh nets, and fish poisons that indiscriminately kill individuals of all sizes for most if not all species present, and which may also impact the habitat where they are. Some species of fishes have also been the focus of commercial fisheries for the aquarium trade (see Chapter 3).

1.2.4.7 Invasive species

There are few data on specific impacts of alien species. One of the most widespread invasive species is the water hyacinth (*Eichhornia crassipes*) which extends throughout the Congo River, as well as several tributaries and the Nyong River of Lower Guinea. The economic impacts of the water hyacinth are estimated at USD 20–50 million every year in seven African countries and may be as much as USD 100 million annually across all of Africa (Chenje and Mohamed-Katerere 2006). Sixteen species of fishes have been introduced to the central Africa region (Welcomme 1988; Stiassny *et al.* 2007 has a chapter on introductions to Lower Guinea; and see Chapter 3).

1.2.4.8 Climate change

Climate change models for Africa are still unclear, and the impacts of anthropogenic climate change on freshwater biodiversity have only recently begun to be considered (Schiermeier 2008; Thieme *et al.* 2010). Nevertheless, it is expected that Africa will be severely

impacted by climate change, and by the 2050s over 80% of Africa's freshwater fish species may experience hydrologic conditions that are substantially different from the existing conditions. Thieme *et al.* (2010) predict that, for much of the Guinean-Congolian forest, a general increase in runoff (spatial land surface and subsurface flow generated locally) and in discharge (river channel flow from accumulated runoff after routing downstream through the drainage network). However, slightly different regional responses have also been observed. Neiland and Béné (2008) have noted that the inland fisheries of Cameroon have been impacted by drought. Inogwabini *et al.* (2006) state that there has been a 4.5% decrease in precipitation in the Congo basin if one compares the levels of 1951–1959 to those of 1960–1989. In the region of Lake Tumba rainfall frequency and intensity declined from 1971 to 1997, and the mean daily temperature decreased from around 25°C between 1970 and 1988, to around 19.5°C between 1989 and 1997 (Inogwabini *et al.* 2006). Those authors commented that there has been a continuous drying up of the Lake Tumba region. They also stated that the depth of Lake Tumba has dropped by 50%, from 6 m in the late 1970s to 3 m (see also Chapter 3) and they attributed this to decreasing rainfall, and to siltation that is caused, in part, by the erosion soils that are newly exposed by the declining water levels.

There are several possible impacts of climate change on hydropower programs. These include increased flooding and sediment loads (in the event of increased rainfall), or a decrease in hydropower potential (in the event of decreased rainfall) (Mukheibir 2007; Paeth and Thamm 2007; Brummett *et al.* 20009a). The fact that many large dams have been developed at the expense of the freshwater local freshwater ecosystems and the rural communities supported by the ecosystems has prompted the development of a series of guidelines and improved practices for decision making and risk assessment by the World Commission on Dams and the dams development project (Brummett *et al.* 2009a).

1.2.5 Regional use and value of wetlands and their biodiversity

A critical aspect of securing the protection of inland waters is a proper economic valuation of the entire range of goods and services that they provide, as discussed at the start of this chapter. Over 200 million of Africa's 1 billion people consume fish regularly, and nearly half of this fish supply comes from the continent's inland waters (UNEP 2010). Freshwater fish provide 22% of protein intake in sub-Saharan Africa (Béné and Heck 2005). Consequently, just within western and central Africa, the main rivers and their floodplains provide a livelihood to 227,000 fishers, and have a potential total annual fishery production of 1.33 million tons, with a potential annual value of USD 749 million. The actual value of all inland fisheries for those countries in western and central Africa that have major fisheries is USD 1,415 million per year (Neiland and Béné 2008).

Artisanal and traditional fisheries account for 90% of the catch from the central African rainforests (Mino-Kahozi and

Mabantshi 1997). Estimates from Cameroon put the productivity of capture fisheries in forest rivers basins at about 1 tonne/km²/yr (du Feu 2001; UNEP 2010). Estimates of annual fish catch from the Congo basin are in the neighbourhood of 120,000 metric tonnes. In addition to generating the majority of animal protein consumed by rural communities, the approximate value of the catch, \$50 million, represents an important proportion of GNI in the rainforest zones. Potential for the fishery in the mid 1980s was estimated at 520,000 tonnes worth \$208 million (Neiland and Béné 2008). Chapman and Chapman (2003) estimate that this value represents only 41% of the potential total catch in the DRC.

The riverine network of the Congo basin also provide a crucial navigation and transportation system that extends for over 12,000 km between the different countries in the region. This network is the primary conduit for the exchange of goods and services and is vital for local livelihoods and the revival of the regional economy. Additionally, seasonally inundated areas are important for rice production. As noted above, properly functioning freshwater ecosystems also moderate the regional impacts of climate change (Kamden-Toham *et al.* 2006). Sheil and Mudiyarso (2009) indicated that intact forest cover in the Congo basin contributes to the high rainfall there.

Emerton (2005) provides a very clear example, from northern Cameroon, of the importance of the proper valuation of freshwater ecosystems. Her study focuses on the Waza Logone floodplain, where annual flooding originally inundated an area of 3,382 km², which was nearly half the total floodplain area. This flooding supported fisheries, agriculture, replenishment of pasture for livestock, and habitat for wildlife for subsistence hunting and tourism. Thus, the flooding contributed over \$10 million a year to the regional economy. A rice irrigation scheme, started in 1979, reduced the extent of seasonal flooding by 30%, and resulted in an annual economic cost to the local population of more than \$2 million. To redress this problem, pilot flood releases were instigated in 1994 and 1997, and these restored floodplain goods and services to a value of over \$800,000 a year. Emerton (2005) noted that further re-inundation options under consideration would generate economic benefits of between USD 1.1 million to \$2.3 million a year, translating into an added net economic value of between \$5.6 million to \$7.8 million when investment and operation costs are taken into account.

1.3 The Precautionary Principle and species conservation

The central argument of the Precautionary Principle is that, in cases where potential threats could lead to serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. This Precautionary Principle should, therefore, be an essential tool for guiding policy decisions concerning environmental protection and management. It is

a critical part of species conservation and should be applied in circumstances where there are reasonable grounds for concern that an activity may cause harm to the environment but where there is uncertainty about the probability of the risk and the degree of harm.

Darwall *et al.* (2009) stated that, even when the economic value of a wetland and its associated biodiversity has been determined as high, it may still remain a difficult task to justify the need to conserve all species in those wetlands. This is particularly true where the diversity is already exceptionally high such as in the freshwater fish communities of many African lakes. In such cases fishery managers may argue that it would be easier to manage a fishery of just a few fast-growing and commercially valuable species than to manage the multi-species fisheries typical of these lakes. However, Darwall *et al.* (2009) showed that this approach may be misguided, using Lake Victoria as an example. In this case, exotic species were introduced to the lake, which then contributed to the population decline or possible extinction of up to 200 species cichlid fishes. These cichlids formerly provided the main source of income and protein to many lakeside communities (Witte *et al.* 1992). However, ongoing research also shows that some formerly rare species that were poorly represented in fishery catches appear to be species that are best adapted to the degraded environmental conditions now prevailing in the lake (e.g. Witte *et al.* 2007b, 2008). A few of these species are now starting to dominate in the fish community and form the basis for some of the present day fisheries. If these species had been lost, having been considered redundant and not worthy of conservation, then it is possible that the remaining species would be unable to survive the present degraded conditions and future fisheries might be lost. The evidence from this study shows that there is considerable ecological and economic value to adopting the Precautionary Principle.

1.4 Objectives of this study

IUCN initiated a programme in 2007 to build capacity to conserve and sustainably manage inland water biodiversity resources throughout central Africa. As noted above, a lack of basic information on species distributions and threatened status in these systems has long been a key obstacle facing freshwater ecosystem managers in the region. Specifically, the project aimed to:

- i) provide the required biodiversity information through establishing a regional network of experts and training them in biodiversity assessment tools;
- ii) collate information for assessments of conservation status and distributions of biodiversity throughout the inland waters of central Africa; and
- iii) store, manage, analyse and make widely available that biodiversity information within the IUCN Species Survival Commission (SSC) data management system, the Species Information Service (SIS), and throughout the regional and global presence of IUCN and partners.

1.5 References

- Abell, R., Thieme, M.L., Revenga, C., Bryer, M., Kottelat, M., Bogutskaya, N., Coad, B., Mandrak, N., Contreras Balderas, S., Bussing, W., Stiassny, M.L.J., Skelton, P., Allen, G.R., Unmack, P., Naseka, A., Ng, R., Sindorf, N., Robertson, J., Armijo, E., Higgins, J.V., Heibel, T.J., Wikramanayake, E., Olson, D., López, H.L., Reis, R.E., Lundberg, J.G., Sabaj Pérez, M.H. and Petry, P. 2008. Freshwater Ecoregions of the World: A new map of biogeographic units for freshwater biodiversity conservation. *BioScience* **58**(5): 403–414.
- Abramovitz, J.N. 1996. Imperilled waters, impoverished future: the decline of freshwater ecosystems. Worldwatch Paper 128. Worldwatch Institute, Washington DC, USA.
- African Development Bank Group. 2006. Eta des lieux de la gestation des resources en eau dans le basin du Congo.
- African Development Bank Group. 2009. Africa Regional Paper. Bridging Divides in Africa's Water Security: An Agenda to Implement Existing Political Commitments. Available at: http://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/5th%20WWF_AFRICA%20REGIONAL%20PAPER_FINAL.pdf
- Amiet, J.-F. 2008. Frog biodiversity in Cameroon. In: Stuart, S.N., Hoffmann, M., Chanson, J.S., Cox, N.A., Berridge, R.J., Ramani, P. and Young, B.E. (eds.) *Threatened Amphibians of the World*, p. 61. Lynx Edicions, Barcelona, Spain; IUCN, Gland, Switzerland; and Conservation International, Arlington, Virginia, USA.
- Andreone, F., Channing, A., Drewes, R., Gerlach, J., Glaw, F., Howell, K., Largen, M., Loader, S., Lötters, S., Minter, L., Pickersgill, M., Raxworthy, C., Rödel, M.-O., Schieltz, A., Vallan, D. and Vences, M. 2008. Amphibians of the Afrotropical realm. In: Stuart, S.N., Hoffmann, M., Chanson, J.S., Cox, N.A., Berridge, R.J., Ramani, P. and Young, B.E. (eds.) *Threatened Amphibians of the World*, pp. 53–64. Lynx Edicions, Barcelona, Spain; IUCN, Gland, Switzerland; and Conservation International, Arlington, Virginia, USA.
- Balian, E.V., Segers, H., Lévéque, C. and Martens, K. 2008a. An introduction to the Freshwater Animal Diversity Assessment (FADA) project. *Hydrobiologia* **595**: 3–8.
- Balian, E.V., Segers, H., Lévéque, C. and Martens, K. 2008b. The Freshwater Animal Diversity Assessment: an overview of the results. *Hydrobiologia* **595**: 627–637.
- Balian, E., Harrison, I., Barber-James, H., Butchart, S.H.M., Chambers, P., Cordeiro, J., Cumberlidge, N., De Moor, F., Gascon, C., Kalkman, V., van Dijk, P.P. and Yeo, D. 2010. A wealth of Life: Species Diversity in Freshwater Systems. In: Mittermeier, R.A., Farrell, T.A., Harrison, I.J., Upgren, A.J. and Brooks, T.M. (eds.) *Fresh water: the essence of life*, pp. 53–89. CEMEX and ILCP, Arlington, Virginia, USA.
- Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R.E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K. and Turner, R.K. 2002. Economic reasons for conserving wild nature. *Science* **297**: 950–953.
- Baron, J.S., Poff, N.L., Angermeier, P.L., Dahm, C.N., Gleick, P.H., Hairston Jr., N.G., Jackson, R.B., Johnston, C.A., Richter, B.D. and Steinman, A.D. 2002. Meeting ecological and societal needs for freshwater. *Ecological Applications* **12**(5): 1247–1260.
- Baron, J.S., Barber, M., Feest, A., Gilliam, F., Lu, X., Stevens, C.J., Woodin, S., Bobbink, R., Adams, M., Agboola, J., Allen, E., Bealy, B., Bobrovsky, M., Bowman, W.D., Branquinho, C., Bustamente, M., Clark, C.M., Cocking, E., Cruz, C., Davidson, E., Denmead, T., Dias, T., Dise, N., Harrison, I., Galloway, J.N., Geiser, L., Khanina, L., Manrique, E., Ochoa-Hueso, R., Ometto, J.P., Payne, R., Scheuschner, T., Sheppard, L.J., Simpson, G., Singh, Y.V., Strachan, I., Sverdrup, H., Tokuchi, N. and van Dobben H. 2011. The effects of atmospheric N deposition on terrestrial and freshwater biodiversity. *Proceedings of the 2009 Workshop of the International Nitrogen Initiative: N Deposition, Critical Loads and Biodiversity*.
- Beadle, L.C. 1981. *The inland waters of tropical Africa*, second edition. Longman, London, UK. 475 pp.
- Béné, C. and Heck, S. 2005. Fish and Food Security in Africa. *Naga The WorldFish Center Quarterly* **28** (3 and 4): 8–13.
- Bogart, A.E. 2008. Global Diversity of Freshwater Mussels (Mollusca, Bivalvia) in Freshwater. *Hydrobiologia* **595**: 139–147.
- Bradshaw, C.J.A., Sodhi, N.S., Peh, K.S.-H. and Brook, B.W. 2007. Global evidence that deforestation amplifies flood risk and severity in the developing World. *Global Change Biology* **13**: 2379–2395.
- Bradshaw, C. J. A., Brook, B.W., Peh, K.S.-H. and Sodhi, N.S. 2009. Flooding policy makers with evidence to save forests. *Ambio* **38**(2): 125–126.
- Brauman K. A., Daily, G.D., Duarte T.K. and Mooney, H.A. 2007. The nature and value of ecosystem services: an overview highlighting hydrologic services. *Annual Review of Environment and Resources* **32**: 67–98.
- Bruijnzeel, L.A. 2004. Hydrological functions of tropical forests: not seeing the soil for the trees? *Agriculture, Ecosystems and Environment* **104**: 185–228.
- Brummett R.E. and Teugels, G.G. 2004. Rainforest rivers of Central Africa: biogeography and sustainable exploitation. In: Welcomme R. and Petr, T. (eds.) *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries, RAP 2004/16*. Food and Agriculture Organization of the United Nations, Bangkok, Thailand.
- Brummett, R., Tanania, C., Pandi, A., Ladel, J., Munzimi, Y., Russell, A., Stiassny, M., Thieme, M., White, S. and Davies, D. 2009a. Water resources, forests and ecosystem goods and services. In: De Wasseige, C., Devers, D., de Marcken, P., Eba'a Atyi, R., Nasi, R. and Mayaux, P. (eds.) *The forests of the Congo Basin: State of the forest 2008*, pp.1411–1457. Publications Office of the European Union, Luxembourg.
- Brummett, R.E., Nguenga, D., Tiotsop, F. and Abina, J.-C. 2009b. The commercial fishery of the middle Nyong River, Cameroon: productivity and environmental threats. *Smithiana, Special Publication of the South African Institute of Aquatic Biodiversity* **11**:3–16.

- Buhlmann, K.A., Akre, T.S.B., Iverson, J.B., Karapatakis, D., Mittermeier, R.A., Georges, A., Rhodin A.G.J., van Dijk, P.P. and Gibbons, J.W. 2009. A global analysis of tortoise and freshwater turtle distributions with identification of priority conservation areas. *Chelonian Conservation and Biology* 8(2): 116–149.
- Burns, J.W. 1972. Some effects of logging and associated road construction on northern California streams. *Transactions of the American Fisheries Society* 101(1): 1–17.
- Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chinery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.-F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Hernández Morcillo, M., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vié, J.-C. and Watson, R. 2010. Global Biodiversity: Indicators of Recent Declines. *Science* 328:1164–1168.
- CARPE 2001. Congo Basin information series; taking action to manage and conserve forest resources in the Congo Basin. Central African Regional Program for the Environment. World Wildlife Fund, Gland, Switzerland.
- Chambers, P.A., Lacoul, P., Murphy, K.J. and Thomaz, S.M. 2008. Global diversity of aquatic macrophytes in freshwater. *Hydrobiologia* 595: 9–26.
- Chapman, L.J. and Chapman, C.A. 2003. Fishes of the African rain forests. In: Crisman, T.L., Chapman, L.J., Chapman, C.A. and Kaufman, L.S. (eds.) *Conservation, Ecology and Management of African Fresh Waters*. University Press of Florida, Gainesville.
- Chapman, L.J., Chapman, C.A., Kaufman, L., Witte, F. and Balirwa, J. 2008. Biodiversity conservation in African inland waters: Lessons of the Lake Victoria Region. *Verhandlungen des Internationalen Verein Limnologie* 30:16–34.
- Chenje, M. and Mohamed-Katerere, J. 2006. Invasive Alien Species. In: *Africa Environment Outlook 2: Our Environment, Our Wealth*. UNEP. Pp.331–349. Available at: http://www.unep.org/dewa/africa/docs/en/AEO2_Our_Environ_Our_Wealth.pdf
- Costanza, R., d'Arge, R., de Groot, R., Farber, Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253–260.
- Cumberlidge, N. 1998. The African and Madagascan freshwater crabs in the Zoologische Staatssammlung, Munich (Crustacea: Decapoda: Brachyura: Potamoidea). *Spixiana* 21(3): 193–214.
- Cumberlidge, N. 2008. Insular Species of Afrotropical Freshwater Crabs (Crustacea: Decapoda: Brachyura: Potamonautidae and Potamidae) with Special Reference to Madagascar and the Seychelles. *Contributions to Zoology* 77(2): 71–81.
- Cumberlidge, N., Ng, P.K.L., Yeo, D.C.J., Magalhães, C., Campos, M.R., Alvarez, F., Naruse, T., Daniels, S.R., Esser, L.J., Attipoe, F.Y.K., Clotilde-Ba, F.-L., Darwall, W., McIvor, A., Baillie, J.E.M., Collen, B. and Ram, M. 2009. Freshwater crabs and the biodiversity crisis: Importance, threats, status, and conservation challenges. *Biological Conservation* 142: 1665–1673.
- Darwall, W.R.T., Smith, K., Lowe, T. and Vié, J.-C. (eds.) 2005. The Status and Distribution of Freshwater Biodiversity in Eastern Africa. *Occasional Paper of the IUCN Species Survival Commission* 31. IUCN, Gland, Switzerland and Cambridge, UK: IUCN SSC Freshwater Biodiversity Assessment Programme.
- Darwall, W.R.T., Smith, K.G., Tweddle, D. and Skelton, P. (eds.) 2009. *The Status and Distribution of Freshwater Biodiversity in Southern Africa*. Gland, Switzerland and Grahamstown, South Africa: IUCN and SAIAB. Available at: <http://data.iucn.org/dbtw-wpd/edocs/2009-003.pdf>
- du Feu, T.A. 2001. Fish and fisheries in the southern zone of the Takamanda Forest Reserve, Southwest Cameroon. Consultant's report to the Cameroonian-German project: Protection of Forests around Akwaya (PROFA), GTZ, Yaoundé, Cameroun.
- Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.-I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.-H., Soto, D., Stiassny, M.L.J. and Sullivan, C.A. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Review* 81:163–182.
- Dugan, P., Sugunan, V.V., Welcomme, R.L., Béné, C., Brummett, R.E., Beveridge, M.C.M.K., Amerasinghe, A., Arthington, U., Blixt, A., Chimatiro, M., Katisha, S., King, P., Kolding, J., Khoa, J., Nguyen, S. and Turpie, J. 2007. Inland fisheries and Aquaculture. In: Molden, D. (ed.) *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*, pp. 459–483. Earthscan, London, UK, Colombo, Sri Lanka.
- Emerton, L. 2005. Values and Rewards: Counting and Capturing Ecosystem Water Services for Sustainable Development. IUCN Water, Nature and Economics Technical Paper No. 1, IUCN – The World Conservation Union, Ecosystems and Livelihoods Group Asia.
- Emerton L. and Bos, E. 2004. Value. Counting Ecosystems as an Economic Part of Water Infrastructure. IUCN, Gland, Switzerland and Cambridge, UK.
- Encyclopedia of Life (EOL). 2010. Available from <http://www.eol.org>. Accessed 1 December 2010.
- Farrell, T.A., Batker, D., Emerton, L. and Turner, W. 2010. Freshwater ecosystem services: essential for human well-being. In: Mittermeier, R.A., Farrell, T.A., Harrison, I.J., Upgren, A.J., and Brooks, T.M. (eds.) *Fresh water: the essence of life*, pp. 187–209. CEMEX and ILCP, Arlington, Virginia, USA.
- Finlayson, M., D'Cruz, R., Aladin, N., Barker, D.R., Beltram, G., Brouwer, J., Davidson, N., Duker, L., Junk, W., Kaplowitz, M.D., Ketelaars, H., Kreuzberg-Mukhina, E., de la Lanza Espino, G., Lévêque, C., Lopez, A., Milton, R.G., Mirabzadeh, P., Pritchard, D., Revenga, C., Rivera, M., Hussainy, A.S., Silvius, M. and Steinkamp, M. 2006. Inland Water Systems.

- In: Scholes R.H. R. and Ash, N. (eds.) *Ecosystems and human well-being. Vol.1. Current State and Trends*, pp. 551–583. Millennium Ecosystem Assessment. Island Press, Washington DC, USA.
- Forslund, A., Renfalt, B.M., Barchiesi, S., Cross, K., Davison, S., Farrell, T., Korsgaard, L., Krchnak, K., McClain, M., Meijer, K. and Smith, M. 2009. Securing water for ecosystems and human-well-being. The Importance of Environmental flows. Swedish Water House Report 24. SIWI.
- Frost, D.R., Grant, T., Faivovich, J., Bain, R.H., Haas, A., Haddad, C.F.B., De Sá, R.O., Channing, A., Wilkinson, M., Donnellan, S.J., Raxworthy, C.J., Campbell, J.A., Blotto, B.L., Moler, P., Drewes, R.C., Nussbaum, R.A., Lynch, J.D., Green, D.M. and Wheeler, W.C. 2006. The Amphibian Tree of Life. *Bulletin of the American Museum of Natural History* **297**: 1–370.
- García, N., Cuttelod, A. and Abdul Malak, D. (eds.) 2010. *The Status and Distribution of Freshwater Biodiversity in Northern Africa*. IUCN, Gland, Switzerland, Cambridge, UK, and Malaga.
- Garman, G.C. and Moring, J.R. 1993. Diet and annual production of two boreal river fishes following clearcut logging. *Environmental Biology of Fishes* **36**: 301–311.
- Géry, J. 1965. Poissons du bassin d' l'Invindo. *Biologica Gabonica* **1**: 375–393.
- Getahun, A. and Stiassny, M.L.J. 1998. The freshwater biodiversity crisis: the case of the Ethiopian fish fauna. SINET: *Ethiopian Journal of Science* **21**: 207–230.
- Gleick, P.H. 1996. Water resources. In: S.H. Schneider (ed.). *Encyclopedia of Climate and Weather*, pp. 817–823. Oxford University Press, New York, USA.
- Gopal, B., Junk, W.J. and Davis, J.A. (eds.) 2000. *Biodiversity in wetlands: assessment, function, and conservation, volume 1*. Leiden, The Netherlands: Backhuys Publishers.
- Groombridge, B. and Jenkins, M. 1998. Freshwater biodiversity: a preliminary global assessment. World Conservation Monitoring Centre, Cambridge, UK.
- Growsn, I.O. and Davis, J.A. 1991. Comparison of the macroinvertebrate communities in streams in logged and undisturbed catchments eight years after harvesting. *Australian Journal of Marine and Freshwater Resources* **42**: 689–706.
- Harrison, I.J. and Stiassny, M.L.J. 1999. The quiet crisis: a preliminary listing of the freshwater fishes of the World that are extinct or “missing in action”. In: R. MacPhee (ed.). *Extinctions in Near Time: Causes, Contexts, and Consequences*, pp. 271–332. Kluwer Academic/Plenum Publishers, New York.
- Hails, C. 2008. *Living Planet Report 2008*. WWF International. Gland, Switzerland.
- Inogwabini, B.I., Sandokan, B.M. and Ndunda, M. 2006. A dramatic decline in rainfall regime in the Congo basin: evidence from a thirty-four year data set from the Mabali Scientific Research Centre, Democratic Republic of Congo. *International Journal of Meteorology* **31** (312): 278–285.
- IUCN 2001. *IUCN Red List Categories and Criteria: Version 3.1*. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.
- IUCN 2010. The *IUCN Red List of Threatened Species*. 2010.4 Available at: www.iucnredlist.org
- Jackson, R.B., Carpenter, S.R., Dahm, C.N., McKnight, D.M., Naiman, R.J., Postel, S.L. and Running, S.W. 2001. Water in a changing world. *Ecological Applications* **11**(4): 1027–1045.
- Kamdem Toham, A. and Teugels, G.G. 1997. Patterns of microhabitat use among fourteen abundant fishes of the lower Ntem River basin (Cameroon). *Aquatic Living Resources* **10**: 289–298.
- Kamdem Toham, A. and Teugels, G.G. 1999. First data on an index of biotic integrity (IBI) based on fish assemblages for the assessment of the impact of deforestation in a tropical West African river system. *Hydrobiologia* **397**: 29–38.
- Kamdem Toham, A., D'Amico, J., Olson, D., Blom, A., Trowbridge, L., Burgess, N., Thieme, M., Abell, R., Carroll, R.W., Gartlan, S., Langrand, O., Mikala Mussavu, R., O'Hara, D. and Strand, H. (eds.) 2003. Biological priorities for conservation in the Guinean-Congolian forest and freshwater region: Report of the Guinean-Congolian forest and freshwater region workshop, Libreville, Gabon, March 30–April 2, 2000. WWF, Libreville, Gabon.
- Kamdem Toham, A., D'Amico, J., Olson, D., Blom, A., Trowbridge, L., Burgess, N., Thieme, M., Abell, R., Carroll, R.W., Gartlan, S., Langrand, O., Mikala Mussavu, R., O'Hara, D. and Strand, H. (eds.) 2006. *A vision for biodiversity conservation in Central Africa: biological priorities for conservation in the Guinean-Congolian forest and freshwater Region*. World Wildlife Fund, USA. Available at: <http://www.worldwildlife.org/what/wherework/congo/WWFBinaryitem2900.pdf>
- Kottelat, M. and Freyhof, J. 2007. *Handbook of European freshwater fishes*. Kottelat, Cornol, Switzerland and Freyhof, Berlin, Germany.
- LePrieur, F., Beauchard, O., Blanchet, S., Oberdorff, T. and Brosse, S. 2008. Fish invasions in the world's river systems: when natural processes are blurred by human activities. *PLoS Biology* **6**: 404–410.
- Lévêque, C. (ed.) 1997. *Biodiversity dynamics and conservation: the freshwater fish of tropical Africa*. ORSTOM, Paris.
- Lévêque, C., Balian, E.V. and Martens, K. 2005. An assessment of animal species diversity in continental waters. In: Segers, H. and Martens, K. (eds.) *The Diversity of Aquatic Ecosystems*. *Hydrobiologia* **542**: 39–67.
- Lévêque, C., Oberdorff, T., Paugy, D., Stiassny, M.L.J. and Tedesco, P.A. 2008. Global diversity of fish (Pisces) in freshwater. *Hydrobiologia* **595**: 545–567.
- Li, L., Liu, C. and Mou, H. 2000. River Conservation in Central and Eastern Asia. In: Boon, P.J., Davies, B.R., and Petts, G.E. (eds.) *Global Perspectives on River Conservation: Science, Policy and Practice*, pp. 263–279. John Wiley & Sons, Chichester, UK.
- Lowe-McConnell, R.H. 1975. Fish communities in tropical freshwaters. Longman, London, UK.
- Lundberg, J.G., Kottelat, M., Smith, G.R., Stiassny, M.L.J. and Gill, A.C. 2000. So many fishes, so little time: an overview of recent ichthyological discoveries in freshwaters. *Annals of the Missouri Botanical Gardens* **87**(1): 26–62.

- Mahé, G. and J-C. Olivry. 1999. Les apports en eau douce à l'Atlantique depuis les côtes de l'Afrique intertropicale. In: Sciences de la terre et des planètes. *C.R.Academie de Sciences de Paris* **328**: 621–626.
- Maley, J. 1987. Fragmentation de la forêt dense humide et extension des biotopes montagnards au Quaternaire récent. *Palaeoecology of Africa* **18**: 207–334.
- Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and Human Well-Being: Wetlands and Water Synthesis*. Island Press, Washington DC, USA. Finlayson, C. M., R. D'Cruz and N. Davidson, *et al.* Washington DC, World Resources Institute.
- Mino-Kahozi, B. and Mbantshi, M. 1997. Pollution and degradation of African aquatic environments and consequences for inland fisheries and aquaculture; the case of the Republic of Zaire. In: Remane, K. (ed.). *African Inland Fisheries, Aquaculture and the Environment*. Blackwell.
- Mukheibir, P. 2007. Possible climate change impacts on large hydroelectricity schemes in Southern Africa. *Journal of Energy in Southern Africa* **18**.
- Neiland, A.E. and Béné, C (eds.) 2008. Tropical river fisheries valuation: background papers to a global synthesis. The WorldFish Center Studies and Reviews **1836**, 290 pp. The WorldFish Center, Penang, Malaysia.
- Paeth, H. and Thamm, H.P. 2007. Regional modelling of future African climate north of 15°S including greenhouse warming and land degradation. *Climatic Change* **83**: 401–427.
- Peyrot, R. 1991. Hydrologie de l'Afrique centrale. In: Lanfranchi, R. and Clist, B. (eds.) *Aux Origines de L'Afrique Centrale, Centre International des Civilisations Bantu, Centre Culturels Français d'Afrique Centrale, Libreville, Gabon*.
- Postel, S.L. 2003. Securing water for people, crops, and ecosystems: new mindset and new priorities. *Natural Resources Forum* **27**: 89–98.
- Postel, S. and Carpenter, S.R. 1997. Freshwater ecosystem services. In: Daily, G. (ed.). *Nature's services*. IslandPress, Washington DC, USA.
- Postel, S. and Richter, B. 2003. *Rivers for Life: Managing Water for People and Nature*. Island Press, Washington DC, USA.
- Rabalais, N.N. 2002. Nitrogen in aquatic ecosystems. *Ambio* **31**: 102–112.
- Revenga, C. and Y. Kura. 2003. Status and Trends of Biodiversity of Inland Water Ecosystems. Secretariat of the Convention on Biological Diversity, Montreal, Technical Series no. 11.
- Revenga, C., Murray, S., Abramovitz, J. and Hammond, A. 1998. Watersheds of the World: ecological value and vulnerability. World Resources Institute and Worldwatch Institute, Washington DC, USA.
- Robert, M. 1946. Le Congo Physique (third edition). Presse Universitaires de France, Liège, 449p.
- Roberts, T.R. 1975. Geographical distribution of African freshwater fishes. *Zoological Journal of the Linnaean Society* **57**: 249–319.
- Roberts, T.R. 1993. Just another dammed river? Negative impacts of Pak Mun on fishes of the Mekong basin. *Natural History Bulletin of the Siam Society*, **41**: 105–133.
- Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sorlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J.A. 2009. A safe operating space for humanity. *Nature* **461**: 472–475.
- Runge, J. 2007. The Congo River, Central Africa. In: Gupta, A. (ed.). *Large rivers: geomorphology and management*, pp. 293–309. John Wiley & Sons, Hoboken, New Jersey, USA.
- Schipper, J., Chanson, J.S., Chiozza, F., Cox, N.A., Hoffmann, M., Katariya, V., Lamoreux, J., Rodrigues, A.S.L., Stuart, S.N., Temple, H.J., Baillie, J., Boitani, L., Lacher, T.E., Mittermeier, R.A., Smith, A.T., Absolon, D., Aguiar, J.M., Amori, G., Bakour, N., Baldi, R., Berridge, R.J., Bielby, J., Black, P.A., Blanc, J., Brooks, T.M., Burton, J.A., Butynski, T.M., Catullo, G., Chapman, R., Cokeliss, Z., Collen, B., Conroy, J., Cooke, J.G., da Fonseca, G.A.B., Derocher, A.E., Dublin, H.T., Duckworth, J.W., Emmons, L., Emslie, R.H., Festa-Bianchet, M., Foster, M., Foster, S., Garshelis, D.L., Gates, C., Gimenez-Dixon, M., Gonzalez, S., Gonzalez-Maya, J.F., Good, T.C., Hammerson, G., Hammond, P.S., Happold, D., Happold, M., Hare, J., Harris, R.B., Hawkins, C.E., Haywood, M., Heaney, L.R., Hedges, S., Helgen, K.M., Hilton-Taylor, C., Ainul Hussain, S., S.A., Ishii, N., Jefferson, T.A., Jenkins, R.K.B., Johnston, C.H., Keith, M., Kingdon, J., Knox, D.H., Kovacs, K.M., Langhammer, P., Leus, K., Lewison, R., Lichtenstein, G., Lowry, L.F., Macavoy, Z., Mace, G.M., Mallon, D.P., Masi, M., McKnight, M.W., Medellín, R.A., Medicci, P., Mills, G., Moehlman, P.D., Molur, S., Mora, A., Nowell, K., Oates, J.F., Olech, W., Oliver, W.R.L., Oprea, M., Patterson, B.D., Perrin, W.F., Polidoro, B.A., Pollock, C., Powel, A., Protas, Y., Racey, P., Ragle, J., Ramani, P., Rathbun, G., Reeves, R.R., Reilly, S.B., Reynolds, J.E., Rondinini, C., Rosell-Ambal, R.G., Rulli, M., Rylands, A.B., Savini, S., Schank, C.J., Sechrest, W., Self-Sullivan, C., Shoemaker, A., Sillero-Zubiri, C., De Silva, N., Smith, D.E., Srinivasulu, C., Stephenson, P.J., van Strien, N., Talukdar, B.K., Taylor, B.L., Timmins, R., Tirira, D.G., Tognelli, M.F., Tsytulsina, K., Veiga, L.M., Vié, J.-C., Williamson, E.A., Wyatt, S.A., Xie, Y. and Young, B.E. (2008). The Status of the world's terrestrial and aquatic mammals. *Science* **322**(5899): 225–230.
- Schiermeier, Q. 2008. A long dry summer. *Nature* **452**: 270–273.
- Schwartz, D. 1991. Les paysages de l'Afrique centrale pendant le quaternaire. In: Lanfranchi, R. and Clist, B. (eds.) *Aux Origines de L'Afrique Centrale, Centre International des Civilisations Bantu, Centre Culturels Français d'Afrique Centrale, Libreville, Gabon*.
- Sheil, D. and Murkiyarso, D. 2009. How Forests Attract Rain: An Examination of a New Hypothesis. *BioScience* **59**(4): 341–347.
- Showers, K.B. 2009. Congo River's Grand Inga hydroelectricity scheme: linking environmental history, policy and impact. *Water Hist.* **1**: 31–58.
- Shumway, C., Musibono, D., Ifuta, S., Sullivan, J., Schelly, R., Punga, J., Palata, J.-C. and Puema, V. 2003. Biodiversity

- Survey: Systematics, ecology, and conservation along the Congo River. Congo River Environment and Development Project (CREDP). New England Aquarium, Boston, Massachusetts, USA.
- Smith, K.G. and Darwall, W.R.T. 2006. *The status and distribution of freshwater fish endemic to the Mediterranean Basin*. IUCN, Gland, Switzerland and Cambridge, UK.
- Smith, K.G., Diop, M.D., Niane, M. and Darwall, W.R.T. (eds.) (2009). *The Status and Distribution of Freshwater Biodiversity in Western Africa*. Gland, Switzerland and Cambridge, UK: IUCN.
- Stiassny, M.L.J. 1996. An overview of freshwater biodiversity with some lessons from African fishes. *Fisheries* **21**(9): 7–13.
- Stiassny, M.L.J. 1999. The medium is the message: freshwater biodiversity in peril. In: Cracraft, J. and Griffioen, F. (eds.) *The Living Planet in Crisis: Biodiversity Science and Policy*, pp. 53–71. Columbia University Press, New York, USA.
- Stiassny, M.L.J. and Hopkins, C.D. 2007 Introduction. In: Stiassny, M.L.J., Teugels, G.G. and Hopkins, C.D. (eds.) *Poissons d'eaux douces et saumâtres de basse Guinée, ouest de l'Afrique centrale*. Volumes 1. pp. 31–45. IRD Éditions, Paris
- Stiassny, M.L.J., Teugels, G.G. and Hopkins, C.D. (eds.) 2007. *Poissons d'eaux douces et saumâtres de basse Guinée, ouest de l'Afrique centrale*. Volumes 1 (800pp) and 2 (603pp), IRD Éditions, Paris.
- Strong, E.E., Gargominy, O., Ponder, W.F. and Bouchet, P. 2008. Global Diversity of Gastropods (Gastropoda; Mollusca) in Freshwater. *Hydrobiologia* **595**:149–166.
- Stuart, S.N., Chanson, J.S., Cox, N.A., Young, B., Rodrigues, A.S.L., Fischman, D.L. and Waller, R.W. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* **306**: 1783–1786.
- Stuart, S., Hoffmann, M., Chanson, J.S., Cox, N.A., Berridge, R.J., Ramani, P. and Young, B.E. (eds.) 2008. *Threatened Amphibians of the World*. Lynx Edicions, Barcelona, Spain; IUCN, Gland, Switzerland; and Conservation International, Arlington, Virginia, USA.
- Stuart, S.N., Wilson, E.O., McNeely, J.A., Mittermeier, R.A. and Rodríguez, J.P. 2010. The barometer of Life. *Science* **328**: 177
- Thieme, M.L., Abell, R., Stiassny, M.L.J., Skelton, P., Lehner, B., Teugels, G.G., Dinerstein, E., Kamdem Toham, A., Burgess, N. and Olson, D. 2005. *Freshwater ecoregions of Africa and Madagascar: a conservation assessment*. Island Press, Washington DC, USA.
- Thieme, M., Shapiro, A., Colom, A., Schliewen, U., Sindorf, N. and Kamdem Toham, A. 2008. Inventaire Rapide des Zones Humides Représentatives en République Démocratique du Congo. Available at: http://www.ramsar.org/pdf/wurc/wurc_dr-congo_inventaire2008.pdf.
- Thieme, M.L., Turak, E., McIntyre, P., Darwall, W., Tockner, K., Cordeiro, J. and Butchart, S.H.M. 2010a. Freshwater ecosystems under threat: the ultimate hotspot. In: Mittermeier, R.A., Farrell, T.A., Harrison, I.J., Upgren, A.J. and Brooks, T.M. (eds.) *Fresh water: the essence of life*, pp. 123–151. CEMEX and ILCP, Arlington, Virginia, USA.
- Thieme, M.L., Lehner, B., Abell, R. and Matthews, J. 2010b. Exposure of Africa's freshwater biodiversity to a changing climate. *Conservation Letters* **3**(5): 324–331.
- Turtle Taxonomy Working Group. 2009. Turtles of the World: Annotated Checklist of Taxonomy and Synonymy, 2009 Update, with Conservation Status Summary. *Chelonian Research Monographs* **5**:39–84.
- UN 2009. World Population Prospects: The 2008 Revision Population Database. Available at: <http://esa.un.org/unpp/>.
- UNEP 1999. Regional overview of land-based sources and activities affecting the coastal and associated freshwater environment in the West and Central African region. Regional Seas Reports and Studies No. 171. UNEP/GPA Co-ordination Office and West and Central Africa Action Plan, Regional Coordinating Unit, The Hague, The Netherlands, and Abidjan, Côte d'Ivoire.
- UNEP 2010. *Blue Harvest: Inland Fisheries as an Ecosystem Service*. WorldFish Center, Penang, Malaysia.
- Van Damme, D. 1984. *The freshwater mollusca of northern Africa*. Developments in Hydrobiologia 25. W. Junk Publishers, Dordrecht, Netherlands.
- Vié, J.-C., Hilton-Taylor, C., Pollock, C.M., Ragle, J., Smart, J., Stuart, S.N. and Tong, R. 2009. The IUCN Red List: a key conservation tool. In: Vié, J.-C., Hilton-Taylor, C. and Stuart, S.N. (eds.) *Wildlife in a changing world: an analysis of the 2008 Red List of Threatened Species*, pp. 1–13. IUCN, Gland, Switzerland.
- Wallace, J.S., Acreman, M.C. and Sullivan, C.A. 2003. The sharing of water between society and ecosystems: from conflict to catchment-based co-management. *Philosophical Transactions of the Royal Society of London B* **358**: 2011–2026.
- Welcomme, R.L. 1976. Some general and theoretical considerations on the fish yield of African rivers. *Journal of Fish Biology* **8**: 351–364.
- Welcomme, R.L. 1998. International introductions of inland fish species. *FAO Fisheries Technical Paper* **294**. FAO, Rome, Italy.
- Wilson, E.O. 2003. The encyclopedia of life. *Trends in Ecology and Evolution* **18**:77–80.
- World Meteorological Organization (WMO). 1997. Comprehensive Assessment of the Freshwater Resources of the World. Stockholm, Sweden: WMO and Stockholm Environment Institute.
- Witte, F., Goldschmidt, T., Wanink, J.H., van Oijen, M., Goudswaard, P.C., Witte-Maas, E. and Bouton, N. 1992. The destruction of an endemic species flock: Quantitative data on the decline of the haplochromine cichlids of Lake Victoria. *Environmental Biology of Fishes* **43**: 1–28.
- Witte, F., Wanink, J.H., Kishe-Machumu, M., Mkumbo, O.C., Goudswaard, P.C. and Seehausen, O. 2007. Differential decline and recovery of haplochromine trophic groups in the Mwanza Gulf of Lake Victoria. *Aquatic Ecosystem Health and Management* **10**(4): 416–433.
- Witte, F., Welten, M., Heemskerk, M., Van Der Stap, I., Ham L., Rutjes, H. and Wanink, J. 2008. Major morphological changes in a Lake Victoria cichlid fish within two decades. *Biological Journal of the Linnean Society* **94**: 41–52.

Chapter 2. Assessment methodology

Darwall, W.R.T. and Smith K.G.¹

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2.1 Selection of priority taxa

In the majority of cases large-scale biodiversity assessments have focused on a limited range of taxonomic groups, most often including those groups that provide obvious benefits to humans through direct consumption, or the more charismatic groups, such as mammals and birds. In the case of aquatic systems it is the wetland birds and fish that have received most attention. It is, however, important that we take a more holistic approach through collating information to conserve those other components of the foodweb essential to the maintenance of healthy functioning wetland ecosystems, even if they are neither charismatic nor often noticed (especially submerged species). Clearly, it is not practical to assess all species. Therefore, a number of priority taxonomic groups were selected to represent a range of trophic levels within the foodwebs that underlie and support wetland ecosystems. Priority groups were selected to include those taxa for which there was thought to be a reasonable level of pre-existing information. The taxonomic groups selected were: fishes; molluscs; odonates (dragonflies and damselflies); crabs and aquatic plants.

Fishermen returning at sunset, Yaekela, DRC. Photo: © K.-D. Dijkstra.



Although fishes provide a clear benefit to the livelihoods of many people throughout the region, either as a source of income or as a valuable food supply, benefits provided by the other taxa may be indirect and poorly appreciated but nonetheless equally important. Given the wide range of trophic levels and ecological roles encompassed within these five taxonomic groups, it is proposed that information on their distributions and conservation status, when combined, will provide a useful indication of the overall status of the associated wetland ecosystems.

2.1.1 Fishes

Arguably fishes form the most important wetland product on a global scale. They provide the primary source of protein for nearly 1 billion people worldwide (FAO 2002) and food security for many more (Coates 1995). It is estimated that in Africa inland fisheries land nearly 3.5 million tonnes per year, which accounts for nearly 25% of the world's inland water capture (FishStat 2010), providing essential nutrition for the poorest of communities and employment and income for many more. For the purposes of this assessment freshwater fishes are defined as those that spend all or a critical part of their life cycle in fresh waters. Those species entirely confined to brackish waters are also assessed. There are around 15,000 freshwater fish species in the world, and by 2008 only 17.5% of them had had their risk of extinction assessed using the IUCN Red List Categories and Criteria.

2.1.2 Molluscs

Freshwater molluscs in some regions of the world are one of the most threatened groups of freshwater taxa (Kay 1995). They remain fairly unobtrusive, and are not normally considered as being charismatic creatures so rarely attract the attention of the popular media. This is unfortunate as they are essential to the maintenance of wetland

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ecosystems, primarily due to their control of water quality and nutrient balance through filter-feeding and algal-grazing and, to a lesser degree, as a food source for predators including a number of fish species. There are an estimated 6,000 freshwater molluscs for which valid descriptions exist, in addition to a possible additional 10,000 undescribed species. Of these species, only a small number have had their conservation status assessed (around 16.5% of freshwater molluscs had been assessed for the IUCN Red List in 2008) and their value to wetland ecosystems is poorly appreciated. The impact of developments such as dams has not been adequately researched and there is little awareness of the complex life histories of some groups such as unionid mussels that rely on the maintenance of migratory fish runs to carry their parasitic larvae to the river headwaters. For example, the construction of dams has been documented as playing a major role in the extinction of many of the North American mussels within the last 100 years. Many species are also restricted to microhabitats such as the riffles (areas of fast current velocity, shallow depth, and broken water surface) between pools and runs (areas of rapid non-turbulent flow). The introduction of alien species, wetland drainage and river channelization, pollution, sedimentation and siltation also impact heavily on unionid mussels.

2.1.3 Odonates

Larvae of almost all of the 5,680 species of the insect order Odonata (dragonflies and damselflies) are dependent on freshwater habitats. The habitat selection of adult dragonflies strongly depends on the terrestrial vegetation type and their larvae develop in water where they play a critical role with regards to water quality, nutrient cycling, and aquatic habitat structure. A full array of ecological types are represented within the group which, as such, has been widely used as an indicator for wetland quality in Europe, Japan, the USA and Australia. Of these 5,680 species, less than 11% had had their risk of extinction assessed using the IUCN Red List Categories and Criteria by 2008. A baseline dataset is needed for Africa to facilitate the development of similar long term monitoring schemes.

Participants in the review workshop held in Yaoundé, Cameroon. Photo: © David Allen.



2.1.4 Crabs

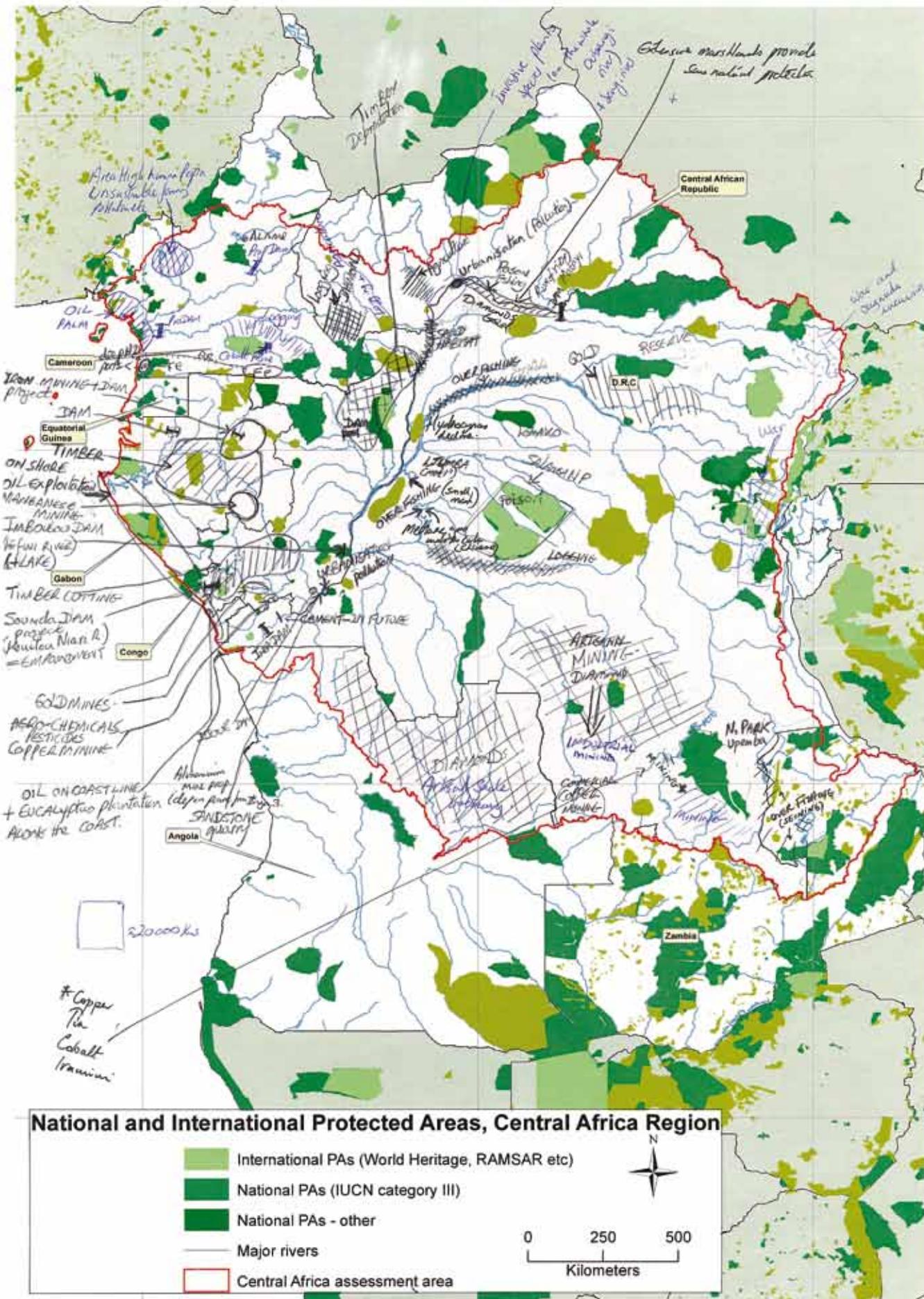
There are an estimated 1,280 species of freshwater crab of which 121 species are recognised from Africa. Density estimates are highly variable, but they consistently show that crabs make up a significant proportion of the invertebrate fauna in terms of overall biomass. The overwhelming importance of detritus in the diet of most species suggests that they are key shredders in African rivers. The detritus shredding guild, apparently almost completely absent from most tropical systems, may be taken up in a large part by crabs in African river systems. This, combined with their general abundance and high biomass, makes them potentially very important to the dynamics of nutrient recycling in African rivers. All of the 121 species native to Africa have had their risk of extinction assessed using the IUCN Red List Categories and Criteria by 2008, these are global assessments and risk of extinction within central Africa is assessed for this project.

2.1.5 Aquatic plants

Aquatic plants are the building blocks of wetland ecosystems, providing food, oxygen and habitats for many other species. They are also a hugely important natural resource providing direct benefits to human communities. Numerous aquatic plants are highly valued for their nutritive, medicinal, cultural, structural or biological properties. They are also key species in wetland ecosystem services such as water filtration and nutrient recycling. An aquatic plant is defined here as a plant that is physiologically bound to water (a hydrophyte) or essentially a terrestrial plants whose photosynthetically active parts tolerate long periods submerged or floating (a helophyte) (Cook 1996). According to Balian *et al.* (2008) there are around 2,614 aquatic plants (hydrophytes only) and only 37 species of aquatic plants had been assessed for the 2008 IUCN Red List.

For this project, the conservation status of all the aquatic plant species from 49 selected plant families were assessed. These families were selected based on the criteria that they had a relatively large

Figure 2.1 Threat map of the central Africa region, drawn by participants at an IUCN workshop held in Yaoundé, Cameroon.



proportion of aquatic species in the family, a reasonable level of available information, a relatively stable taxonomy, that selected families would cover a range of ecological niches and contain a substantial number of species, and that the families would cover a wide distribution at the global scale. A list of families is given in Chapter 7.

2.2 Data collation and quality control

The biodiversity assessment required sourcing and collating the best available information on all known species within the priority taxa (see section 2.1). Regional and international experts for these taxa were identified by IUCN, and through consultation with the relevant IUCN SSC Specialist Groups. These experts were then trained in the use of the project database, the Species Information Service Data Entry Module (SIS DEM), in the application of the IUCN Red List Categories and Criteria (IUCN 2001) to assess a species risk of extinction in the wild, and in mapping freshwater species distributions. In the case of fishes and Odonates, the experts had previous knowledge of the methods and software through participation in previous assessment projects in Africa.

A workshop was held (in Yaoundé, Cameroon) to peer review completed species assessments and distribution maps and to provide additional guidance and training to experts undertaking assessments. Each completed assessment was evaluated by at least two independent experts to ensure that: i) the information presented was both complete and correct, and ii) the Red List criteria had been applied correctly. Assessments not completed in time for the workshop were reviewed remotely by sending assessment reports at a later date to experts who had agreed to participate in the process.

Knowledge of threats to species and their habitats are an integral part of IUCN Red List assessments, and by mapping threats at the workshop, the experts can work with consistent knowledge of generalised threats across the entire region. As an additional exercise, the experts present at the workshop were asked to create a ‘threat map’ for the central Africa assessment region (Figure 2.1). The effect these threats may have on an individual species is determined on a case by case basis, but the map can be used, together with other sources, to inform the assessments.

2.3 Species mapping

All species distributions were mapped to river sub-basins (apart from plants) as delineated by the HYDRO1k Elevation Derivative Database (USGS EROS) (Figure 2.2) using ArcView/Map GIS software. The majority of plant species were mapped to countries due to the lack of detailed distribution information. It is recognised that species ranges may not always extend throughout a river sub-basin but until finer scale spatial detail is provided each species is assumed to be present throughout the sub-basin where it has been

recorded. River basins were selected as the spatial unit for mapping and analysing species distributions as it is generally accepted that the river/lake basin or catchment is the most appropriate management unit for inland waters.

For the fishes, odonates and crabs, point localities (the exact latitude and longitude where the species was recorded) were used to identify which sub-basins are known to contain the species. The point localities for the fishes came from the publication “*The fresh and brackish water fishes of Lower Guinea, West-Central Africa*” (Stiassny, Teugels and Hopkins 2007), from museum specimens stored at the American Museum of Natural History (AMNH) and the Royal Museum for Central Africa (RMCA), as well as from the assessors personal records. The odonate points were obtained from the ‘Odonata Database Africa’ compiled by the SSC Odonata Specialist Group, and additional points collated through visits undertaken by Dr K.-D. Dijkstra, with financial assistance from the project, to collections held at the Muséum national d’Histoire naturelle, Paris, and RMCA. The crab point localities were based on museum records from major collections, supplemented in a small number of cases by expert knowledge of presence at sites where no voucher specimens were collected. During the evaluation workshop, errors and dubious records were deleted from the maps.

Connected sub-basins, where a species is expected to occur, although presence is not yet confirmed, are known as ‘inferred basins’. Inferred distributions were determined through a combination of expert knowledge, course scale distribution records and unpublished information. For the plants and molluscs the distribution maps are all for inferred basins as digitized point localities were not available.

The preliminary species distribution maps were digitised and then further edited at the review workshop.

Species distributions were also described within the context of the Freshwater Ecoregions for central Africa as defined and delineated by WWF-US (Thieme *et al.* 2005) (Figure 1.2).

2.4 Assessment of species threatened status

The risk of extinction for each species was assessed according to the *IUCN Red List Categories and Criteria: Version 3.1* (IUCN 2001), (see Figure 2.3). As such, the Categories of threat reflect the risk that a species will go extinct within a specified time period. A species assessed as “Critically Endangered” is considered to be facing an extremely high risk of extinction in the wild. A species assessed as “Endangered” is considered to be facing a very high risk of extinction in the wild. A species assessed as “Vulnerable” is considered to be facing a high risk of extinction in the wild. All taxa listed as Critically Endangered, Endangered or Vulnerable are described as “threatened”. For an explanation of the full range of Categories and the Criteria which must be met for a species



Figure 2.2 Level 6 river basins as delineated by HYDRO1K and as used to map and analyse species distributions, mapped to river sub-catchments.

to qualify under each Category please refer to the following documentation: The *IUCN Red List Categories and Criteria: Version 3.1, Guidelines on application of the Red List Categories and Criteria, and Guidelines for Application of IUCN Red List Criteria at Regional Levels: Version 3.0* which can be downloaded from www.iucnredlist.org/info/categories_criteria.

The following settings and filters were agreed during the initial workshop and were applied in the completion of this regional Red List assessment:

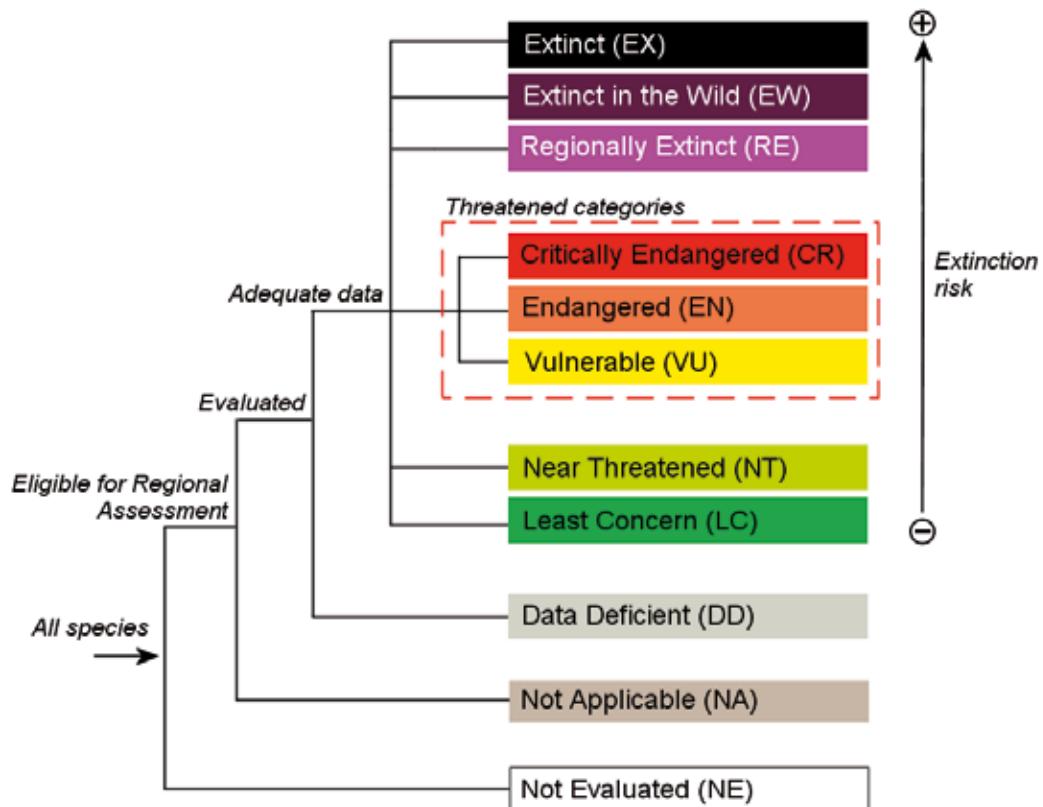
1. Any species having less than 5% of its range within central Africa should not be assessed, the main assessment being completed for the neighbouring region.

2. Species present in central Africa prior to 1500 were treated as being “naturalised” and subject to a Red List assessment. Those species arriving in central Africa post 1500 were not assessed but their distributions were mapped where possible.

For each species the Red List Category is either written out in full or abbreviated as follows:

Extinct, EX	Near Threatened, NT
Extinct in the Wild, EW	Least Concern, LC
Regionally Extinct, RE	Data Deficient, DD
Critically Endangered, CR	Not Applicable, NA
Endangered, EN	Not Evaluated, NE
Vulnerable, VU	

Figure 2.3 IUCN Red List Categories at the Regional scale.



A regional as opposed to a global species Red List Category is indicated in the text by the superscript ^{RG} following the Category assigned. For example, a species assessed as regionally Vulnerable is documented as VU^{RG}.

Species summaries and distribution maps are presented for all species assessed on the accompanying DVD. An example output is given in Appendix 1.

2.5 References

- Balian, E.V., Segers, H., Lévêque, C. and Martens, K. 2008. The freshwater animal diversity assessment. *Hydrobiologia* 595:1–637.
- Coates, D. 1995. Inland capture fisheries and enhancement: Status, constraints and prospects for food security. In: *International Conference on Sustainable Contribution of Fisheries to Food Security, Kyoto, Japan, 4–9 December 1995*. KC/FI/95/TECH/3. Government of Japan, Tokyo, Japan and FAO, Rome, Italy.
- Cook, D.K. 1996. *Aquatic Plant Book*. SPB Academic Publishing, Amsterdam/New York.
- FAO (Food and Agriculture Organization of the United Nations). 2002. *The state of world fisheries and aquaculture 2002*. FAO Fisheries Department, Rome, Italy.

FishStat 2010. Food and Agriculture Organization (FAO) FISHSTAT Capture Fisheries and Production and Trade Databases 1950–2008. Available online at www.fao.org/fishery/statistics/software/fishstat/en.

IUCN 2001. *IUCN Red List Categories and Criteria: Version 3.1*. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.

Kay, E.A. 1995. The conservation biology of molluscs. Including a status report on molluscan diversity. In: *Proceedings of a symposium held at the 9th International Malacological Congress, Edinburgh, Scotland, 1986*. IUCN – The World Conservation Union, Gland, Switzerland and Cambridge, UK.

Stiassny, M.L.J., Teugels, G.G., and Hopkins, C.D. (eds.) 2007. *Poissons d'eaux douces et saumâtres de basse Guinée, ouest de l'Afrique centrale / The Fresh and Brackish Water Fishes of Lower Guinea, West-Central Africa*. Volumes 1 (800pp) and 2 (603pp). IRD Éditions, Paris.

Thieme M.L., Abell, R., Stiassny, M.L.J., Skelton, P., Lehner, B., Teugels, G.G., Dinerstein, E., Toham, A.K., Burgess, N. and Olson D. 2005. *Freshwater Ecoregions of Africa and Madagascar: A Conservation Assessment*. Island Press, Washington DC, USA.

United States Geological Survey's Center for Earth Resources Observation and Science (USGS EROS) HYDRO1k Elevation Derivative Database. Available at: <http://edc.usgs.gov/products/elevation/gtopo30/hydro/index.html>.

Chapter 3. The status and distribution of freshwater fishes in central Africa

Stiassny M.L.J.¹, Brummett, R.E.², Harrison, I.J.³, Monsembula, R.⁴ and Mamonekene, V.⁵

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3.1 Overview of the regional fauna

Based broadly on the composition and distribution of fishes, two main ‘ichthyological provinces’ are recognized within central Africa (i.e., based on the composition of the fish fauna), the Lower Guinean and the Congo basin Provinces (see Figure 1.2) (Roberts 1975; Leveque 1997). However, the northern part of Lower Guinea shares a number of species in common with the neighbouring Nilo-Sudanian ichthyological province that covers most of northern sub-Saharan Africa. This faunal overlap is also reflected in the fact that two of the freshwater ecoregions (Thieme *et al.* 2005) in northern Lower Guinea extend north and west into Nilo-Sudanian West Africa: these are the **Northern Gulf of Guinea Drainages**, and the large **Lower Niger-Benue** ecoregion. The Lower Guinean component of the **Lower Niger-Benue** ecoregion is formed by the upper reaches of the Sanaga River and its headwaters, which differ markedly in taxonomic composition from that of its lower reaches. The rest of the Lower Guinea province has an ichthyofauna quite distinct

from that of Nilo-Sudanic West Africa. Endemism of the fish fauna is extremely high, with some notable areas of endemism including the **Western Equatorial Crater Lakes** ecoregion in the Cameroonian highlands north of the Wouri River, which includes several endemic and threatened cichlids (see below). However, some areas, particularly in the Nyong, Ntem and Ogowe-Ivindo basins, share faunal affinities with the Congo basin province. This is especially true for the Dja River, a tributary of the Sangha (itself a large right bank affluent of the Congo River). Thys van den Audenaerde (1966) posited historical headwater captures between the Nyong, Ntem, Ivindo and Dja as a mechanism for fish dispersal across contemporary terrestrial barriers, and this appears to be the most reasonable explanation for the shared presence of many fish species in these currently isolated basins. Unlike the Lower Guinean province, which includes several small to medium size rivers that flow independently to the sea, the Congo basin includes several very large tributary basins (e.g. the Kasai, Ubangi, Uele, Lomami), connected to the main Congo River channel (see also section 3.3.1 below).

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3.1.1 A knowledge impediment

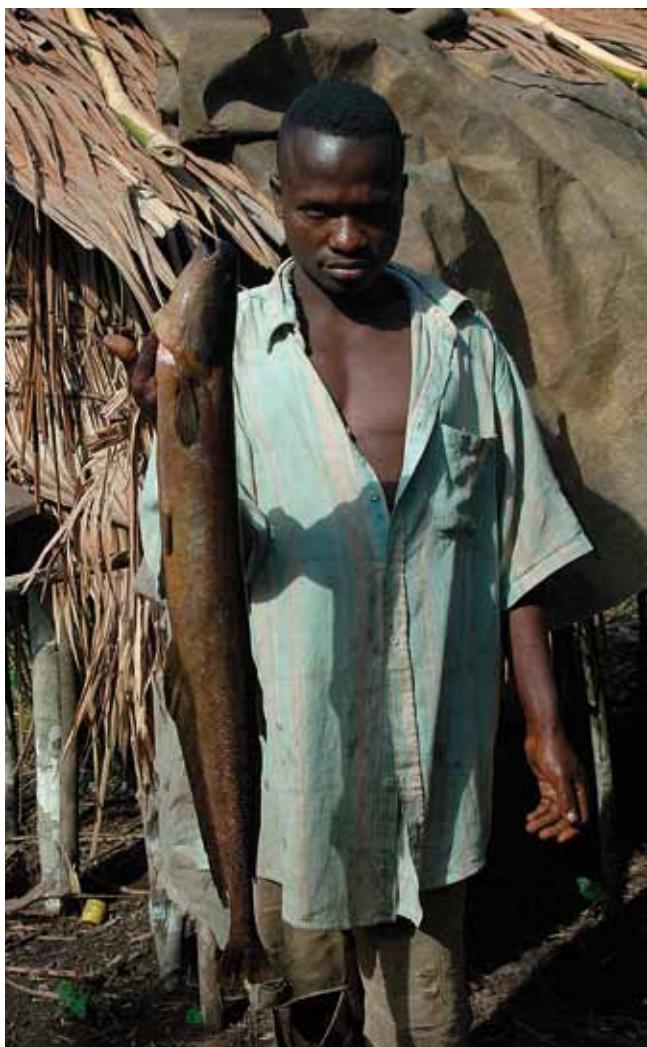
On a continental scale, central Africa exhibits high levels of species richness and endemism (see section 3.3), but equally noteworthy is our lack of basic taxonomic, geographic or even the most rudimentary ecological information for the great majority of the species. In the Congo basin most scientific collecting of fishes has been restricted to the main channels of the Congo River and its larger tributaries, where it was almost exclusively concentrated around old colonial centres, along the main transportation routes. Fish collections from the Congo River and associated drainages were made and sporadically deposited in European and US museums, beginning in the late 1800s and continuing into the early half of the 1900s during the French and Belgian colonial periods. Some historically important collection localities include Kinshasha (formerly Leopoldville), the colonial settlement of Kwamouth situated near the junction of the Kasai, the Congo, and the large settlement of Mbandaka (formerly Coquilhatville) at the confluence of the Ruki and the Congo, and Mankanza (formerly New Antwerp).

Post-colonial researchers continued with some regional collecting and fisheries work in the 1960s and through to the late 1970s.

However, political conditions throughout the post-colonial era rendered fieldwork difficult, and numerous smaller rivers, streams, and swamplands located in less accessible regions (especially in the central Congo basin and its southern tributaries) have never been scientifically surveyed. While the freshwater habitats of Lower Guinea have certainly been more extensively studied than those of the Congo basin there are still many rivers and lakes that have been sampled infrequently, and then often only from one or a few localities (Brummett and Teugels 2004). Consequently, many of the central African fish species considered herein are very poorly known biologically, and many are known only from their types (i.e., the actual specimen or specimens originally used in the formal scientific description of the species). For example, Stiassny (1999) showed that, for a random selection of catfishes and mormyrids included in the Check List of Freshwater Fishes of Africa (CLOFFA, Daget *et al.* 1984, 1986, 1991), between 25–80% were known only from the type series or the type locality from where the species was first described. While such findings may accurately reflect restricted distributions for these species it is rather more likely that they indicate a real lack of knowledge of the distribution of these central African species. The latter conclusion is amply supported by recent targeted studies. For example, ongoing surveys in the lower section of the Congo River downstream of Pool Malebo have more than

Local children, near Matadi, Democratic Republic of Congo. Photo: © Robert Schelly.





Mormyrops anguilloides is a representative of the highly diverse African endemic family Mormyridae. The weak electric fields generated by these fishes help them find food and mates in the dark waters of the rainforest. Photo: © Randy Brummett.

doubled the number of species documented to occur there, and have resulted in the identification of over 10 new species in this short stretch of river over the past five years (Stiassny pers. obs.). Even relatively small basins, such as the Inkisi River in the lower section of the Congo, or the Itimbiri River in the middle Congo, have recently been found to harbour many more species than previously reported (Thieme *et al.* 2008; Wamuini *et al.* 2008; Schliewen pers. comm.).

In recent years, following the reduction of civil unrest in both the Republic of Congo and the Democratic Republic of Congo, coordinated fieldwork in the Congo basin has resumed, and research and PhD projects are now ongoing at: the Royal Museum for central Africa, Belgium; the American Museum of Natural History, USA; the Museum of Vertebrate Zoology, Cornell University, USA; the Zoologische Staatssammlung München, Germany; the South African Institute of Aquatic Biology, Republic of South Africa; the Universities of Kinshasa and Kisangani, Democratic Republic of Congo; and the University of Marien Ngouabi, Republic of Congo.

The fish fauna of the Lower Guinean province was also, until recently, rather poorly documented. Teugels *et al.* (1992) found that the number of species in the Cross River at the northern limit of the Lower Guinean province had previously been underestimated by as much as 73%. Such a finding was especially significant as the Cross River had widely been assumed to be one of the better surveyed and biologically described rivers of western central Africa, clearly suggesting that our knowledge of many of the other rivers in this region was also incomplete. However, in the last 20 years there has been a reasonable amount of ichthyological survey work focused in the Lower Guinean province. Like the Congo basin, this work has been coordinated by several European and North American natural history museums, and the NGO WorldFish based in Yaoundé, Cameroon (Brummett and Teugels 2004). This in turn has promoted extensive taxonomic and revisionary work, including the description of many new species. Part of the stimulus for this focused effort, at least in the past decade, has been the production of a guide to the freshwater fish fauna of the region, which summarizes many of these findings and includes keys to the genera and species of the region (Stiassny *et al.* 2007). As a result, despite some remaining knowledge gaps, the Lower Guinean ichthyofauna is now generally regarded as one of the better known on the African continent

With such a renewed focus on survey work and intensified efforts to fully document the status, extent and distributional limits of central African fish species we can reasonably anticipate the discovery of many scores, if not hundreds, of new species in the coming decade. In many respects it is the profound lack of knowledge of the true extent of aquatic diversity, and of its distribution and biology in central Africa, that has presented one of the greatest challenges to the compilation of this assessment. This also presents a significant impediment to sustainable development and long-term conservation of these rich resources (see section 3.5).

3.2 Conservation status (IUCN Red List Criteria: Regional scale)

Of the 1,327 central African fish species considered to be present in the central Africa region, 116 were classified as Not Applicable (see Chapter 2 on ‘Assessment methodology’ for further explanation why species are placed in this category). Table 3.1 shows that of the remaining 1,207 species included in this assessment, the majority are classed as Least Concern (62%). This is perhaps not unexpected given that, compared to much of the remainder of sub-Saharan Africa, the central African region is sparsely populated and industrialization and urbanization is strongly regionalized, leaving large areas of the interior sparsely inhabited and relatively undeveloped. Most of the population is concentrated along rivers and roads. In the Congo basin the greatest concentrations occur along the main channels of the Congo and Ubangi/Uele Rivers, and especially in the mid to lower parts of the Congo river near Kinshasa, and in the upper section of the Congo in the headwaters of the Lualaba and Luvua

Table 3.1 The number of freshwater fish species in each regional Red List Category in the central Africa region.

	Regional Red List Category	Number of Species	Number of Regional Endemics
Threatened Categories	Critically Endangered	26	22
	Endangered	64	58
	Vulnerable	90	78
	Near Threatened	4	4
	Least Concern	749	530
	Data Deficient	274	241
	Not Applicable	116	17
Total*		1,207	933

* The total figure does not include NA (Not Applicable) species.

All species assessed as regionally threatened which are endemic to the region are also globally threatened.

systems, as well as in parts of the Kwango and Kwilu in the Kasai drainage. Lower Guinea generally has denser human populations, more industrial development, and a greater development of road networks compared to the Congo Basin, and this development, combined with a better knowledge of the fauna, has resulted in the recognition of a greater percentage of threatened species in this region (see below).

Species classified as Data Deficient are the next highest in number after Least Concern species, with 23% of the total number (Figure 3.1 – see also section 3.3.3). There are 180 species that are classified regionally as threatened (20% of the total number of species, excluding those that are Data Deficient); 158 of these species (i.e. 88% of the species classified as regionally threatened) are endemic to central Africa. Of the 180 threatened species, 50% are classified as Vulnerable, 36% are classified as Endangered and 14% are Critically Endangered.

3.3 Patterns of species richness

3.3.1 All fish species

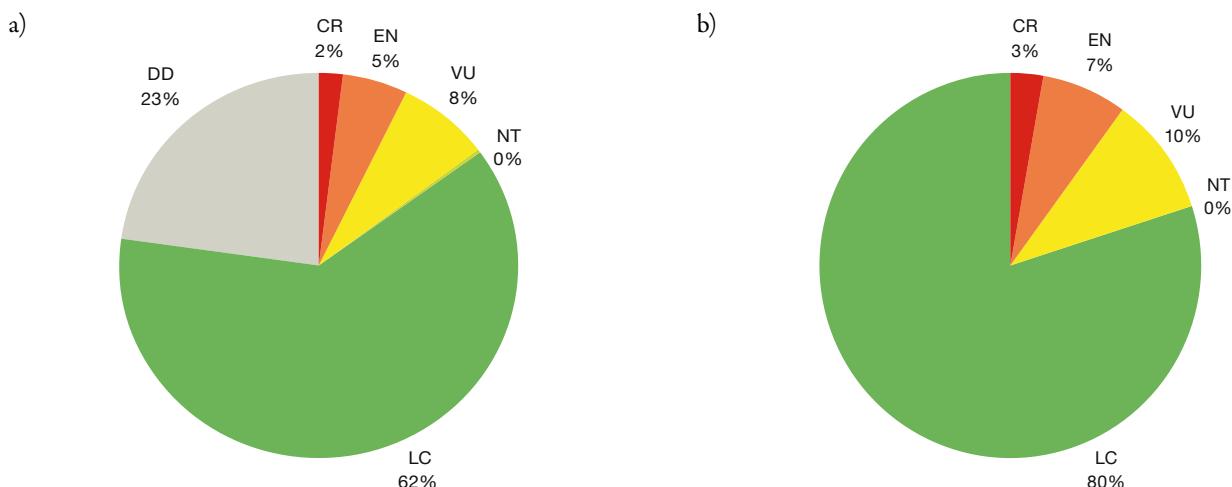
Certain species migrate along the river according to patterns of their reproductive seasonality (Lowe-McConnell 1975; Mdaihl *et al.* 2003), and others may occupy different habitats during different life stages. Therefore, species diversity at any point in a river may change quite markedly over the seasons, in terms of total numbers and taxonomic diversity (Lowe-McConnell 1977). Nevertheless, it is possible to draw some tentative conclusions about species richness in the different regions.

Relative to much of the remainder of sub-Saharan Africa (excluding the hyperdiverse Great Lakes region), fish diversity in central Africa is extremely high. Over 550 and 700 species have been reported from the two provinces respectively (Teugels and Guegan 1994; Thieme *et al.* 2005; Stiassny *et al.* 2007), but these numbers are constantly rising with ongoing fieldwork and systematic research (Lowenstein *et al.*, in press). For example, a total of 1,327 named fish species are included in this study of central African fishes (1,207 of which were assessed). The total number of 1,327 species are included in 47 different taxonomic families, of which the five most species-rich are: Cyprinidae (240 species; 18.1% of total species number for central Africa), Cichlidae (175 species; 13.2% of total), Mormyridae (142 species; 10.7% of total), Nothobranchiidae (136 species; 10.3% of total) and Mochokidae (97 species; 7.3% of total). Although individual families of catfishes (Siluriformes) are less species rich than many other families, the combined total of all catfishes (from the families Amphiliidae, Bagridae, Clariidae, Claroteidae, Malapteruridae, Mochokidae and Schilbeidae) is 280 species (21% of the total number of species in the region).

For the Lower Guinea, 367 species were assessed. Most sub-basins of the Lower Guinean province have between about 30 and 100

Figure 3.1 The proportion (%) of freshwater fish species in each regional IUCN Red List Category in central Africa.

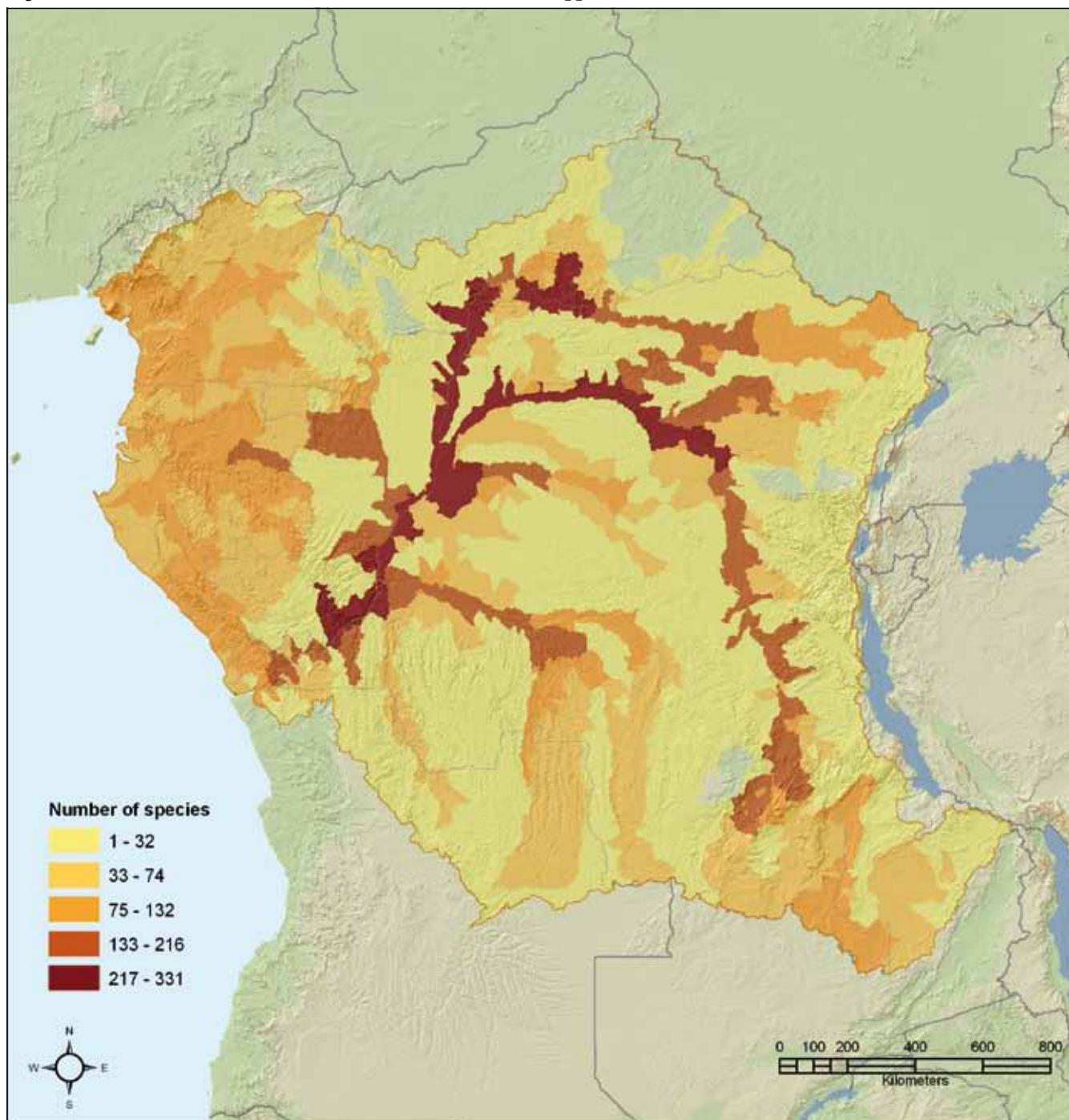
a) All 1,207 species assessed from the region, b) the 933 non-DD species from the region that were assessed. IUCN Red List Categories: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient.



species. The Ogowe, upper Ngounie, and lower Kouilou systems are the most species rich in Lower Guinea, each with more than 100 recorded species. No regions of the Lower Guinean province reach the same levels of species richness as in the Congo basin main channels (Figure 3.2). This is unsurprising since Lower Guinean rivers are significantly smaller than the main channel of the Congo; the Congo River is the largest drainage basin in Africa, and its dense and complex hydrographic network is the only 10th order stream on the continent. Positive correlation between species richness and river size (in terms of watershed area and discharge volume) is well documented (Hugueny 1989; Tedesco *et al.* 2005). The main channel of rainforest rivers is the most stable biotope and offers the greatest range of micro-habitats. Lowe-McConnell (1975) noted that, within the main channel, fish diversity and abundance is

higher in shallow marginal waters along banks and islands than in mid-river. In these areas, sheltered from the main current, abundant aquatic vegetation representing a number of genera (e.g., *Anubias*, *Crinum*, *Commelinia*, *Limnophyton*, *Nymphaea*) creates habitat for a wide variety of species and their offspring (Kamdem-Toham and Teugels 1998). The Lower Guinean province differs markedly from the Congo in its hydrographic network, and in addition to a few large drainages it includes numerous isolated coastal rivers, many of which flow through dense forest en route to the Atlantic Ocean. Possibly in reflection of this habitat complexity, several Lower Guinean sub-basins are disproportionately rich in fish species relative to their small size. For example, the upper part of the Mbini in Equatorial Guinea and some of the small coastal sub-basins of the Republic of Congo each harbour over 40 species.

Figure 3.2 The distribution of freshwater fish in central Africa, mapped to river sub-catchments.



Species richness is high in the Congo basin, with upwards of 858 species assessed for the region. The total number of species of fishes documented for the basin is increasing annually as more species are described each year (Thieme *et al.* 2008; Lowenstein *et al.*, in press). Species richness is greatest along the main courses of the major rivers of the Congo basin, with over 150 species reported for almost the entire length of the Congo and Lualaba, as well as sections of the Kasai, Ubangi/Uele, and Sangha. Greatest species numbers are found in the middle Congo, with sections having over 300 species; the Malebo Pool region includes 334 assessed fish species. The smaller tributaries in the Congo basin have relatively fewer species (fewer than 30 in many cases).

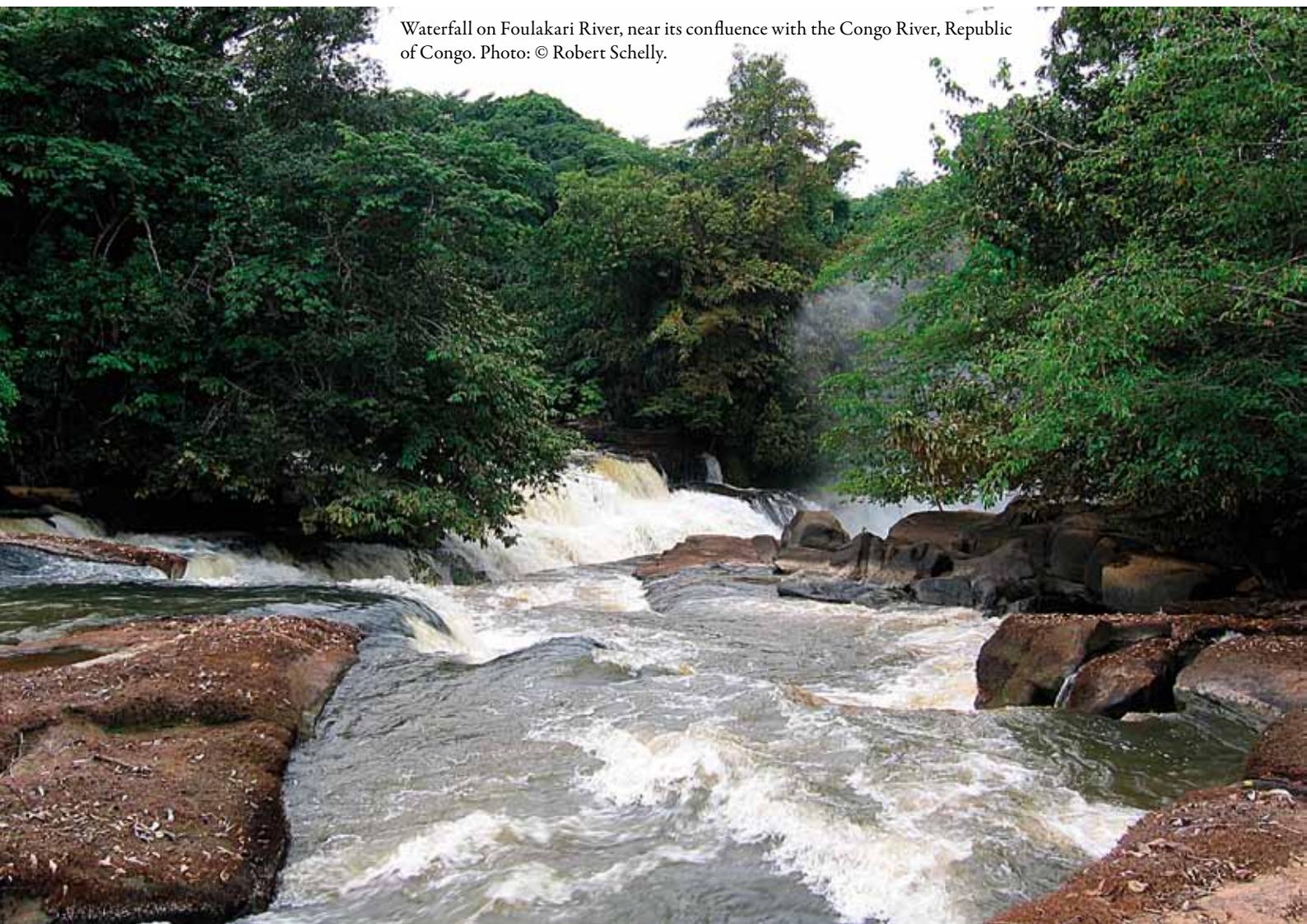
Interestingly, low species numbers (fewer than 30) are also recorded from the larger drainages of the Inzia and Loange systems draining to the Kasai in the south of the Congo basin, in the upper parts of the Lukenie basin, the Lokoro, Lulaka, and Salonga basins draining to Busira/Ruki Rivers, and much of the upper Lomami. Such low species numbers reported for these drainages and several of the smaller ones in the Congo basin are most likely an indication of relatively incomplete surveying and inventorying in these regions.

Many factors combine to contribute to the high levels of species richness of the central African ichthyofauna. The effect of river size is discussed above; the region's equatorial location and the relative longevity and climatic stability of the forested, moist tropical

regions have also likely been important (Kamdem-Toham *et al.* 2006; Thieme *et al.* 2008), as has the large geographic extent of the region, encompassing a high diversity of aquatic habitat types and innumerable microhabitats (Stiassny *et al.* 2010). Central Africa includes a complex mosaic of moist forests, extensive swamp forests and seasonally flooded grasslands, large savannah rivers, small rainforest rivers, numerous stretches of main channel rapids, deep pools, shallow lakes and swamps, and high and low gradient black water, white-water and clear water streams, as well as extensive estuarine reaches and mangrove forests (also see Chapter 1).

Hydrographic barriers between habitats also tend to promote species diversification and resultant richness; notable in this regard are the many waterfalls and rapids that ring the Congo basin as source waters descend into the central basin from the Lunda Rise and Shaba highlands in the south, the Mitumba Mountains of the Albertine Highlands in the east, and the Asande rise in the north. The major tributaries and sub-basins of the Kasai, Uele, Mbomou and Ubangui are all dissected by large series of rapids, and in the Congo main channel the major rapids in the **Upper Congo Rapids** and **Lower Congo Rapids** ecoregions are among the largest on the planet (Thieme *et al.* 2005; Brummett *et al.* 2009, Markert *et al.* 2010). As noted above, the ichthyofaunal extent of the Congo Province has expanded due to past capture of Lower Guinean rivers by Congo province drainages in the Sangha basin. Similarly, species transfers via shared headwater swamps between

Waterfall on Foulakari River, near its confluence with the Congo River, Republic of Congo. Photo: © Robert Schelly.



the upper Kasai drainages and the Upper Zambezi of southern Africa has facilitated the migration and subsequent divergence of populations at this southern interface of the Congo and Zambezi. However, as Tweddle *et al.* (2009) note, the headwater streams of the Congo in the vicinity of the Upper Zambezi are extremely poorly known, so the true extent of faunal exchange between these two systems has yet to be determined.

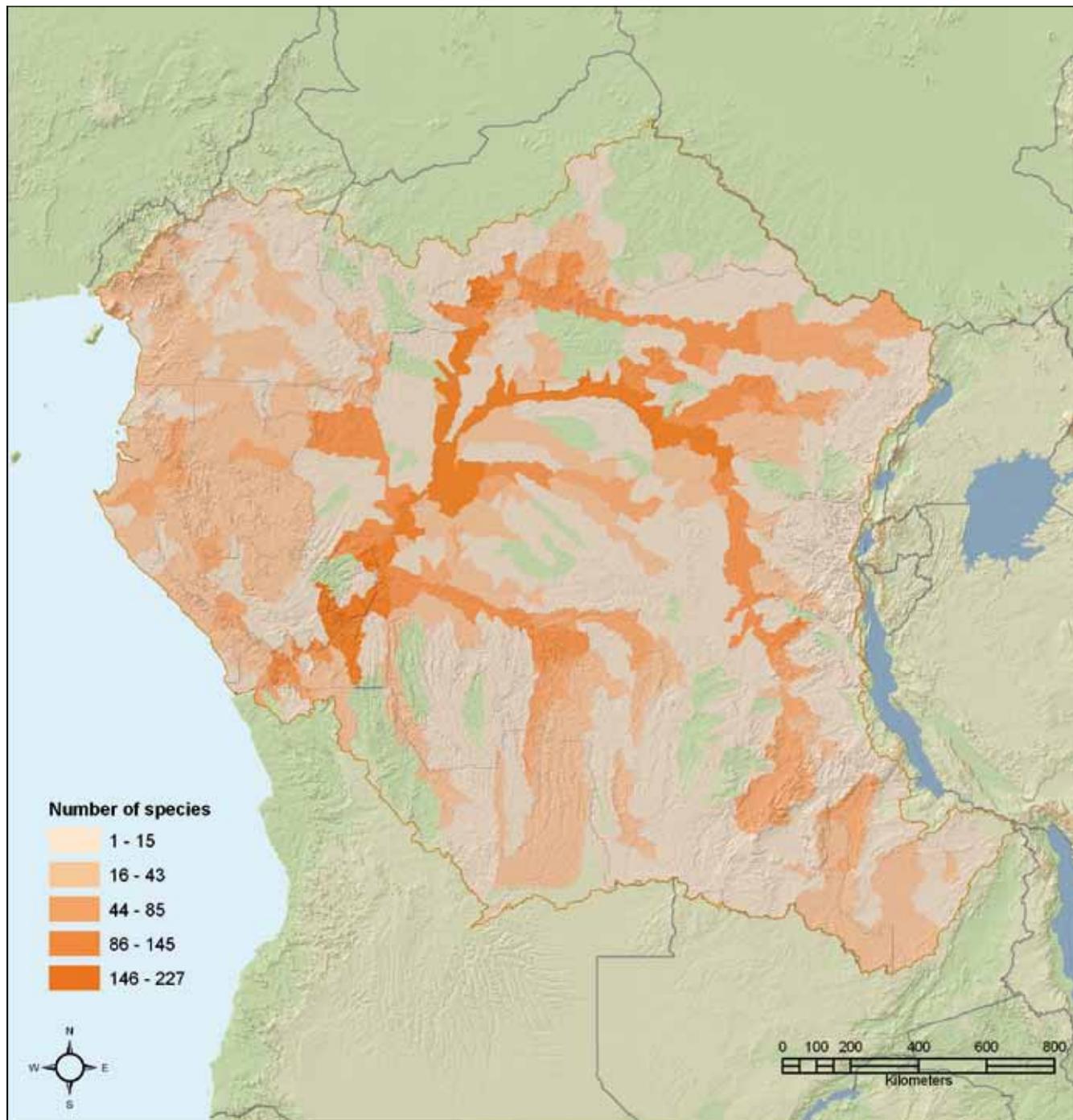
3.3.2 Endemic Species

In total, about 71% of the 1,207 species that were evaluated in this study are assessed to be endemic to the central Africa region. Comparison of all 1,327 species of fishes in found in central Africa with data from IUCN's biodiversity assessments of the

Nile basin indicate that only 31 species (2.3%) are shared; and a similar comparison with the Zambezi basin indicates that 62 species (4.7%) are currently known to be shared (but see above).

Based on the information at hand, and acknowledging the partial nature of the dataset, we find the greatest numbers of species that are endemic to central Africa are present along the main channels of the largest rivers of the Congo basin (e.g., the Congo, Ubangi/Uele, Itimbiri, Aruwimi, and parts of the Kasai/Sankuru), and in the Sangha river of the Republic of Congo draining to the Congo (Figure 3.3). This is contrary to the expected relationship of higher endemism in the isolated headwaters of river basins (Stiassny *et al.* 2010). However, this trend might be because species that are endemic to central Africa are found in many parts of the

Figure 3.3 The distribution of freshwater fish species endemic to central Africa, mapped to river sub-catchments.



region's river systems. The apparent trend may also be an artefact resulting from a surveying bias, as indicated by the fact that regions having greater levels of endemism also include many of the areas where greatest species richness is recorded. As already noted, the smaller tributaries and headwaters of the Congo basin have been poorly surveyed, even as compared to the main channels, and the numbers of species present in those smaller rivers are likely to be under-reported. Besides lack of adequate distribution data, simple misidentification of species may be biasing the apparent distribution of endemic species (Stiassny 1996; Lowenstein *et al.*, in press).

Although the numbers of central African endemic species in Lower Guinea are lower than those found in the Congo basin main channels, numbers of endemics (20 or more endemic species) are found more consistently across sub-basins in Lower Guinea compared to the Congo basin province. This is probably also an indication that this province has been surveyed more completely and uniformly than the Congo basin.

Several basins and sub-basins within central Africa are also noteworthy for having species that are restricted only to those basins or sub-basins (i.e., range restricted species, endemic to the basins) and these do not seem to be artefacts of sampling bias. Indeed, Brummett *et al.* (2009) note that approximately 50% and 80% of species found in rivers and streams of the Lower Guinea and Congo provinces respectively are endemic to individual basins within these regions. For example, the crater lakes of northern Cameroon, although low in total numbers of species, have some of the highest percentages of endemic fishes for the central Africa region. Also, Brummett *et al.* (2009) reported that over 80 of 300+ species (i.e. 27%) recorded from Malebo Pool and downstream through the Lower Congo are endemic just to that area. Even greater proportions of species of fishes (up to 50%) are thought to be endemic just to the **Lower Congo Rapids** ecoregion, where many of these species are adapted to the fast-flowing and highly turbulent waters (Thieme *et al.* 2005, 2008; Markert *et al.* 2010; Lowenstein *et al.*, in press). Of the 692 species endemic to the central Africa region (excluding those that are Data Deficient or Not Applicable), 158 (23%) are classified as threatened and four are Near Threatened (see below for a discussion of the distribution of threatened species).

Tilapia gutturosa (CR), endemic to Lake Bermin, a crater lake in Cameroon. © Oliver Lucanus/Belowwater.com



3.3.3 Data Deficient species

Data Deficient species are recorded in several parts of the Congo basin, and are even more widespread through the sub-basins of Lower Guinea. Data Deficient species are found most frequently (11 or more Data Deficient species) around Kinshasa and Brazzaville in the lower Congo, around Kisanagani at the boundary between the middle and upper Congo, and adjacent to Bangui on the Ubangi (Figure 3.4). Between seven and 10 Data Deficient species are found in parts of the **Lower Congo Rapids** ecoregion, the middle Congo downstream from Kisangani and adjacent to the confluence with the Lomami, upper tributaries of the Lowa, draining the **Albertine Highlands** ecoregion to the Lualaba, the Ubangi river between Bangui and Mobaye, and the upper part of the Bouniandjé in Gabon. Data Deficient species are also recorded for large parts of the **Upper Lualaba** and **Bengweulu-Mweru** ecoregions.

Species are recorded as Data Deficient if they are believed to be present in a region but there is insufficient information to reliably judge how they might be impacted by threats. For example, the species might be known from only one or two records; in the absence of reliable information about the total distribution of the species it is impossible to assess the extent to which the species might be impacted by any local or regional threat. As noted above, many of the rivers and tributaries of central Africa have been incompletely surveyed, and the complete distribution and ecology of many of the species of fishes in central Africa is not well known. For example, the amphiliid catfish *Phractura fasciata* is only known from the type locality of Wagenia Falls (Stanley Falls) (Skelton and Teugels 1986). The species may be more widespread than this, and an assessment of the conservation status of the species cannot be made until more information on the species' distribution is available. In some cases the species may be so poorly represented by collected specimens that its taxonomy is in question (e.g., there may be some debate about whether novel morphological or genetic features of the specimens indicate that they represent a distinct species from all others present, or whether those features represent intraspecific variation of some other species; Lowenstein *et al.*, in press). For instance, *Haplochromis luluae*, named for the Lulua River, which is the only river where it has been collected, might be a synonym of the more widespread *Haplochromis stigmatogenys*, and is recorded as Data Deficient until its taxonomic status has been revised.

Several of the regions where there are Data Deficient species also include relatively high numbers of threatened species (e.g. the Lower Congo and the upper part of the Bouniandjé). Therefore, it is quite possible that the Data Deficient species are themselves threatened; these regions (and the neighbouring areas where the species might also be present but are currently undetected) should be identified as priorities for further surveying and monitoring in order to resolve the Data Deficiency for species.

There are also some areas where there is a lack of data for any species of fishes (i.e., there is no available documentation of species

present in these regions). The largest of these regions is formed by the Mbari, Chinko, and Ouara basins draining to the Mbomo, in the sparsely populated eastern part of the Central African Republic. However, there are also several small sub-basins within the Congo province that also have no records of fish species. These include the upper parts of the Mambéré and Lobaye rivers in the Central African Republic; the Motaba river in the Republic of Congo; in northern Democratic Republic of Congo, the upper tributaries of the Mogala, and the Yekokora and Lomako rivers draining to the Lulonga; the upper parts of the Lokoro draining to Lake Mai Ndome in central Democratic Republic of Congo; the Maiko river joining the Congo upstream from Kisangani, in eastern Democratic Republic of Congo; several sub-basins of the **Kasai** ecoregion including the Wamba river, tributaries draining from Angola to the

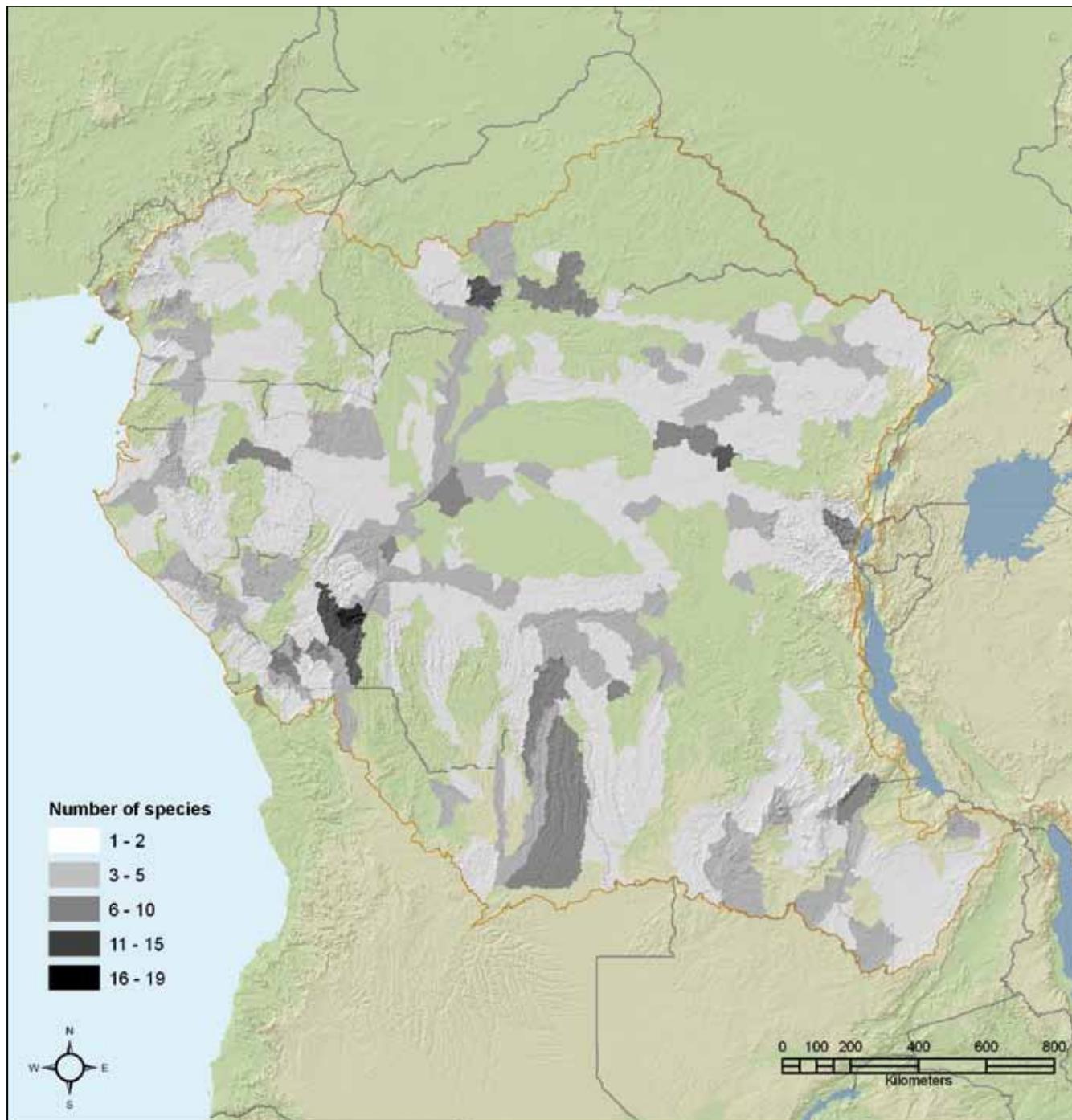
Kwango, the upper parts of the Kwilu, and the Lubishi draining to the Sankuru; and in the **Upper Lualaba** ecoregion, the Lovio river draining to the Lualaba. Several of these basins are in undisturbed parts of the Congo forest and are likely to have high numbers of species. However, some of the sub-basins, such as some in the **Kasai** ecoregion, face numerous current and imminent threats (see below), indicating an urgent need to complete surveys of these regions before rare or undescribed species are extirpated.

3.3.4 Threatened species

3.3.4.1 Lower Guinea Province

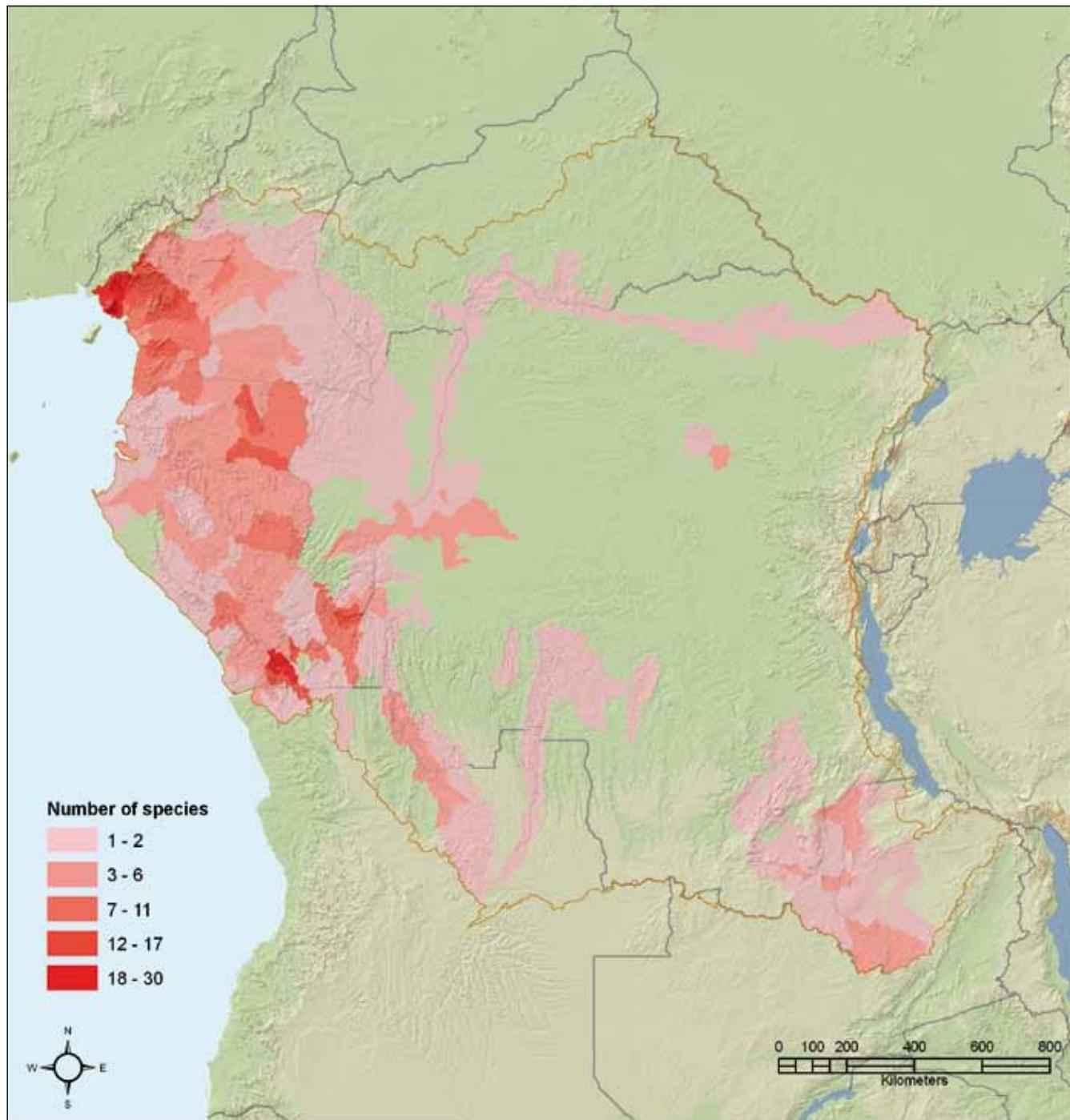
Species classified as threatened according to the IUCN Red List Criteria are distributed throughout most of the Lower Guinea

Figure 3.4 The distribution of Data Deficient freshwater fish species in central Africa, mapped to river sub-catchments.



province, with greatest numbers in the **Western Equatorial Crater Lakes** ecoregion in south-western Cameroon, near the border with Nigeria (Figure 3.5). Relatively high numbers of threatened species (10 or more species, compared to an average for the entire central African region of fewer than one threatened species per sub-basin) are also found in the Wouri and Sanaga basins in northern Cameroon, as well as the Bouniandjé system in Gabon. Only slightly lower numbers of threatened species are found in some of the smaller coastal basins of southern Cameroon; in Gabon, in the mid-section of the Ogoïe and the Abanga, the upper parts of the Ngounié, and the more upstream affluents of the Ogoïe such as the Ivindo, Zadié, Libouma, Leyou and Passa rivers; and in the Kouilou in the Republic of Congo.

Figure 3.5 The distribution of threatened species of freshwater fish in central Africa, mapped to river sub-catchments.



Twenty-three out of the 26 species of fishes that are categorized as Critically Endangered for the central Africa region are recorded from the **Western Equatorial Crater Lakes** ecoregion; 21 of these are lake cichlids (Stiassny *et al.*, 1992; Schlieben *et al.* 1994; Schlieben 2005), the other two are a clariid catfish, *Clarias macularis*, and a nothobranchiid killifish *Funduluspanchax gardneri lacustris*. Other species found in the Lower Guinea province that are categorized as Critically Endangered for central Africa are the mormyrid *Brienomyrus longianalis*, and the sawfish *Pristis pristis*. In central Africa, *Brienomyrus longianalis* is known only from near the Kribi (Kienké) river (see 3.4.1., below), but it is also known from the lower Niger and coastal basins of western Africa, where it is less threatened. Therefore, while populations of this species are severely threatened in central Africa, globally it is categorized as

Least Concern (Lalèyè and Moelants 2009a). *Pristis pristis*, which is found in fresh or brackish water recorded from the lower Ogowe and its estuary (Séret 1990) is also widespread through the eastern Atlantic; however it faces significant threats throughout its range and it is also Critically Endangered at a global level (Cook and Compagno 2005).

Species classified as Endangered are found in several of the larger basins of Lower Guinea (e.g., Sanaga, Nyong, the Ogowe-Ivindo and Ngounie systems, and the Kouilou-Niari systems), some of the smaller coastal basins in Cameroon (e.g. the Kribi and Lobe) and all of the small coastal basins of the Republic of Congo. Vulnerable species are found in almost all the sub-basins of Lower Guinea. Two distinct regions where no threatened species have been recorded are in Gabon, in the vicinity of Wonga-Wongué Reserve to the north of the Ogowe estuary, and the small coastal basins of the Ngové-Ndogo region to the south of the Ogowe. The lack of threatened species in these regions cannot be attributed to poor sampling, since between 37 and 64 species of fishes have been recorded from these basins.

3.3.4.2 Congo Basin Province

There are far fewer threatened species in the Congo basin province compared to Lower Guinea (Figure 3.5). Most of the threatened species are found in the lower Congo River, from Malebo Pool downstream to Matadi. Greatest concentrations of threatened species are found in the **Lower Congo Rapids** ecoregion, adjacent to Inga (24 threatened species) and downstream from Luozi (15 threatened species). The large numbers of threatened species found in the vicinity of Inga can be attributed to threats from dams (see below). Eleven or twelve threatened species are found in regions upstream from Luozi and in tributaries on the north side of Malebo Pool (around the Djoué basin), and slightly fewer (six threatened species) are found in the drainages to the south of Malebo Pool (i.e. the Nsélé basin).

Six threatened species are recorded from the Mai Ndombe region. Between three and five threatened species are found in several parts of the Congo Province: the Congo River immediately north of Malebo Pool, Lake Tumba, the **Upper Congo Rapids** ecoregion adjacent to Kisangani, the Kafila drainage to the Lufira in the **Upper Lualaba** ecoregion; the drainages to Lake Mweru and some of the upper tributaries to the Luapula upstream from Lake Mweru in the **Bangweulu-Mweru** ecoregion; and in the upper parts of the Kwango, along the border between Angola and the Democratic Republic of Congo. Elsewhere in the Congo province the numbers of threatened species are lower, and tend to be restricted to the larger main channels where only one or two threatened species are found at most. These include the Congo river between Malebo Pool and the confluence with the Ubangi; the Sangha and adjacent drainages to the middle Congo from the south and east; the region of the lakes and wetlands of the upper Lualaba near Malemba Nkulu, the Lufira river, and several parts of the **Bangweulu-Mweru** ecoregion near the border of the Democratic Republic of Congo and Zambia. In south-western Congo, the Inzia and Luie rivers, draining to the Kasai, each have a single threatened species, and a threatened species is reported for the upper part of the Kasai and associated basins

(including the have Lovua and Thsikapa affluents from Angola, the Lulua, and the Lubi river draining to the Sankuaria). Large parts of the **Sudanic Congo – Ubangi, Cuvette Central** and **Upper Lulaba** ecoregions lack any threatened species, and none are recorded from the Albertine Highlands. Threats are expected to be low, because many of these regions are extremely remote, but not non-existent (see section 3.4.4. below). The very low number of threatened species from these regions may, therefore, be an underestimate. This certainly seems to be the case for the northern part of the **Sudanic Congo-Ubangi** ecoregion, in the Central African Republic, where there has been low sampling (see discussion of Data Deficient species, section 3.3.3).

One species of fish is recorded as Critically Endangered from the Congo basin province, *Teleogramma brichardi*. This is a small cichlid, abundant in the region of Kinsuka Rapids on the south side of the river Congo, on the outskirts of Kinshasa. It is categorized as Critically Endangered because the species is currently only reliably known from this region and it is considered to be threatened by the impacts of urbanization at Kinshasa and Brazzaville (see below). Other locations reported for this species are probably based on misidentifications. Further collections are necessary to establish the precise distribution of this species; in addition, *T. brichardi* may represent a complex of more than one species (Stiassny, pers obs; Moelants 2009).

Endangered species are known from the Lower Congo, Malebo Pool and its tributaries, and parts of the middle Congo immediately upstream of Malebo Pool, regions around Lakes Mai Ndombe and Tumba, the **Upper Congo Rapids** ecoregion adjacent to Kisangani, parts of the **Upper Lualaba** ecoregion (especially in the wetlands near Malemba Nkulu); much of the southern portion of the **Bangweulu-Mweru** ecoregion; and the Inzia/Lukulu system draining to the Kwilu. However, they are present in low species numbers in many of these regions (see above). Vulnerable species show a similar distribution (also in low numbers of species for many regions; see above), although they are more widespread through the lower Congo, and the middle Congo between Malebo Pool and Lake Tumba, and parts of the Kasai basin. Additional Endangered species are found in the Sangha and a large part of the Ubangi/Uele system.

3.4 Major threats to fishes

The main threats to fishes in central Africa are shown in Figure 3.6. The greatest threat to freshwater fishes in the region is habitat loss and degradation, in particular due to mining, agriculture and infrastructure development. Water pollution is also having a substantial impact on the fishes of central Africa, in particular as a result of sedimentation due to deforestation.

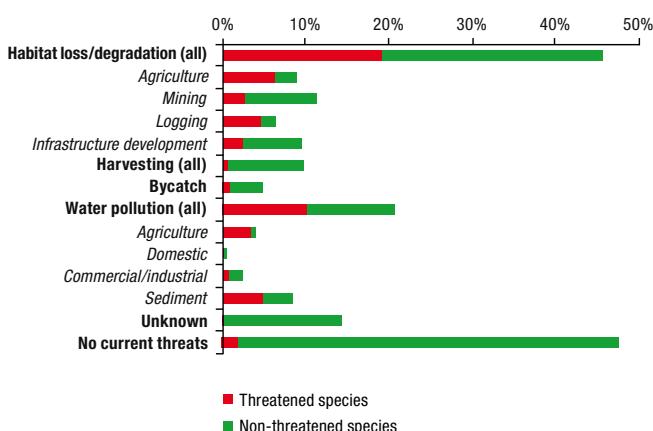
3.4.1 Lower Guinea

Human population densities are greatest in the northern part of the Lower Guinea province, especially in the **Northern Gulf**

of Guinea Drainages, Western Equatorial Crater Lakes, and Lower Niger-Benue ecoregions. Pollution and other types of habitat disturbance from urbanization and agriculture are therefore higher in these areas than elsewhere. Agricultural impacts include pollution from pesticides and fertilizers, and sedimentation from soil erosion where slash and burn practices have been adopted. Habitat degradation from banana plantations, including pollution and sedimentation, are particular problems in the region around upper Mungo basin (Cameroon). For example, the cyprinid *Barbus thysi*, an Endangered species known from relatively few locations in coastal rivers of south west Cameroon (principally around the Mungo and Wouri/Nkan basins) and on the island of Bioko, is threatened by sedimentation and pollution from banana plantations. In addition, the coastal locations where *B. thysi* is found are threatened by oil palm plantations (see Chapter 1, section 1.2.4.2 for further discussion on extent of plantations in central Africa). Urbanisation in the region of Kribi (Cameroon) is thought to have destroyed available habitat for the mormyrid *Brienomyrus longianalis* (regionally classified as Critically Endangered, see 3.3.4.1 above) which was previously known from the Kribi region. This mormyrid is otherwise only known in central Africa from marshes around Fifinda, to the north of Kribi, where it is likely impacted by increased sedimentation and habitat loss caused by barrage fishing.

Deforestation is a major threat through many parts of the Lower Guinea province. Commercial logging is a principal cause of deforestation and has, therefore, contributed to several species of fishes being listed as Endangered. Nevertheless, there are several other causes of deforestation; the geographic extent of these drivers of deforestation, and the impacts they have on freshwater ecosystems, are discussed in more detail in Chapter 1, section 1.2.4.1. Allochthonous input of plant material from the riparian forest is important for supporting aquatic food webs, particularly in the blackwater systems that are common in the southern part of Lower Guinea province and the Congo province (Thieme *et al.* 2005; Stiassny *et al.* 2007; and see Chapter 1). Deforestation is usually followed by increased sediment run-off, impacting fishes and many other aquatic organisms (see Chapter 1).

Figure 3.6 Percentage of fish species known to be affected by each threat. Note that many species may have more than one threat listed.



Some mining occurs in Lower Guinea and, while it is not as extensive as in the Congo basin (see below and Chapter 1, section 1.2.4.3), it presents threats to the species present via pollution, sedimentation, and deforestation. Iron mining occurs in the Ogowe system, in the vicinity of the Ivindo and Bouniandjé rivers, and threatens species with distributions that appear to be restricted to this area (e.g., the Endangered nothobranchiid *Aphyosemion fulgens* and the mormyrid *Stomatorhinus ivindoensis*). Plans for iron mining and the development of a deep water port on the Ntem River (Cameroon) also represent important potential threats. Manganese mining, occurring nearby in the vicinity of the Lekoudi and upper tributaries of the Ogowe, similarly threatens fish species (e.g., the Endangered nothobranchiid *Aphyosemion tirkaki* and poeciliid *Plataplochilus terveri*). Gold mining occurs in the Kouilou basin (at least at an artisanal level) and near the headwaters of the Chiloango river (Cabinda/Democratic Republic of Congo). Oil exploration along the coast of Gabon, the Republic of Congo impacts some of the coastal drainages. This may occur either directly from oil pollution, or from the impacts on coastal habitat caused by development of service industries supplying the oil companies.

Several dams have been constructed on rivers in Lower Guinea (see Chapter 1, section 1.2.4.4). Dams are also planned for development on other rivers (e.g. the Ntem in Cameroon). These present severe threats to freshwater fishes, significantly impacting species that show seasonal migrations along rivers, usually associated with spawning. These include several species of cyprinids and distichodontids, in particular species of *Labeo*, *Labeobarbus*, and *Distichodus*. Kamdem-Toham *et al.* (2003, cited in Thieme *et al.* 2005) have already reported that the 60 m high Moukououlou dam on the Bouenza River in the Republic of Congo has prevented migration of fish species.

In some cases these planned dams are in regions where species are already impacted by existing threats, and hence are likely to be very susceptible to further declines. For example, a dam that was started on the lower Kouilou before the civil war in the Republic of Congo, and then stopped in 1997, might now be constructed. The fishes of this region are already impacted by deforestation, and possibly also gold mining, with several different catfishes and cyprinids (e.g. species of *Amphilophus*, *Anaspisoglanis*, and *Barbus* listed as Vulnerable or Endangered).

Threats from poorly managed freshwater fisheries are not common in Lower Guinea, but have been noted in the Ogowe and Kouilou river basins. The sawfish, *Pristis pristis*, is recorded from the lower part of the Ogowe basin and is Critically Endangered (see section 3.3.4.1) because it is caught as bycatch, and because the elasmobranch fishery effort in Africa has increased. Some species have been introduced into Lower Guinea for fisheries, e.g. the bonytongue *Heterotis niloticus* and the cichlid *Oreochromis niloticus*. There are few data on specific impacts of these alien species on the native ones (Stiassny *et al.* 2007). Commercial fisheries for the aquarium and ornamental fish trade are not a significant threat for many species in Lower Guinea. Killifishes

(of the order Cyprinodontiformes) are a possible exception because these are popular in the aquarium trade and include several species that have restricted distributions (e.g., species of *Aphyosemion*). Intense collection efforts for these species could, therefore, severely impact these species. Cichlids are also popular aquarium fishes but there is little information to show that the aquarium trade is impacting these species to the same extent as other threats such as habitat degradation, sedimentation, and pollution.

There are several other species classified as threatened because they are known from very few localities, and the impacts of regional or local threats could have very significant impacts on the entire species. More than 75% of the fish species found in the small lakes and associated freshwater ecosystems of the **Western Equatorial Crater Lakes** ecoregion in the north-west of the Lower Guinea Province are endemic to the region. The crater lakes are all relatively small and, therefore, local environmental change can seriously affect the entire lake and have a significant impact on the conservation status of the endemic species (Reid 1990; Thieme *et al.* 2005; see also section 3.3.4.1. for discussion of numbers of Critically Endangered species). Several of the threats mentioned above for rivers of northern Lower Guinea are also major threats for these lakes. Deforestation is a problem because the lake ecosystems are heavily dependent on nutrients derived from the surrounding rainforest (Reid 1990;

Stiassny *et al.* 1992). These exogenous nutrients support the lakes' phytoplankton communities that are critical to aquatic food webs. Logs and leaf litter that fall into the lake provide an important supply of substrates for many different species (e.g., sponges), as well as sites for foraging and breeding for species of fishes. Oil palm plantation and slash-and-burn agriculture, which are associated with the deforestation, also contribute to increased sedimentation in the lakes from soil erosion, pollution from pesticides and fertilizers. Increased wind exposure on the lake surface, caused by deforestation, may create an additional threat to some of the lakes that are known to be stratified, with a lower zone of water that is high in organic material and low in oxygen (e.g., Lake Barombi-ba-Kotto). In these lakes, the wind exposure promotes mixing of surface waters with deeper waters, and as the deeper, oxygen depleted water rises to the surface it may kill the fishes living at these shallow depths. A similar threat is posed by the periodic 'degassing' of certain crater lakes, where there is a sudden release of carbon dioxide that has been under pressure in very high concentrations in deep waters and saturated sediments. The rapid diffusion of carbon dioxide into the main water column and from there into the atmosphere can be fatal to many organisms; the Cameroonian Lake Nyos disaster of 1986 is perhaps the best-known example of this phenomenon. Such natural events are especially threatening when the populations of the endemic species have already been compromised by other

Boys with Mormyrops. Bomane, Lower Aruwimi, DRC. Photo: © K.-D. Dijkstra.



threats. Extraction of water occurs in some lakes, and the changes in lake levels may alter the breeding habitat available to some endemic cichlids. The water extraction may also disturb lake stratification, resulting in large-scale fish kills as discussed above.

3.4.2 The Lower Congo River

The rivers of this region, which encompasses the **Lower Congo**, **Lower Congo Rapids**, and **Malebo Pool** ecoregions, have high numbers of threatened species of fishes for central Africa (see above). The area has a high population density which impacts the rivers through pollution, especially in Malebo Pool in the vicinity of the large cities of Kinshasa and Brazzaville, and large distances downstream from these cities (see Chapter 1, section 1.2.4.5). The small poeciliid *Poropanchax myersi* is categorized as Endangered because it is only found in Malebo Pool and the entire species population may be impacted by the impacts of sewage and industrial waste from these large cities. Proposed development of a major bridge crossing between the Republic of Congo and the Democratic Republic of Congo, in the region of Kinsuka rapids immediately downstream from Malebo Pool, is also a significant threat to species (such as the Critically Endangered cichlid *Teleogramma brichardi*) through habitat disturbance in the region during the course of bridge and road construction. Tourist facilities are being developed in this region, on ‘Kinsuka Island,’ and open-air bars are common along rivers close to Kinshasa (e.g., in the Nsele basin). Though these facilities pose only local threats, from habitat disturbance and pollution, they are present in large enough numbers (and may be expected to increase in number) that they might impact fish species in the region.

The broad channels of **Malebo Pool** support large species of fishes which can be easily fished because of the slow moving, shallow waters. This region augments supplies to Kinshasa and Brazzaville with fish for consumption and is becoming heavily overfished. The quantity of fishes being caught, and the unregulated use of fish poisons, fine-mesh nets, and recently also grenades and explosives, are highly destructive to the habitat and present a significant threat to the native fishes (Thieme *et al.* 2005, 2008). There is small-scale fish collecting, centered in the rapids immediately downstream of Kinshasa, for the aquarium trade but this does not seem to be impacting targeted species at present (Stiassny, pers. obs.).

Mining (mainly for limestone) along the lower portion of the Congo river and its tributaries adds to the sediment load, as does sandstone quarrying that occurs especially along the main channel of the Congo just downstream of Malebo Pool. These activities increase turbidity and sediment deposition on river beds. Most rural areas throughout the region have been largely deforested for many decades to support agriculture and for hunting. The deforestation of most vestiges of riparian forest continues, to provide firewood and charcoal for markets in Kinshasa (Thieme *et al.* 2008). Deforestation, and the hilly topography of the region, has resulted in problems of erosion and added siltation into the watershed. Developing agriculture

on some of the large islands of Malebo Pool is also causing increased siltation.

The Mbanzagungu (Thysville) caves which were originally classified as their own ecoregion by Thieme *et al.* (2005) are considered here within the **Lower Congo** region. These numerous limestone caves and subterranean conduits are home to an endemic hypogean species, *Caecobarbus geertsii*, classified as Vulnerable. A significant threat is from sedimentation of waters in the caves, caused by surrounding agricultural development (Thieme *et al.* 2008). Other threats include domestic and agricultural pollution, changes in hydrology, and habitat destruction. There is increasing human population in the region and accompanying agricultural development, and the caves are also a growing tourist destination.

Dams represent a very significant threat to fishes in the Lower Congo region (see Chapter 1, section 1.2.2.4), with at least six dams over 20 m, including the 36 m Djoue dam on the Djoue River near Brazzaville, and the 17 m Zongo dam on the Inkisi River built to increase the power capacity supplied to Kinshasha. By far the largest dam project is in the region of the rapids at Inga, where two out of a projected complex of four dams have been built (see Chapter 1, section 1.2.2.4). If plans to develop Inga 3, and Grand Inga cascades proceeds according to plan, the compound effect of these dams and the infrastructure required to maintain and operate them and their associated power stations could be severe. Future threats for the region include a proposed aluminium processing plant in the vicinity of Moanda (its development is contingent on the development of the Inga 3 dam to provide power for the energy intensive plants), and plans for industrial cement production in the region of Luozzi, both of which are likely to contribute to pollution and sedimentation in rivers.

3.4.3 The Middle Congo

Most of the middle section of the Congo (from Malebo Pool to Boyoma Falls [also called Wagenia Falls] near Kisangani) forms the **Cuvette Centrale** ecoregion, and includes large parts of the central Congo basin. The **Cuvette Centrale** mainly comprises forests and associated seasonally flooded wetlands. Much of the region is inaccessible, and threats are relatively low. However, even by the early 1990s, 37% of the total exploitable rainforest of the Democratic Republic of Congo (much of it in the **Cuvette Centrale** ecoregion) had been designated for timber concessions, and this removal of riparian forest would affect the diversity of fishes in the rivers and wetlands (Thieme *et al.* 2005). Deforestation is currently a problem in the north-eastern parts of the Cuvette Centrale, caused by illegal logging from Uganda and by refugees displaced by the civil unrest in neighbouring countries. As noted in Chapter 1 (section 1.2.4.2), the Lake Tumba region is increasingly impacted by slash and burn agriculture and, in the future, may be subject to the development of Chinese subsidized oil palm plantations. Both these activities degrade water quality and potentially impact species present in



Lungfish for sale, Yaekela, DRC.
Photo: © K.-D. Dijkstra.

the lake and surrounding rivers and streams. Further, Inogwabini *et al.* (2006) note that the depth of Lake Tumba has dropped by 50%, from 6 m in the late 1970s to 3 m, and they attributed this to decreasing rainfall, and to siltation caused, in part, by the erosion soils that are newly exposed by the declining water levels. Mining in the vicinity of the confluence of the Itimbiri and Congo rivers and upriver to Kisangani (Chapter 1, section 1.2.4.3) is also likely to impact fishes through habitat loss and declining water quality. Similarly, urban pollution near Kisangani (Chapter 1, section 1.2.4.5) is a growing threat to populations in this region.

Fishing pressure is generally low in the Cuvette Centrale. However, Shumway *et al.* (2003) report high levels of fishing along the main channel of the Congo in the vicinity of Mbandaka, to support the markets in the town and as export to supply growing demand in Kinshasa. Surveys of fisheries in the Mbandaka-Ngombe region in 2003 showed that 74% of the catch of four species were composed of juveniles, indicating that stocks were even then overexploited (ERGS Research Group, cited in Thieme *et al.* (2005)). Fishing pressure is also relatively high in the neighbouring Lake Tumba, which drains to the main channel of the Congo River (Inogwabini *et al.* 2010). Fishing nets of undersized mesh (1 cm or less) are reported from Lake Tumba, along with other non-selective artisanal methods (e.g. the use of chemicals, and fishing in spawning grounds during the reproductive season). Fishermen have noted declining yields and in Lake Tumba, and large species seem to be disappearing. These

unregulated and unselective fishing practices also pose significant threats to smaller, bycatch species of no current fisheries value. The cichlids *Lamprologus tumbanus* and *Tylochromis microdon*, both endemic to the lake, are recorded as Endangered, and the alestid *Clupeocharax schoutedeni* is classified as Vulnerable. Unregulated use of fish poisons has also been reported in the main channel of the Congo (Shumway *et al.* 2003) and from Salonga National Park (Inogwabini 2005; Monsembula 2008).

Although invasive fish species are generally not abundant in the Congo basin, *Oreochromis niloticus* is found, albeit in low numbers, throughout much of the region, and the bonytongue, *Heterotis niloticus* has become a dominant component in many rivers of the Cuvette Centrale and in large sections of the main channel of the Middle Congo. Another significant problem is posed by the water hyacinth *Eichhornia crassipes*, which accumulates in medium and large channels of the Congo from the lower to the upper sections of the river (see Chapter 1, section 1.2.4.7).

3.4.4 The Upper Congo

While there are no threatened fishes reported from the entire Lomami basin, and the upper part of the Congo and its tributaries (including rivers of the Albertine Highlands) from Boyoma Falls south to the confluence with the Luvua (see section 3.3.4.2, above), several threats have been documented for many of these

Much of the rural population in the central African rainforest spends the fishing seasons in temporary camps, harvesting what is for them an essential component of livelihoods and protein supply. Photo: © Randy Brummett.



regions. There is a significant threat of deforestation in the **Upper Congo** ecoregion, with the Kivu Province experiencing the greatest current levels of deforestation for the entire Democratic Republic of Congo (Thieme *et al.* 2005). Habitat conversion for oil palm and agriculture also impacts the freshwaters of the **Upper Congo** ecoregion; deforestation and mining, has occurred especially along the eastern perimeter of the **Upper Congo** ecoregion and the north-eastern Albertine Highlands (see Chapter 1). Much of the mining in these regions is artisanal because civil unrest has prevented full scale industrialization of commercial operations. Pollution from domestic and some industrial sources is also a problem in certain populous regions of the **Upper Congo**.

The headwaters of the Congo drainage include the upper Lualaba, Lufira, Luvua, and Luapula rivers in the **Upper Lualaba** and **Bangweulu-Mweru** ecoregions, and encompass large floodplains, swamps and lakes. Unregulated fishing, with use of fish poisons, occur in both ecoregions and impacts several species; e.g., the killifishes *Nothobranchius symoensis* and *N. rosenstocki* from the Luapula system in the **Bangweulu-Mweru** ecoregion are both listed as Endangered. Mining occurs for different minerals in the **Upper Lualaba** ecoregion (see Chapter 1, section 1.2.4.3) and several large dams have been built in the headwaters of the rivers, to supply power to the mining industry (see also Chapter 1, sections 1.2.4.3. and 1.2.4.4). Some species of fishes in the **Upper Lualaba** region have been classified as Endangered because of

the combined threats from mining, dams, and fisheries (e.g. the catfish *Synodontis dorsomaculatus*, and the nothobranchiid killifish, *Nothobranchus polli*).

3.4.5 Kasai drainage

Much of the **Kasai** basin has already undergone significant deforestation (see Chapter 1, section 1.2.4.1) and like the **Upper Lualaba** region immediately to the east, significant impacts from mining (particularly diamond and copper mining, see Chapter 1, section 1.2.4.3) are present throughout the region and are currently unregulated and increasing in intensity. Shumway *et al.* (2003) also observed evidence of overfishing with illegally sized nets along the lower Kasai, and they note that presence of oil in the lower Kasai region may attract industrial exploration which would pose significant future threats. Dams are also planned for development on certain Kasai tributaries (e.g., the Lulua).

3.4.6 Lake Mai Ndombe

Lake Mai Ndombe, which is connected to the Kasai via its drainage into the Lukenie river, is threatened by poorly regulated fisheries, most significantly from very fine mesh-size ‘mosquito nets’ that remove all species present. The species whose ranges are restricted to Mai Ndombe can be significantly impacted by local threats (e.g., the freshwater herring *Nannostrissa stewarti*, and the cichlids *Nanochromis transvestitus* and *Hemichromis cerasogaster*,

Lower section of Congo river, near Inga, Democratic Republic of Congo. New species recently discovered from this region include *Micralestes schelly*, a member of the poorly defined genus, *Micralestes*. Photo: © Ulrich Schliewen.



are all classified as Endangered). As noted in Chapter 1, additional threats to the fishes comes from the extensive clearing of logging concessions around the lake and possible future exploitation of methane deposits in the area (see Chapter 1; sections 1.2.4.2 and 1.2.4.3).

3.4.7 Sangha

The main threats to fishes in the **Sangha** ecoregion come from deforestation caused by logging, and the pollution and habitat damage that follow once the forest has been opened up and made more accessible. Industrial gold mining and alluvial diamond mining have further increased sedimentation and pollution in rivers in parts of the **Sangha** ecoregion.

3.4.8 Ubangi-Uele drainage system

Several activities have resulted in extremely high sediment loads in the Ubangi River, including logging activities in the northern Republic of Congo, and diamond mining and agricultural development upstream of Bangui. This has impacted the river fisheries in the river and seasonally impedes river transportation (Brummett *et al.* 2009). Pollution from the city of Bangui and the 30 m Mobaye dam are also likely to affect local fish populations (see Chapter 1). Further upriver the Uele faces fewer threats, although some mining and the impacts of civil disturbance near the border with Uganda may pose a low level of threat.

3.5 Conservation recommendations

Perhaps the most significant finding of this assessment of the status and distribution of freshwater fishes in central Africa is the recognition that a large number of species (23%) are Data Deficient and that taxonomic knowledge and distributional data is rudimentary for much of the ichthyofauna. For other regions in Africa comprehensively assessed thus far (northern, western, eastern, and southern Africa, and freshwater Mediterranean basin), only northern Africa has a higher percentage of Data Deficient fish species (32%; García *et al.* 2010) but in the latter case species numbers are considerably lower. Moreover, in central Africa there are several sub-basins covering large areas for which there are no records for any freshwater fishes. Therefore, despite recent, focused efforts by international teams of ichthyologists to conduct more comprehensive sampling in the region, there is still a need to conduct more extensive surveying throughout much of central Africa, particularly in the forested regions of the Republic of Congo, Democratic Republic of Congo, and Central African Republic.

While many parts of the central Africa have been impacted by diverse threats (see section 3.4), there are large areas, especially in the Congo basin and central Lower Guinea, that remain relatively undisturbed. However, several of these regions face incipient threats from, for example, planned timber concessions, dams, and mining activity. There is clearly a need to identify pristine areas of habitats and implement programs for their protection, as

well as strengthening efforts to mitigate the impacts of threats in some of the more severely affected regions such as northern Lower Guinea, the lower Congo, and the Kasai basin. Development of parks and protected areas that encompass rivers and wetlands are therefore an essential part of the conservation recommendations. The Ministry of Environment for the Democratic Republic of Congo and the Institut Congolais Pour la Conservation de la Nature (ICCN) initiated a country-wide biodiversity assessment to identify priority areas for conservation and identified 30 wetland priority areas (Thieme *et al.* 2008). Efforts to augment national or international protected areas will also be assisted by the agreement at the 10th Conference of the Parties to the Convention on Biological Diversity (CBD-COP10, held at Nagoya in November 2010) that 17% of terrestrial and inland water areas globally should be protected (Cameroon, Gabon, Republic of Congo, Democratic Republic of Congo, Central African Republic, and Angola have all ratified the CBD).

Several parks or reserves already exist (e.g., at Odzala, Dzanga-Sangha, the Zemong Faunal Reserve and Yata-Ngaya reserve, the Lake Tele/Likouala aux Herbes Reserve and Ramsar site, and Salonga National Park and World Heritage Centre). However, for some of the more isolated regions of central Africa (e.g., the north-eastern parts of the Ubangi-Uele drainage, Salonga National Park) there are insufficient resources to properly manage the existing parks. This becomes a particular problem where human encroachment (much of it driven by civil unrest) is now threatened previously sparsely populated areas. Therefore, a recommended conservation priority is for investment in greater capacity for support of the existing protected areas on central Africa. Other mechanisms for promoting and integrating community involvement in conservation and sustainable development programs are urgently needed throughout the region. Brummett (2005) discusses the potential of sustainable, locally managed fisheries for the aquarium trade in African freshwaters could provide an important ecosystem service that would support rural livelihoods.

Maintenance of natural flow regimes (including quantity, quality and timing of water flows) is an ideal conservation recommendation. However, modification of some flows is unavoidable in order to meet essential human requirements. Under these circumstances, the implementation of comprehensive environmental impact assessments (e.g., for areas where dams are planned) with recommendations as to how to mitigate the most deleterious impacts is crucial. As noted for other parts of Africa, the political will and action of the central African countries is essential to ensure that conservation recommendations are successful.

3.6 References

- Brummett, R.E. 2005. Freshwater ornamental fishes: a rural livelihood option for Africa? In: *Freshwater ecoregions of Africa and Madagascar: a conservation assessment*. Eds. Thieme, M.L., Abell, R., Stiassny, M.L.J., Skelton, P., Lehner, B., Teugels,

- G.G., Dinerstein, E., Kamdem Toham, A., Burgess, N. and Olson, D. pp. 132–135. Island Press, Washington DC, USA.
- Brummett R.E. and G.G. Teugels. 2004. Rainforest rivers of Central Africa: biogeography and sustainable exploitation. In: *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries. RAP 2004/16*, Eds. Welcomme, R. and Petr, T. pp. 149–171. Food and Agriculture Organization of the United Nations, Bangkok, Thailand.
- Brummett, R., Tanania, C., Pandi, A., Ladel, J., Munzimi, Y., Russell, A., Stiassny, M., Thieme, M., White, S. and Davies, D. 2009. Water resources, forests and ecosystem goods and services. In: The forests of the Congo Basin: State of the forest 2008. Eds. De Wasseige, C., Devers, D., de Marcken, P. Eba'a Atyi, R., Nasi, R. and Mayaux, P. pp.1411–157. Publications Office of the European Union, Luxembourg.
- Cook, S.F. and Compagno, L.J.V. 2005. *Pristis pristis*. In: IUCN 2010. *IUCN Red List of Threatened Species*. Version 2010.4. <www.iucnredlist.org>. Downloaded on 30 November 2010.
- Daget, J., Gosse, J.-P. and Thys van den Audenaerde, D.F.E. (eds.) 1984. Check-list of the freshwater fishes of Africa, Vol. 1. ORSTOM-MRAC, Tervuren, Belgium.
- Daget, J., Gosse, J.-P. and Thys van den Audenaerde, D.F.E. 1986. Check-list of the freshwater fishes of Africa, Vol. 2. ORSTOM-MRAC, Tervuren, Belgium.
- Daget, J., Gosse, J.-P., Teugels, G.G. and Thys van den Audenaerde, D.F.E. 1991. Check-list of the freshwater fishes of Africa, Vol. 4. ORSTOM-MRAC, Tervuren, Belgium.
- García, N., Cuttelod, A. and Abdul Malak, D. (eds.) 2010. *The Status and Distribution of Freshwater Biodiversity in Northern Africa*. IUCN, Gland, Switzerland, Cambridge, UK, and Malaga. xiii+141pp.
- Hugueny, B. 1989. West African rivers as biogeographic islands: species richness of fish communities. *Oecologia* **79**: 236–243.
- Inogwabini, B.-I. 2005. Fishes of the Salonga National Park, Democratic Republic of Congo: survey and conservation issues. *Oryx* **39** (1): 78–81.
- Inogwabini, B.I., Sandokan, B.M. and Ndunda, M. 2006. A dramatic decline in rainfall regime in the Congo basin: evidence from a thirty-four year data set from the Mabali Scientific Research Centre, Democratic Republic of Congo. *International Journal of Meteorology* **31** (312): 278–285.
- Inogwabini, B.-I., Dianda, M. and Lingopa, Z. 2010. The use of breeding sites of *Tilapia congica* (Thys and van Audenaerde 1960) to delineate conservation sites in the Lake Tumba, Democratic Republic of Congo: toward the conservation of the lake ecosystem. *African Journal of Ecology* **48** (3): 800–806.
- Kamdem Toham, A. and Teugels, G.G. 1998. Diversity patterns of fish assemblages in the Lower Ntem River Basin (Cameroon), with notes on potential effects of deforestation. *Archives of Hydrobiology* **141**(4): 421–446.
- Kamdem Toham, A., D'Amico, J., Olson, D., Blom, A., Trowbridge, L., Burgess, N., Thieme, M., Abell, R., Carroll, R.W., Gartlan, S., Langrand, O., Mikala Mussavu, R., O'Hara, D. and Strand, H. (eds.) 2003. Biological priorities for conservation in the Guinean-Congolian forest and freshwater region: Report of the Guinean-Congolian forest and freshwater region workshop, Libreville, Gabon, March 30–April 2, 2000. WWF, Libreville, Gabon.
- Kamdem Toham, A., D'Amico, J., Olson, D., Blom, A., Trowbridge, L., Burgess, N., Thieme, M., Abell, R., Carroll, R.W., Gartlan, S., Langrand, O., Mikala Mussavu, R., O'Hara, D. and Strand, H. (eds.) 2006. A vision for biodiversity conservation in Central Africa: biological priorities for conservation in the Guinean-Congolian forest and freshwater Region. World Wildlife Fund, USA. <http://www.worldwildlife.org/what/wherework/congo/WWFBinaryitem2900.pdf>
- Lalèyè, P. and Moelants, T. 2009. *Brienomyrus longianalis*. In: IUCN 2010. *IUCN Red List of Threatened Species*. Version 2010.4. <www.iucnredlist.org>. Downloaded on 30 November 2010.
- Lévéque, C. (ed.) 1997. *Biodiversity Dynamics and Conservation: the Freshwater Fish of Tropical Africa*. ORSTOM, Paris.
- Lowe-McConnell, R.H. 1975. *Fish Communities in Tropical Freshwaters*. Longman, London, UK.
- Lowe-McConnell, R.H. 1977. *Ecology of fishes in tropical waters*. Edward Arnold, London, UK.
- Lowenstein J.H., Osmundson T.W., Tshibwabwa S.M., Becker S., Hanner R. and Stiassny, M.L.J. in press. Incorporating DNA barcodes into a multi-year inventory of the fishes of the hyperdiverse Lower Congo River, with a multi-gene performance assessment of the genus *Labeo* as a case study. *Mitochondrial DNA*.
- Markert J.A., Schelly R.C. and Stiassny M.L.J. 2010. Genetic isolation and morphological divergence mediated by high-energy rapids in two cichlid genera from the lower Congo rapids. *BMC Evolutionary Biology* **10**:149.
- Mdaihli, M., T. du Feu, T. and Ayeni, J.S.O 2003. Fisheries in the southern border zone of Takamanda Forest Reserve, Cameroon. In: *Takamanda: the biodiversity of an African rainforest*. Eds. Comiskey, J.A., Sunderland, T.C.H. and Sunderland-Groves, J.L. SI/MAB Series #8, Smithsonian Institution, Washington DC, USA.
- Moelants, T. 2009a. *Caecobarbus geertsii*. In: IUCN 2010. *IUCN Red List of Threatened Species*. Version 2010.4. <www.iucnredlist.org>. Downloaded on 30 November 2010.
- Moelants, T. 2009b. *Teleogramma brichardi*. In: IUCN 2010. *IUCN Red List of Threatened Species*. Version 2010.4. <www.iucnredlist.org>. Downloaded on 30 November 2010.
- Monsembula, R. 2008. Inventaire et modes d'exploitation de l'Ictyofaune des rivières du Parc National de la Salonga. Mémoire de DEA, Université de Kinshasa, 60pp.
- Reid, G. McGregor 1990. Threatened fishes of Barombi Mbo: a crater lake in Cameroon. *Journal of Fish Biology* **37** (Supplement A): 209–211.
- Roberts, T.R. 1975. Geographical distribution of African freshwater fishes. *Zoological Journal of the Linnaean Society* **57**: 249–319.
- Schliewen, U. 2005. Cichlid species flocks in small Cameroonian lakes. In: *Freshwater ecoregions of Africa and Madagascar: a*

- conservation assessment*. Eds. Thieme, M.L., Abell, R., Stiassny, M.L.J., Skelton, P., Lehner, B., Teugels, G.G., Dinerstein, E., Kamdem Toham, A., Burgess, N. and Olson, D. pp. 58–60. Island Press, Washington DC, USA.
- Schliewen, U.K., Tautz, D. and Pääbo, S. 1994. Sympatric speciation suggested by monophyly of crater lake cichlids. *Nature* **368** (6472): 629–632.
- Séret, B. 1990. Pristidae. In: *Faune des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest*. Vol. 1. Eds. Lévêque, C., Paugy, D. and Teugels, G.G. ORSTOM-MRAC, Tervuren, Belgium.
- Shumway, C., Musibono, D., Ifuta, S., Sullivan, J., Schelly, R., Punga, J., Palata, J.-C. and Puema, V. 2003. Biodiversity Survey: Systematics, ecology, and conservation along the Congo River. Congo River Environment and Development Project (CREDP). New England Aquarium, Boston, Massachusetts, USA.
- Skelton, P.H. and Teugels, G.G. 1986. Amphiliidae. In: *Checklist of the freshwater fishes of Africa*, Vol. 2. Eds. Daget, J., Gosse, J.-P., and Thys van den Audenaerde, D.F.E. pp 54–65. ORSTOM-MRAC, Tervuren, Belgium.
- Stiassny, M.L.J. 1996. An overview of freshwater biodiversity: with some lessons from African fishes. *Fisheries* **21**(9): 7–13.
- Stiassny, M.L.J. 1999. The medium is the message: freshwater biodiversity in peril. Pp. 53–71. In: *The Living Planet in Crisis: Biodiversity Science and Policy*. Cracraft, J. and Griffio, F. (eds.) Pp. 53–71. Columbia University Press, New York, USA.
- Stiassny, M.L.J., Schliewen, U.K. and Dominey, W.J. 1992. A new species flock of cichlid fishes from Lake Bermin, Cameroon with a description of eight new species of *Tilapia* (Labroidei; Cichlidae). *Ichthyological Exploration of Freshwaters* **3**(4): 311–346.
- Stiassny, M.L.J., Teugels, G.G. and Hopkins, C.D. (eds.) 2007. *Poissons d'eaux douces et saumâtres de basse Guinée, ouest de l'Afrique centrale*. Volumes 1 (800pp) and 2 (603pp), IRD Éditions, Paris.
- Stiassny, M.L.J., Revenga, C. and Comer, P. 2010. Aquatic ecosystems: diversity and dynamism. In: *Fresh water: the essence of life*. Eds. Mittermeier, R.A., Farrell, T.A., Harrison, I.J., Upgren, A.J. and Brooks, T.M. pp. 93–117. CEMEX and ILCP, Arlington, Virginia, USA.
- Tedesco, P.A., Oberdorff, T., Lasso, C.A., Zapata, M. and Hugueny, B. 2005. Evidence of history in explaining diversity patterns in tropical riverine fish. *Journal of Biogeography* **32**: 1899–1907.
- Teugels, G.G. and Guégan, J.F. 1994. Diversité biologique des poissons d'eaux douces de la Basse-Guinée et de l'Afrique Centrale. In: *Diversité Biologique des Poissons des Eaux Douces et Saumâtres d'Afrique*. Annales Sciences Zoologiques **275**. Eds. Teugels, G.G., Guégan, J.F. and Albaret, J.-J. Musée Royal de l'Afrique Centrale, Tervuren, Belgium.
- Teugels, G.G., Reid, G. and King, R.P. 1992. Fishes of the Cross River basin: taxonomy, zoogeography, ecology and conservation. *Annales Sciences Zoologiques* **266**.
- Thieme, M.L., Abell, R., Stiassny, M.L.J., Skelton, P., Lehner, B., Teugels, G.G., Dinerstein, E., Kamdem Toham, A., Burgess, N. and Olson, D. 2005. Freshwater ecoregions of Africa and Madagascar: a conservation assessment. Island Press, Washington DC, USA.
- Thieme, M. Shapiro, A., Colom, A., Schliewen, U., Sindorf, N., and Kamdem Toham, A. 2008. Inventaire Rapide des Zones Humides Représentatives en République Démocratique du Congo. http://www.ramsar.org/pdf/wurc/wurc_dr-congo_inventaire2008.pdf
- Thys van den Audenaerde, D.F.E. 1966. Les *Tilapia* (Pisces, Cichlidae) du Sud-Cameroun et du Gabon. Étude systématique. *Musée royal de l'Afrique Centrale, Tervuren, Belgique, Annales Série in-8, Sciences zoologiques*, **153**: 1–98.
- Tweddle, D., Bills, R., Swartz, E., Coetzer, W., Da Costa, L., Engelbrecht, J., Cambray, J., Marshall, B., Impson, D., Skelton, P.H., Darwall, W.R.T. and Smith, K.S. 2009. The status and distribution of freshwater fishes. In: *The Status and Distribution of Freshwater Biodiversity in Southern Africa*. Eds. Darwall, W.R.T., Smith, K.G., Tweddle, D. and Skelton, P. IUCN, Gland, Switzerland; and SAIAB, South Africa. Viii+120pp.
- Wamuini, S.L., Vreven, E., Vandewalle, P., Mutambue, S. and Snoeks, J. 2008. The ichthyofauna of the Inkisi (Lower Congo Basin). Abstract, 91, PAFFA, Addis Ababa.

Market day, Lower Lomami, DRC. Photo: © K.-D. Dijkstra.



Chapter 4. The status and distribution of freshwater molluscs (Mollusca)

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4.1 Overview of the regional fauna

The focus of this chapter is the conservation status of the freshwater molluscs of the central region of Africa. The region extends from the Sanaga to the Congo Basin (excluding Lake Tanganyika) and includes the countries of Cameroon, Equatorial Guinea, Gabon, the Central African Republic, the Republic of Congo, the Democratic Republic of Congo (DRC), Angola and Zambia. The fresh waters of the region comprise 18 freshwater ecoregions (plus part of the Niger-Benue ecoregion), as devised by Thieme *et al.* (2005; see section 1.2.1). These ecoregions are useful reference points when considering threats to freshwater molluscs with restricted ranges, although species endemism often occurs over even smaller scales.

The largest single basin within the central African region is the Congo. The Congo River is roughly 4,700 km long, and the entire basin covers 3,680,000 km². The river flows in a giant, inverted question mark (?) with its dual heads in Katanga, DRC and Zambia's Northern and Luapula provinces. The latter headwater region includes two large lake systems: Mweru and Bangweulu. The Lualaba (the upper Congo, once thought to be the upper Nile until Henry Morton Stanley proved otherwise) flows north to Kisangani and the Upper Congo Rapids (dropping 60 m over ca. 100 km). From the rapids, the Congo arcs west through the Central Cuvette. The Cuvette, a former (Pliocene) endorheic

basin (Beadle, 1981), is today largely a tropical rainforest with soft, "black" water and few mollusc species outside the sluggish main channel. Below the Cuvette, the Congo turns south-west and is joined on the right by the Ubangi and on the left by the Kasai. Immediately above Kinshasa, DRC and Brazzaville, Congo, the river widens to a near circular (ca. 30 km diameter) series of channels collectively known as Malebo Pool. The foot of the Pool is a bedrock sill and the head of the Lower Congo Rapids. Over a distance of 350 km the river drops 280 m. From the foot of rapids, there is a short navigable stretch through a large estuary to the Atlantic Ocean. Because the basin straddles the equator, it is always the rainy season somewhere, and as a result, the river typically has high discharge that varies from 30,000–75,000 m³s⁻¹. The central African region also includes basins draining directly to the Atlantic, west of the Congo Basin. The principal ones are the Niari, Kouilou, Ogooué, and Sanaga Basins.

The freshwater Mollusca are represented by two classes in the region, Gastropoda and Bivalvia. Description of mollusc species from central Africa began in the late nineteenth century, most notably by French, Belgian, and German malacologists, accounting for a large number of specimens available in museum collections in London, Paris, Berlin, Frankfurt and Brussels in particular. From 1909–1915 the Lang-Chapin Expedition from the American Museum of Natural History in New York extracted a wealth of animal specimens from the region, including many

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Sampling high-gradient freshwater molluscs at the head of the Lower Congo Rapids. Photo © Kevin S. Cummings.



Sample of freshwater molluscs from Lake Bangweulu, Zambia. Photo © William Bone.

freshwater molluscs (Osborn and Bequaert 1919). This descriptive phase culminated in the seminal revisionary works of Pilsbry and Bequaert (1927) and Haas (1936).

Over the subsequent half century, gastropod research in Africa focused not only on exploration and discovery but also the importance of many species as intermediate hosts for human trematode parasites. That work was ably synthesized by Brown (1994) on a Pan-African scale in his *Freshwater Snails of Africa and Their Medical Importance*. The taxonomy of the Afrotropical bivalves was similarly reviewed by Mandahl-Barth (1988) and Daget (1998). Subsequent taxonomic research has not been comprehensive, and we expect that future revisions applying modern methods and comprehensive data sets may demonstrate an even greater diversity than documented here.

Table 4.1 The number of freshwater mollusc species in each regional Red List Category in the central African region.

	Regional Red List Category	Number of Species	Number of Regional Endemics
Threatened Categories	Critically Endangered	15	15
	Endangered	22	22
	Vulnerable	12	12
	Near Threatened	3	3
	Least Concern	76	24
	Data Deficient	31	19
	Not Applicable	35	0
Total*		159	95

* The Total figure does not include NA (Not Applicable) species.

All species assessed as regionally threatened that are endemic to the region are also globally threatened.

In addition to lotic communities, the molluscs discussed herein are also important species in standing fresh waters (from large permanent lakes to ephemeral pools) and coastal/estuarine brackish water habitats.

Our current best estimate for the number of freshwater mollusc species in central Africa is 159, 95 (60%) of which are endemic to the Region (Table 4.1). These taxa represent 53 genera in 24 families. The majority (110 species, 69%; 16 families) are gastropods; the remainder are bivalves (49 species; 8 families). Thirty-one species are listed as Data Deficient, and of the remaining 128 mollusc species, 49 (38%) are ranked as threatened. These magnitudes of species richness and endemism are the highest of the regional assessments done for Africa (Kristensen *et al.* 2009a, Kristensen *et al.* 2009b), with the proportion of threatened species second only to northern Africa, an area heavily impacted by development (Van Damme *et al.* 2010). Our analysis of patterns of molluscan species richness and endemism within the region, as well as our review of present and future threats, identifies several “hotspots” that merit attention. Our assessments also highlight the need for additional research.

4.2 Conservation status (IUCN Red List: Regional Scale)

The conservation status of each species of freshwater mollusc occurring in central Africa was assessed by applying the *IUCN Red List Categories and Criteria: Version 3.1* on a regional scale (IUCN 2001). The regional Red List status is equivalent to a global status for species endemic to the region, and all species ranked in threatened categories (Critically Endangered, Endangered and Vulnerable) herein are endemic to central Africa and indeed most are restricted to much smaller areas of occurrence/occupancy.

Twenty mollusc species from central Africa had been analysed in previous assessments. Ten were completed under current Red List criteria (vers. 3.1), but the other half were evaluated by David Brown in 1996 under version 2.3 (IUCN 1994) and are thus in need of updating. Of the species previously assessed under the current criteria, only two have changed status, both going from Data Deficient to Least Concern. Since 1996, some new information as well as improved evaluation criteria have allowed three species previously considered Vulnerable or Near Threatened to be down-graded to Least Concern, and one more previously Endangered species is now classed as Data Deficient (*Bellamya leopoldvillensis*). Of the other taxa previously ranked in threatened categories in 1996, all six remain threatened under the current assessment (Table 4.2).

Roughly half (79 species) of 159 mollusc species that we report on here are not assessed as threatened, although three species (2%) are considered Near Threatened. Forty-nine mollusc species (31%) are ranked as threatened in central Africa (Figure 4.1, Table 4.1). Critically small range size (criterion B) was cited as a decisive factor for 42 (86%) of the 49 threatened taxa (Table 4.2).

The remaining 31 species (19%) were assessed as Data Deficient. This proportion is typical for other African mollusc regional assessments (15–33%) (Kristensen *et al.* 2009a, 2009b; Van Damme *et al.* 2010). Patterns of Data Deficient species are discussed below (section 4.5.2). In addition, 35 mollusc species in the central African region were categorized as Not Applicable, either because they represent introduced species or a significant majority (95%) of their populations were determined to occur outside the region. Unless stated otherwise, these NA species are excluded from all tallies reported herein.

4.2.1 Gastropoda

The gastropod fauna of central Africa is diverse. We estimate that there is a total of 143 species in 37 genera and 16 families. This tally includes 33 extrazonal and exotic species that were considered Not Applicable in the current assessment. This molluscan class is represented by two taxonomically and morphologically distinct groups of snail species: the monophyletic Pulmonata and the paraphyletic grade formerly arranged as “prosobranchs.” The pulmonates are represented in central Africa by 22 species (11 genera; 3 families), only two (10%) of which are considered threatened. The prosobranchs were assessed with both a higher species richness in the region at 88 species (23 genera; 11 families) and a larger proportion of species ranked in threatened categories (45%, 40 species). This difference can be generally attributed to biological differences in dispersal ability among the species of these assemblages. Pulmonates are “air breathers,” and because they are less susceptible to exposure and capable of overland transport (e.g., via birds), they tend to have relatively large ranges. Prosobranchs, on the other hand, retain their plesiomorphic gills, have restricted vagility only through aquatic habitats, and as a result often have more limited areas of occurrence.

4.2.1.1 Pulmonata

Two genera of the Ellobiidae have been recorded from central Africa; *Melampus* and *Tralia*. Each is represented by a single species. *M. liberianus* is widespread in tropical, western African estuaries and reaches its southern limit in the central African region. *T. ovula* is introduced from the western Atlantic. Both are regarded as Not Applicable to the Region.

Three species are recorded from the Lymnaeidae, all belonging to the genus *Lymnaea*. Two are extrazonal/introduced Palearctic species (NA), and the widespread, Afrotropical species *L. natalensis* is considered to be of Least Concern.

The family Planorbidae is represented in central Africa by nine genera: *Planorbella*, *Lentorbis*, *Gyraulus*, *Afrogyrus*, *Biomphalaria*, *Ceratophallus*, *Segmentorbis* and *Bulinus*. *P. duryi* was introduced from South America (for biocontrol) and is listed as Not Applicable. *Lentorbis* is represented only by two extrazonal species (both NA). *G. costulatus*, *A. coretus*, *C. natalensis*, and *Biomphalaria camerunensis* are each considered species of Least Concern, and the last two genera each include two additional, extrazonal species considered Not Applicable to the central African region.

Two planorbid genera, *Segmentorbis* and *Bulinus*, are represented by both widespread species of Least Concern and endemic, threatened taxa. *S. excavatus* is limited to a small area of the Upper Congo in the area of Lubumbashi (= Elizabethville) and is ranked as Critically Endangered, while the widespread *S. kanisaensis* is considered of Least Concern. In addition, two more species (or perhaps one — the taxonomy is questionable)

Figure 4.1 The proportions (%) of freshwater mollusc species in each regional Red List category in the central African region. IUCN Red List Categories: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient.

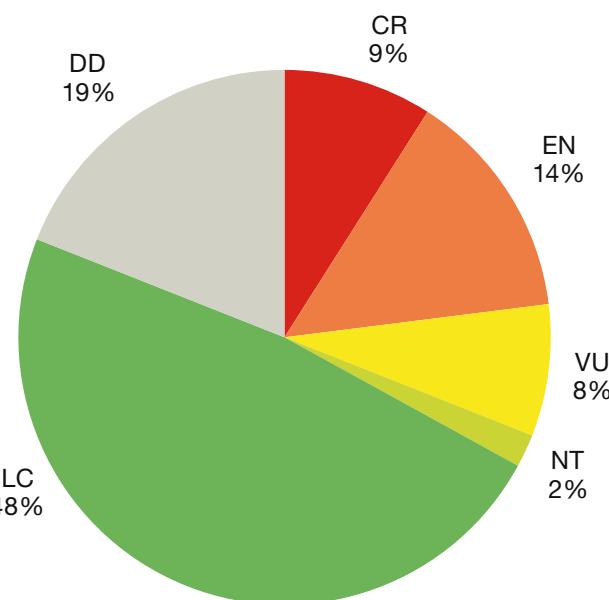


Table 4.2 Threatened freshwater mollusc species in the central African region. All listed species are endemic to the region. Species marked with an asterisk have been previously assessed.

Family	Species	Red List Category	Criteria
PLANORBIDAE	<i>Segmentorbis excavatus</i>	CR	B2ab(iii)
PLANORBIDAE	<i>Bulinus camerunensis</i> *	EN	B1ab(iii)
AMPULLARIIDAE	<i>Lanistes neritoides</i> *	CR	B1ab(iii)
VIVIPARIDAE	<i>Bellamya contracta</i> *	EN	B1ab(iii)
VIVIPARIDAE	<i>Bellamya craushayi</i> *	EN	B1ab(ii,iii)
VIVIPARIDAE	<i>Bellamya mweruensis</i> *	CR	C2a(ii)
VIVIPARIDAE	<i>Bellamya pagodiformis</i> *	CR	C2a(ii)
HYDROBIIDAE	<i>Hydrobia luvilana</i>	VU	D2
HYDROBIIDAE	<i>Hydrobia plena</i>	EN	B1ab(iii)
HYDROBIIDAE	<i>Hydrobia rheophila</i>	CR	B1ab(iii)
HYDROBIIDAE	<i>Hydrobia schoutedeni</i>	EN	B1ab(iii)
BITHYNIIDAE	<i>Gabbiella depressa</i>	CR	B1ab(iii)
BITHYNIIDAE	<i>Gabbiella matadina</i>	CR	B1ab(iii)+2ab(iii)
BITHYNIIDAE	<i>Gabbiella spiralis</i>	EN	B1ab(iii)+2ab(iii)
BITHYNIIDAE	<i>Congodoma zariensis</i>	VU	B1ab(iii)+2ab(iii)
BITHYNIIDAE	<i>Funduella incisa</i>	EN	B1ab(iii)
BITHYNIIDAE	<i>Liminitesta sulcata</i>	EN	B1ab(iii)+2ab(iii)
ASSIMINEIDAE	<i>Pseudogibbula cara</i>	CR	B1ab(iii)
ASSIMINEIDAE	<i>Pseudogibbula duponti</i>	CR	B1ab(iii)
ASSIMINEIDAE	<i>Septariellina congolensis</i>	CR	B1ab(iii)
ASSIMINEIDAE	<i>Valvatorbis mauritii</i>	CR	B1ab(iii)
THIARIDAE	<i>Melanoides agglutinans</i>	CR	B1ab(iii)
THIARIDAE	<i>Melanoides crawshayi</i>	EN	B1ab(iii)
THIARIDAE	<i>Melanoides depravata</i>	VU	D2
THIARIDAE	<i>Melanoides dupuisi</i>	VU	B2ab(iii); D2
THIARIDAE	<i>Melanoides kinshassaensis</i>	EN	B1ab(iii)
THIARIDAE	<i>Melanoides mweruensis</i>	VU	B1ab(ii,iii)
THIARIDAE	<i>Melanoides wagenia</i>	EN	B1ab(iii)+2ab(iii)
PLEUROCERIDAE	<i>Potadoma alutacea</i>	VU	B1ab(iii)
PLEUROCERIDAE	<i>Potadoma angulata</i>	EN	B1ab(iii)
PLEUROCERIDAE	<i>Potadoma kadeii</i>	CR	B1ab(iii)
PLEUROCERIDAE	<i>Potadoma nyongensis</i>	EN	B1ab(ii,iii)
PLEUROCERIDAE	<i>Potadoma ponthiervillensis</i>	EN	B1ab(iii)
PLEUROCERIDAE	<i>Potadoma trochiformis</i>	EN	B1ab(iii)
PLEUROCERIDAE	<i>Potadoma schoutedeni</i>	VU	D2
PLEUROCERIDAE	<i>Potadoma wansoni</i>	CR	B1ab(iii)+2ab(iii)
PLEUROCERIDAE	<i>Potadoma zenkeri</i>	EN	B2ab(iii)
PALUDOMIDAE	<i>Cleopatra mweruensis</i>	EN	B1ab(iii)
PALUDOMIDAE	<i>Cleopatra obscura</i>	VU	D2
PALUDOMIDAE	<i>Cleopatra pilula</i>	EN	B1ab(iii)
PALUDOMIDAE	<i>Pseudocleopatra bennikei</i>	EN	B1ab(iii)+2ab(iii)
PALUDOMIDAE	<i>Pseudocleopatra dartevellei</i>	CR	B1ab(iii)
IRIDINIDAE	<i>Mutela langi</i>	EN	B1ab(iii)+2ab(iii)
IRIDINIDAE	<i>Mutela legumen</i>	VU	B2ab(iii)
UNIONIDAE	<i>Coelatura lobensis</i>	VU	D2
UNIONIDAE	<i>Coelatura rotula</i>	VU	B1b(iii)
UNIONIDAE	<i>Coelatura stagnorum</i>	EN	B1ab(iii)+2ab(iii)
UNIONIDAE	<i>Mweruella mweruensis</i>	VU	B1ab(iii)
UNIONIDAE	<i>Prisodontopsis aviculaeformis</i>	EN	B1b(iii)

are extralimital (NA). *Bulinus camerunensis* is endemic to two crater lakes in Cameroon and ranked as Endangered. Five more widespread species of Least Concern are known from central Africa, in addition to four *Bulinus* species reported as NA or Data Deficient. Planorbid species, especially those of *Biomphalaria* and *Bulinus*, are human health concerns because they serve as hosts for parasitic trematodes of the genus *Schistosoma*, and as a result, they are often the targets of biocontrol efforts (Kristensen and Brown 1998).

The Physidae is represented only by the introduced *Physa acuta* (NA).

The minute, limpet-like Aculyidae of the genera *Burnupia* (seven species) and *Ferrissia* (six species) are poorly known from the central African region, and all are categorized as either Not Applicable or Data Deficient. This approach was consistent with the southern African assessment (Kristiansen *et al.* 2009a), as the level of distributional data and the taxonomic uncertainty of the records based on shell data alone, means that we should not take a precautionary attitude to these species within this family. This includes three endemic species (*B. alta*, *B. kimiloloensis* and *B. walkeri*) reported from the Upper Congo. Brown (1994) merely lumped these under the single, widespread species: *B. caffra*.

4.2.1.2 Neritimorpha and Caenogastropoda (“Prosobranchs”)

The family Neritidae is represented in central Africa by seven species in two genera. Neritids are generally brackish or fresh water species occurring in coastal environments. *Neritilia manoeli* is endemic to Principe and São Tomé islands and coastal Cameroon but is ranked as Least Concern. *Neritina* is represented by four, widespread species (also of Least Concern), plus two poorly known species (*N. rubricata*, DD, and *N. afra*, NA).

The apple snails (Family Ampullariidae) are common in the Congo Basin. The two species of the dextral genus *Pila* are ranked as Least Concern, and a third is categorized as Not Applicable. *Lanistes* (sinistral) in central Africa is represented by three widespread species of Least Concern, as well as six endemic species. One of these, *L. neritoides*, is known only from pristine habitats in a tributary of the Kouilou and is regarded as Critically Endangered. A tenth extralimital, East African species is listed as Not Applicable.

Four Congolese species of *Bellamya* of the family Viviparidae have threatened status. *B. contracta* and *B. crawshayi* are assessed as Endangered, and *B. mweruensis* and *B. pagodiformis* are Critically Endangered. All four are endemic to the area around Lake Mweru in the Upper Congo. A fifth endemic *Bellamya* species was assessed as Data Deficient, and two more were treated as Not Applicable.

The diminutive Hydrobiidae shares a similar pattern of endemism and threatened status, especially in the genus *Hydrobia*. The Hydrobiidae in Europe, Australia and North America have many range restricted taxa, however in comparison there are very few

species in sub-Saharan Africa. These Congo species are however the most distinct on the continent. *H. rheophila*, *H. plena*, and *H. schoutedeni* are endemic to the **Lower Congo Rapids**. The first is ranked as Critically Endangered, while the other two are Endangered. *H. luvilana*, an endemic species with a slightly larger range in western central Africa, is categorized as Vulnerable. Another species from Gabon (*H. gabonensis*) is Data Deficient. A second central African hydrobiid genus, *Lobogenes*, is found in the Upper Congo. The endemic *L. pusilla* from the area of Kipopo is ranked as Near Threatened, and two other species are treated as Least Concern. Finally, *Potamopyrgus ciliatus* is a widespread, tropical, estuarine species that reaches its southern limit in the Congo estuary (NA).

The Pomatiopsidae is represented by two poorly known endemic species of the genus *Tomichia*. Both species are recorded from the eastern part of the region, but both were assessed as Data Deficient. This is the northernmost extension of this genus, which is largely restricted to southern Africa, and is separated from the *Tricula* species in Asia.

In central Africa, the Bithyniidae is represented by four genera, each with threatened species: *Gabbiella*, *Congodoma*, *Funduella* and *Liminitesta*. *G. depressa* and *G. matadina* both have restricted ranges and are Critically Endangered. The former is known from only the Nyong River in Cameroon, and the latter is known only from the type locality (Matadi). The Endangered *G. spiralis* is known from the area of Malebo Pool. A fourth species of *Gabbiella* is found in the Upper Congo is considered of Least Concern, and three more extralimital species were regarded as Not Applicable. Each of the other three bithyniid genera is represented by a single, threatened species. Both *Congodoma zariensis* (Vulnerable) and *Liminitesta sulcata* (Endangered) are known only from the area around Malebo Pool and the Lower Congo Rapids. *Funduella incisa* is endemic to the western extreme of the region and is ranked as Endangered.

There are four Critically Endangered species of the Assimineidae known only from high gradient habitats in the Congo Basin. This group are poorly known, so the assessments are based on a precautionary attitude to the data, as the river rapids were viewed to be habitats that were vulnerable to habitat degradation. *Pseudogibbula duponti* and *P. cara* are restricted to localities in the **Lower and Upper Congo Rapids**, respectively. Both *Septariellina congolensis* and *Valvatorbis mauritii* are known only from the Lower Congo Rapids near Matadi. A fifth, brackish water species known only from its original 19th century collection of shells, *Assiminea hessei*, was listed as Data Deficient.

The Potamididae is represented by three species of Least Concern in two genera, *Pachymelania* and *Tymanotonus*. These taxa are widespread gastropods found in coastal habitats such as mangroves and river estuaries.

The Thiaridae in central Africa is represented by at least 11 species of *Melanoides*, plus four more regarded as Data Deficient or Not

Applicable. *M. agglutinans* is a Critically Endangered species known only from a single locality on the **Lower Congo Rapids**. It has not been captured in recent surveys. Three more species with restricted ranges are listed as Endangered: *M. wagenia* (**Upper Congo Rapids**), *M. crawshayi* (Lake Mweru) and *M. kinshassaensis* (Malebo Pool). Another three species are regarded as Vulnerable: *M. mweruensis* is known from the Lake Mweru, *M. depravata* is from the Lualaba, and *M. dupuisi* ranges from Malebo Pool to the Ubangi. In addition to these seven threatened species, *M. nsendweensis* is ranked as Near Threatened, and three more species are assessed as Least Concern.

The Pleuroceridae is represented in central Africa by two genera, *Potadoma* and *Potadomoides*. Both genera have recently been reviewed and further work is ongoing to investigate the origins and relationships between the species in the Tanganyika basin and the Congo basin. Of the 13 species of *Potadoma* in the region, eleven are endemic and nine are ranked as threatened. *Potadoma kadeii* is Critically Endangered in eastern Cameroon. It is a member of a radiation of endemic species in that area that includes the Endangered *P. nyongensis*, *P. trochiformis*, *P. zenkeri* and *P. angulata*. A sixth Cameroonian species, *P. riperti*, is known only from a single collection and regarded as Data Deficient. The Critically Endangered *P. wansoni* is found only in the **Lower Congo Rapids**, while *P. ponthiervillensis* (Endangered) and *P. alutacea* (Vulnerable) are limited to the vicinity of the **Upper Congo Rapids**. A second Vulnerable species, *Potadoma schoutedeni* is known from the coastal rivers west of the Congo Basin. *P. liricincta* of the Ituri area of eastern DRC is ranked as Near Threatened. Two more species of *Potadoma* with ranges extending beyond central Africa are regarded as Least Concern. Four species of *Potadomoides* are endemic to the central African region, but only one (*Potadomoides schoutedeni*) is known well enough to rank as Least Concern. The other three are Data Deficient.

Cleopatra (eight species plus one NA) and *Pseudocleopatra* (two species) comprise the central African Paludomidae. Six species of *Cleopatra* are endemic to the region, three of them threatened. The Endangered *C. mweruensis* is found only in the area around Lake Mweru, and *C. obscura* (Vulnerable) is from the Upper Congo as well. *C. pilula* is known from the Kasai Basin and is ranked as Endangered. A fourth endemic species, *C. langi* from Kisangani, is regarded as Data Deficient. Four other species of *Cleopatra* are categorized as Least Concern. The species of *Pseudocleopatra* are threatened due to their small range sizes. Both *P. dartevellei* (Critically Endangered) and *P. bennikei* (Endangered) are reported only from the **Lower Congo Rapids**.

4.2.2 Bivalvia

Fifty-one species (16 genera, eight families) comprise the freshwater bivalve fauna in central Africa, including two extrazonal (NA) species. The assemblage is represented by two orders. The Unionoida, commonly known as freshwater mussels or naiads, is represented by 26 central African species (plus one extrazonal NA; eight genera, three families). The order is

restricted to freshwater rivers and lakes. The Veneroida (23 plus one NA species) has both primarily freshwater taxa (five genera, in the families Sphaeriidae, Corbiculidae and Dreissenidae) and secondarily brackish/estuarine taxa in primarily marine families (three genera, in the families Cyrenoididae and Donacidae). The freshwater families of the Veneroida and all families of the Unionoida exhibit life history traits adapted to fresh water habitats, such as parental care (i.e., brooding) and/or direct development. Moreover, freshwater mussel larvae are obligate parasites of freshwater fishes, their hosts being the bivalves' principal means of dispersal.

4.2.2.1 Unionoida (Freshwater Mussels)

The Unionidae in central Africa is represented by three genera: *Coelatura*, *Mweruella* and *Prisodontopsis*. All but one unionid species are endemic to the region. *Coelatura* is represented by eight species in central Africa (plus one extrazonal species), three of which have threatened status. *C. stagnorum* is endemic to the lower Congo below the rapids and is ranked as Endangered, and *C. rotula* from the vicinity of Malebo Pool is regarded as Vulnerable. In southern Cameroon, *C. lobensis* also is ranked as Vulnerable. *C. horei* (Not Applicable) has previously been reported from only Lake Tanganyika, however questionable museum records exist from Lake Mweru. The remaining Congolese species of *Coelatura* are considered of Least Concern. Both *Mweruella* and *Prisodontopsis* are monotypic and found only in Lake Mweru Basin. *M. mweruensis* is ranked as Vulnerable, while *P. aviculaformis* is considered Endangered.

Four genera in the region – *Aspatharia*, *Chambardia*, *Chelidonopsis* and *Mutela* – correspond to the strictly Afrotropical family Iridinidae. Two species of *Aspatharia* occur in the Congo Basin and one more is known from southern Cameroon. All three are of Least Concern, and all three may be endemic to the region (the relationship of central African *A. pfeifferiana* to Southern African *A. subreniformis* requires further evaluation; Graf and Cummings 2006). *Chambardia* is represented by two Least Concern species, one of which, *C. dautzenbergi*, is endemic to the Upper Congo.

Etheria elliptica (Bivalvia: Etheriidae) in the Chambeshi River, Zambia. Photo © Daniel L. Graf and Kevin S. Cummings.



The most diverse iridinid genus in central Africa is *Mutela*. There are at least eight species known from the Region. *M. langi* is endemic to the lower Congo below the rapids and is ranked as Endangered, and *M. legumen* is considered Vulnerable because it is only found in and immediately above Malebo Pool. Three more species of Least Concern are known from the Congo Basin, two of which are endemic. Populations of one of these, *M. rostrata*, are currently considered conspecific with those in western Africa and the Nile although they are conchologically distinct. Taxonomic revision may reveal them as another endemic species. Three more *Mutela* species are treated as Data Deficient because they are either known from few specimens or are of unknown relationship with other Congolese congeners.

Chelidonopsis hirundo is widespread in the Congo Basin and ranked as Least Concern.

The family Etheriidae is represented by a single, widespread species of Least Concern, *Etheria elliptica*. *E. elliptica* occurs widely throughout tropical Africa and Madagascar (Graf and Cummings 2009) and is unique among African bivalves for its habit of cementing to firm substrates.

4.2.2.2 Veneroida (Clams)

The Corbiculidae is represented by a single, widespread species of Least Concern, *Corbicula fluminalis*.

The fingernail, pill, and pea clams of the family Sphaeriidae are widespread in Africa (and the world). Five species (all Least Concern) in three genera are known from central Africa: *Eupera* (two species), *Pisidium* (one species) and *Sphaerium* (two species). A second species of *Pisidium* reaches its northern limit in Lake Bangweulu and was treated as Not Applicable. Only *E. sturanyi* is considered endemic to the region. All are of small size (<2 cm), and none have been widely studied. This species is widely overlooked due to the difficulty in identifying the species, and are likely to be under-recorded in the region. The greater number of species

recognised in Europe may be an artefact of sampling effort, and sending suitable specimens for review to specialists.

The Dreissenidae is represented by a single, widespread, generally estuarine/brackish water species: *Mytilopsis africanus*. It is distributed widely in coastal western Africa and ranked as Least Concern.

Two species of *Cyrenoida* of the family Cyrenoididae are found in central Africa. Each is a widespread, brackish water species of western tropical Africa that reaches its southern limit in Congo. Both are ranked as Least Concern.

Fourteen species of the Family Donacidae are reported from the region. All are estuarine/brackish water species of a predominantly marine family. Four species of *Iphigenia* are widespread in tropical western Africa, all Least Concern. Ten more species of the genus *Egeria* have similar distributions, although three are considered endemic to the Congo estuary, and one is from the lower Sanaga in southern Cameroon. All but three *Egeria* species are Least Concern; the rest are poorly known and regarded as Data Deficient.

4.3 Patterns of species richness

4.3.1 All mollusc species

Of the 159 species of freshwater molluscs in the central African region, the highest diversity is found in the Congo Basin. Fresh water habitats extending over a large area from **Malebo Pool** (above the **Lower Congo Rapids**) to the **Upper Lualaba** support 25–28 species of gastropods and bivalves (Figure 4.2). Similar levels of species richness are observed in tributary basins in the **Kasai**, **Katanga** and **Bangweulu-Mweru** areas. The highest category of richness (29–35 species) corresponds to the **Lower Congo Rapids**, **Malebo Pool**, the **Upper Congo Rapids**, and the vicinity of Nyangwe on the Lualaba.

Chelidonopsis hirundo. Photos © Daniel L. Graf and Kevin S. Cummings.



4.3.2 Endemic species richness

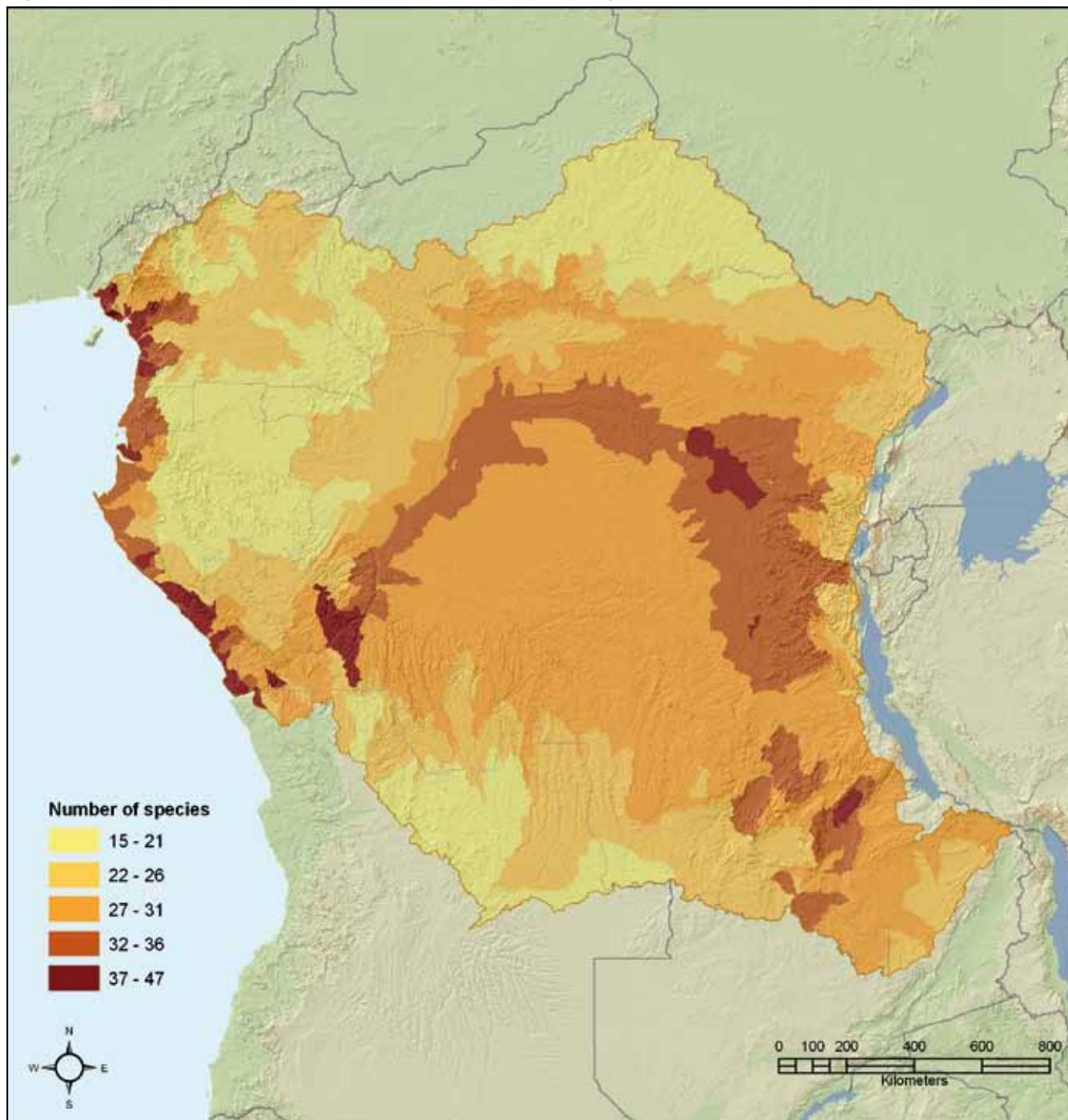
More than half of the freshwater mollusc species in central Africa are endemic to the Region (95 species, 60%; Table 4.1). Areas of high species richness in central Africa correspond to peaks in molluscan species endemism (Figure 4.3). The hotspots with the highest category of endemic species richness (12–17 species) are focused in the **Lower Congo Rapids, Malebo Pool, Upper Congo Rapids** and Nyangwe. Local peaks in endemic species richness are also manifest in southern Cameroon (Sanaga Basin) and the area between and including **Lakes Mweru** and **Bangweulu**. This tally includes both species that are endemic to the region but widespread within the Congo Basin as well as species of highly restricted ranges – some limited exclusively to only a single hotspot.

Variation in molluscan species richness and endemism is as much a result of sampling effort as of genuine biological diversity. For example, the small hotspot in the Lower Congo Rapids is situated around Matadi. That locality, like Nyangwe upstream, was a common historical collecting locality. At the same time, these hotspots of richness in the **Lower Congo Rapids, Malebo Pool**, the **Upper Congo Rapids**, and, to a lesser extent, Katanga and **Lakes Mweru** and **Bangweulu** reflect the significance of locally unique habitats on maintaining molluscan diversity.

4.3.3 Threatened species

Forty-nine species of freshwater molluscs were ranked in threatened categories as a result of this project. That is just under

Figure 4.2 Freshwater mollusc species richness in the central African region, mapped to river sub-catchments.



a third (31%) of the estimated mollusc species richness for central Africa (Table 4.1). All threatened freshwater mollusc species in the region are endemic to central Africa.

The pattern of richness for threatened freshwater mollusc species in central Africa reflects the general endemic hotspots for freshwater molluscs compounded by the assessed conservation threats to the taxa in those areas (Figure 4.4). In both the **Lower Congo Rapids** and **Malebo Pool**, the majority of endemic mollusc species were assessed as threatened. This represents roughly a quarter of the total molluscan richness in those areas.

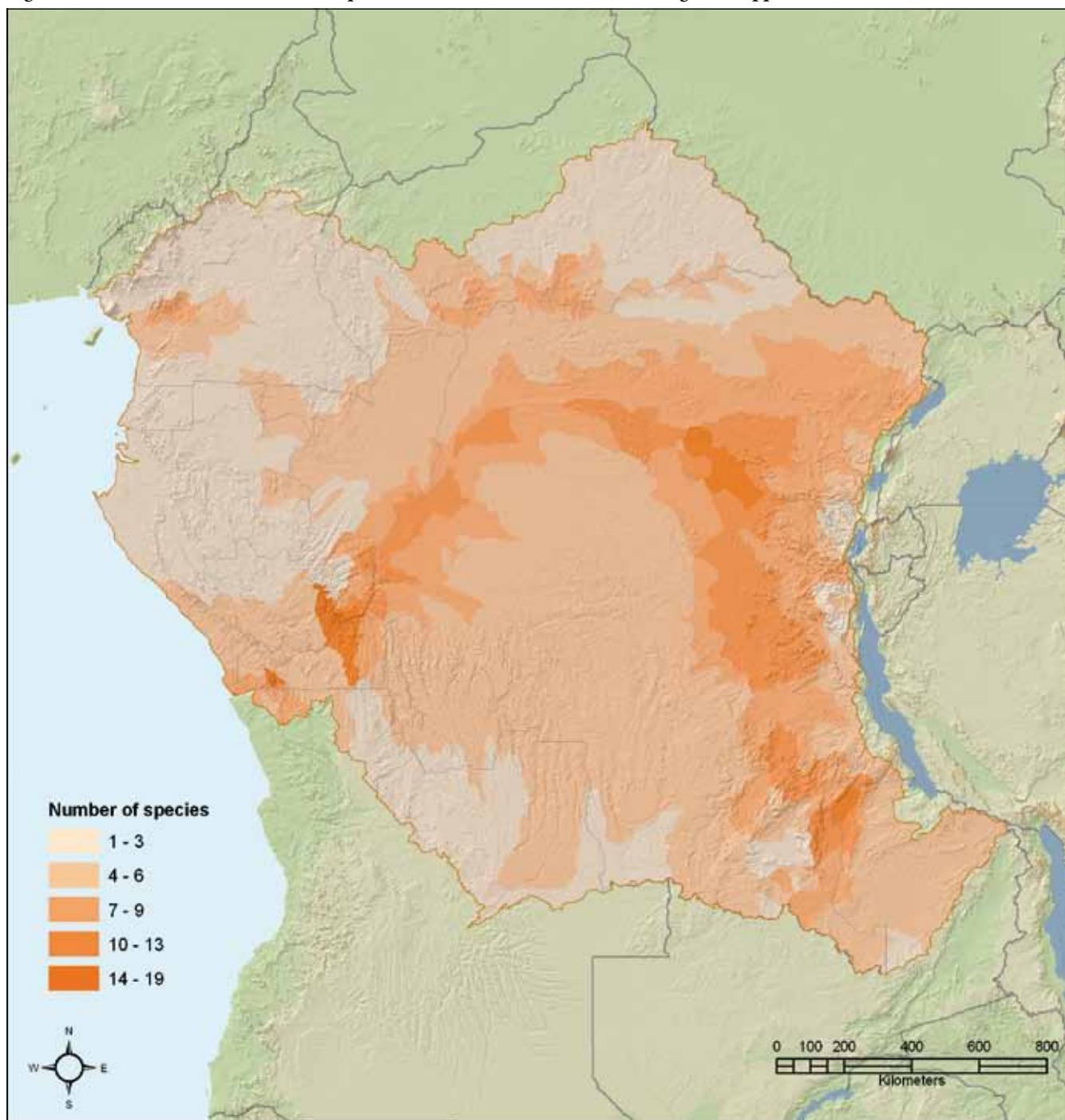
Other areas within the region with appreciably higher concentrations of threatened species richness include the **Upper**

Congo Rapids, the **Upper Lualaba** in Katanga, Lakes **Mweru** and **Bangweulu**, and the Lower Sanaga Basin in Cameroon.

4.4 Major Threats to molluscs

With few exceptions, freshwater mollusc species are not directly targeted by humans. Freshwater molluscs in central Africa are not harvested beyond subsistence use, but a few species of pulmonate gastropods are targeted with molluscicides as an intervention against human trematode infections. Among these “nuisance” species might be included the Endangered *Bulinus camerunensis*. However, for the most part the major threats to freshwater molluscs in the region are indirect – collateral damage

Figure 4.3 Endemic freshwater mollusc species richness in the central African region, mapped to river sub-catchments.



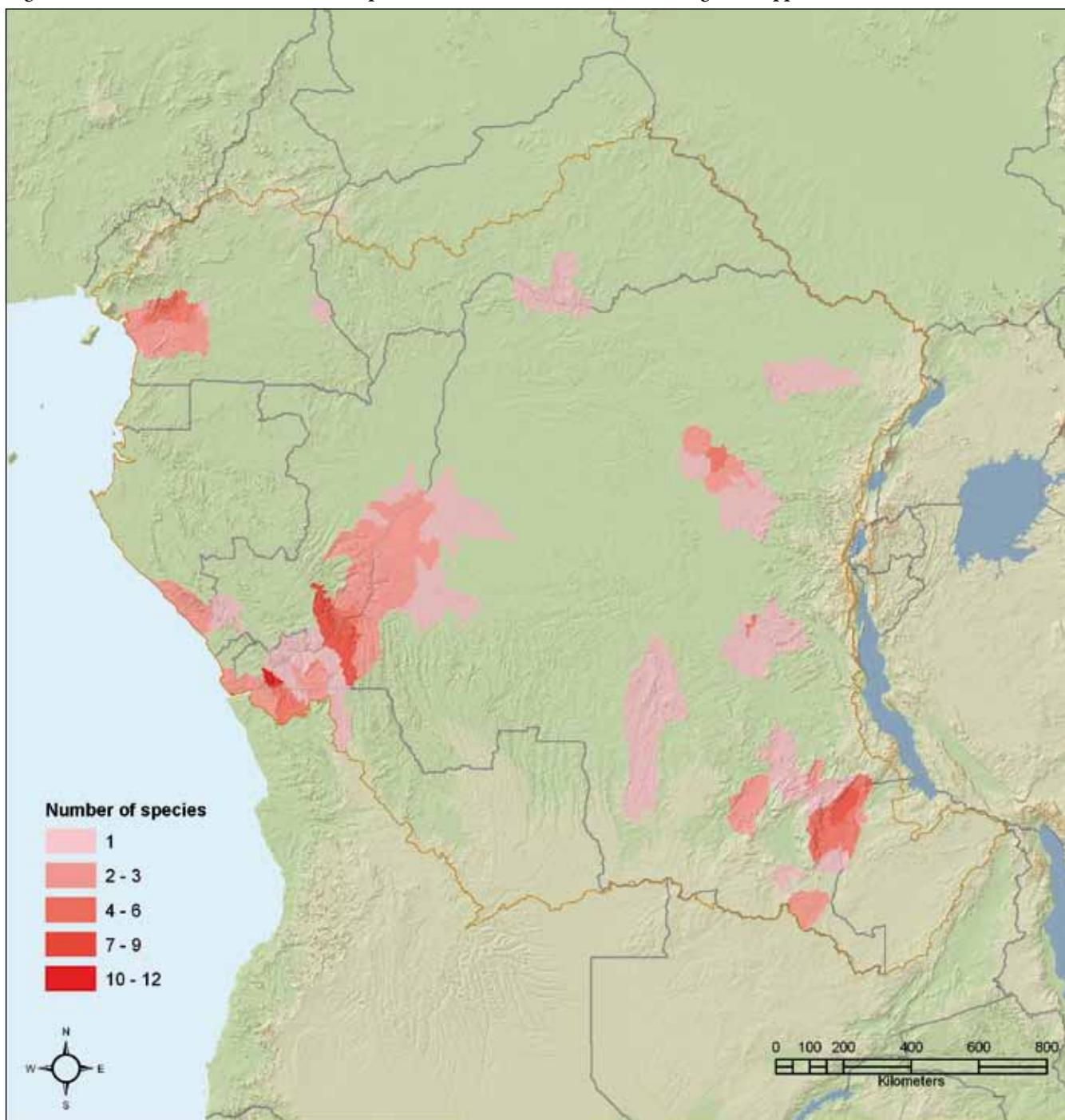
from human impacts in watersheds due to urban development, agriculture, deforestation and extraction of natural resources.

Habitat loss and water pollution were the most cited threats to freshwater molluscs in the region, for all species generally and for threatened species specifically (Figure 4.5). These two categories of threats are difficult to separate, as human practices that modify watersheds tend to impact water quality. Large areas are targeted by deforestation programmes, and mining is taking over significant areas, in particular in the headland waters of southern and eastern DRC. Logging and mining degrade fresh water habitats not only through pollution by industrial wastes but also by increasing erosional sediment loads. This is one of the most influential threats to molluscs in the region. Not only does

the resulting sedimentation lead to major changes in the river flow patterns, but it clears areas of vital shading from the rapids where gastropod species are found. This leads to temperature change, followed by oxygen-level changes and then changes in the plant community which impacts the mollusc in multiple ways. As a knock-on effect, many of these species are the primary source of food for specialist fishes, so long term impacts include a decline in the fish communities, which in turn are used as subsistence foods for local villages.

Cleared lands are often converted to agriculture, contributing another set of wastes to adjacent and downstream habitats. Many species occur just downstream of mining areas, particularly prevalent in the headwaters of the Congo River, where

Figure 4.4 Threatened freshwater mollusc species richness in the central African region, mapped to river sub-catchments.



uncontrolled release of waste and waste-water have an impact on the range-restricted species. Mineral and timber extraction and associated water pollution were determined to be current or likely future threats to mollusc species in central Africa, including those of southern Cameroon, Katanga, the Lower Congo, and the Lualaba above the Upper Congo Rapids. These are identified hotspots of freshwater molluscan richness and endemism (Figures 4.2–4.4).

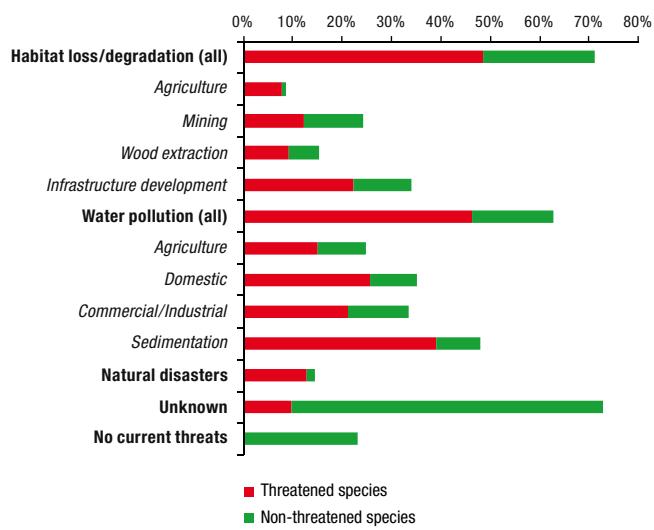
Increasing urbanisation around population centres like Kinshasa, Brazzaville, and Kisangani threaten mollusc diversity hotspots around **Malebo Pool**, the **Upper Congo Rapids**, and the **Lower Congo Rapids** through watershed degradation increasing sediment loads and by release of untreated domestic and industrial waste waters and including sewage into the Congo River. There is an increase in runoff from roads and paved surfaces, with polluting chemicals as well as sediment loads. The pressures on mollusc populations are predicted to increase as the human population in the region continues to grow.

The proposed Grand Inga Dam, if ever completed, would significantly impact not only the freshwater molluscs of the Lower Congo Rapids but also those of the estuary below and Malebo Pool above. A portion of the Congo River at present-day Inga is diverted through the Vallée Nkokolo through two hydroelectric dams, Inga I and II. The century-old reverie to harness the power of the entire Congo River has been recently resurrected (Thieme *et al.* 2005; Kabemba 2007; Showers 2009). If this proposal comes to fruition, regionally exceptional habitats will be destroyed. For example, the freshwater mollusc hotspot at Matadi at the base of the Lower Congo Rapids would have substantially altered flows, posing a threat to locally-adapted, endemic gastropods and bivalves.

Refuse-strewn port on Malebo Pool at Brazzaville, Congo. Photo © Daniel L. Graf and Kevin S. Cummings.



Figure 4.5 Percentage of mollusc species known to be affected by each threat. Note that many species may have more than one threat listed.



Not all threats to freshwater mollusc diversity in central Africa are anthropogenic. Species with restricted ranges are in danger from natural phenomena as well. For example, the Critically Endangered gastropod *Gabbiella depressa* has likely been extirpated from a volcanic crater lake near Wum in Cameroon due to gas release as a result of volcanic activity. While that species may still survive in the Nyong River, the Endangered *Bulinus camerunensis* is currently limited to only two similarly vulnerable crater lakes in the same area. On a larger scale, Lake Mweru is a shallow lake basin accumulating sediments from the Luapula and eroding its outlet. These natural causes of lake shrinkage are exacerbated by increased sediment loads due to watershed deforestation and increased water-use by a growing



Coelatura stagnorum (EN), a bivalve endemic to the Congo below Inga. Scale bar = 5 cm. Photo © Daniel L. Graf and Kevin S. Cummings.

human population. The lake is currently the sole habitat for endemic, threatened species of the genera *Bellamya*, *Melanoides*, *Cleopatra*, *Mweruella* and *Prisodontopsis*. It is unknown how global climate change will influence the rate of shrinkage of this large, tropical lake, but there is concern that the lake is becoming more vulnerable to stochastic events. An increase in sedimentation and a decrease in water level could lead to a sudden deoxygenating event due to stirring of anoxic layers throughout the lake. This event could be initiated by the turbulence of wind-flow over the surface, and the increase of storms could amplify the likelihood of a widespread system failure.

4.5 Conservation recommendations

In central Africa, only the few species that impact human health have a life history that is well known and studied. The majority of species of conservation concern have limited distributional data and little knowledge is available of their lifecycles. For the threatened species assessed herein, the extent of our knowledge is often limited to the results of historic sampling. In the extreme, seven threatened species of gastropods and bivalves are reported as known only from the localities at which they were originally collected. This dearth of specific information limits our conservation recommendations to generalities. We strongly recommend further research to develop a baseline database on the distributions, population biology, and ecology of these taxa, as well as the implementation of conservation measures to mitigate declines in freshwater mollusc diversity.

4.5.1 Conservation measures

No local conservation measures are in place to protect any of the threatened freshwater mollusc species of central Africa. Indeed, in our experience the unique molluscan diversity of the region is fully appreciated by neither the relevant governments



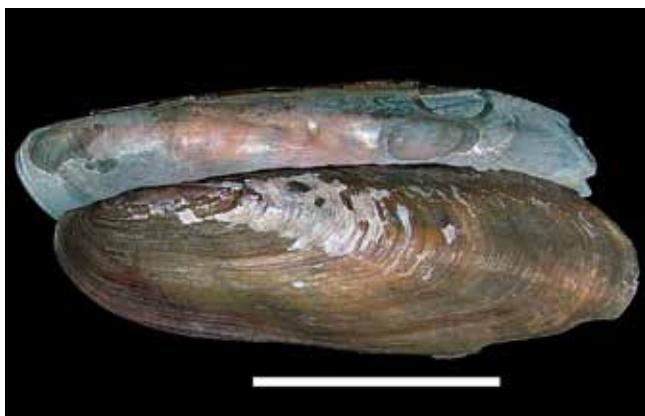
Threatened *Prisodontopsis aviculaeformis* (EN) from Lake Mweru, Zambia. Photo © Daniel L. Graf.

nor indigenous communities. Capacity building through community outreach and collaboration with local wildlife and fisheries departments is recommended to raise awareness and facilitate monitoring of local populations of gastropods and bivalves. This can range from local field guides to aid identification, to resource guides for fisheries managers and park officials to highlight the role of molluscs in freshwater ecosystems, and the impacts threats such as deforestation has on inland waterways.

The high level of mollusc species endemism within the central African region and incomplete knowledge of individual species points to the protection of fresh water habitats against the impacts of human developments such as logging, mining, dam construction, and urbanization. This is especially true for the hotspots of molluscan diversity centred around the **Lower Congo Rapids**, **Malebo Pool**, the **Upper Congo Rapids**, and **Lakes Mweru and Bangweulu**. Environmental Impact Assessments by qualified surveyors familiar with the taxa and best sampling-practices should be required for all proposed commercial and infrastructure projects. The limited survey data and the possibility that other undescribed species are present in the un-surveyed river rapids, suggests that comprehensive EIA's including molluscs should be a requirement for all major development projects and remedial works involving dredging activity or water transfer between catchments.

Recommendations accompanying new development works may include retaining a fringe of forest along the banks of waterways, and reducing sediment run-off through careful planning of access roads. Better waste management can also be achieved if it is considered in the planning stages for the exploitation of resources through mining.

Care must also be taken to limit the introduction of non-native species with any aquaculture development in the region.



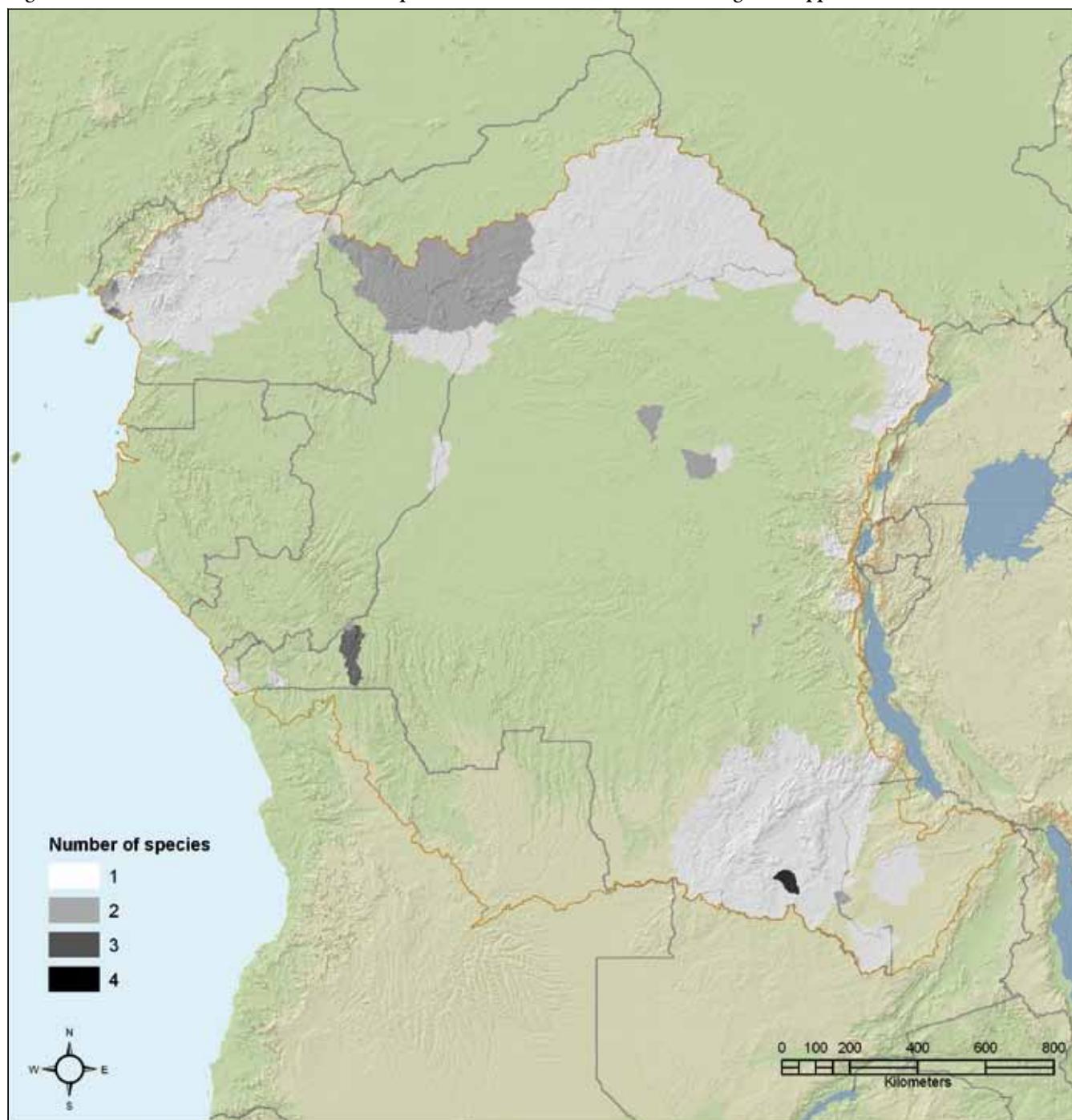
Type specimen (MNHN) of *Mutela joubini* from the Upper Ubangi. Scale bar = 5 cm. Photo © Daniel L. Graf and Kevin S. Cummings.

4.5.2 Research action required

For many freshwater mollusc taxa in the region, demographic, ecological and life history data are insufficient to make meaningful predictions about how gastropod and bivalve species will respond to changing fresh water environments. For example, information on the host-fish for the parasitic larvae freshwater mussels of the families Unionidae, Iridinidae and Etheridae are minimal, prohibiting evaluation of the specific impacts of overfishing or aquaculture on these bivalves.

Thirty-one (19%) of the freshwater mollusc species reported from central Africa were assessed as Data Deficient (Table 4.1). With the exception of a few from the vicinity of Malebo Pool and main

Figure 4.6 Data Deficient freshwater mollusc species richness in the central African region, mapped to river sub-catchments.



stem of the Congo, the remaining species are distributed around the periphery of the region (Figure 4.6).

For many of these Data Deficient species, as well as some threatened taxa, it is difficult to determine the relationships of described, nominal species to better-known species in the core of the region, or to populations of species occurring in other regions. Except for a handful of taxa, published data are unavailable to incorporate phylogenetic or genetic diversity into conservation assessments. For both bivalves and gastropods, modern taxonomic revisions based upon Pan-African phylogenies would be highly valuable.

Many freshwater mollusc species in the region are known from only a relatively small number of specimens, and most of those have not been corroborated by recent collecting. For example, *Mutela joubini* (Iridinidae) was originally described from “Haut-Oubanghi.” This species is known from only five museum lots, mostly in the Chad-Chari Basin of the western African region. Targeted field surveys for Data Deficient and poorly documented threatened freshwater mollusc species are necessary to make informed conservation and management decisions about central Africa’s freshwater biodiversity.

4.6 References

- Beadle, L.C. 1981. *The Inland Waters of Tropical Africa: An Introduction to Tropical Limnology*, second edition. Longman Group Limited, New York. 475 pp.
- Brown, D.S. 1994. *Freshwater Snails of Africa and their Medical Importance*, second edition. Taylor and Francis Ltd., London. 608 pp.
- Daget, J. 1998. *Catalogue raisonné des mollusques bivalves d'eau douce Africains*. Paris: Backhuys Publishers, Leiden, and Ostrom. 329 pp.
- Graf, D.L. and K.S. Cummings. 2006. Freshwater mussels (Mollusca: Bivalvia: Unionoida) of Angola, with description of a new species, *Mutela wistarmorri*. *Proceedings of the Academy of Natural Sciences of Philadelphia* **155**: 163–194.
- Graf, D.L. and K.S. Cummings. 2009. Actual and alleged freshwater mussels (Mollusca: Bivalvia: Unionoida) from Madagascar and the Mascarenes, with description of a new genus, *Germainaia*. *Proceedings of the Academy of Natural Sciences of Philadelphia* **158**: 221–238.
- Haas, F. 1936. Binnen-Mollusken aus Inner-Afrika, hauptsächlich gesammelt von Dr Haas während der Schomburgk-Expedition in den Jahren 1931/1932. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft* **431**: 1–156.
- IUCN. 1994. *IUCN Red List Categories*. Prepared by the IUCN Species Survival Commission. IUCN, Gland, Switzerland.
- IUCN. 2001. *IUCN Red List Categories and Criteria: Version 3.1*. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.
- Kabemba, C. 2007. South Africa in the DRC: renaissance or neo-imperialism? pp. 533–551. In: B. Sakhela, J. Daniel and R. Southall, (eds.) *State of the Nation: South Africa 2007*. HSRC Press. Cape Town. 586 pp.
- Kristensen, T.K. and Brown, D.S. 1998. Control of intermediate host snails for parasitic diseases: a threat to biodiversity in African waters? In: Bieler, R. and Mikkelsen, P. (eds.) *Abstracts World Congress of Malacology*. Washington DC, USA. **181**. Malacologia.
- Kristensen, T.K., Appleton, C.C., Curtis, B. and Stensgaard, A.-S. 2009a. The status and distribution of freshwater molluscs: Ch.4: 38–47. In: Darwall, W.R.T., Smith, K.G., Tweddle, D. and Skelton, P. (eds.) 2009. *The Status and Distribution of Freshwater Biodiversity in Southern Africa*. Gland, Switzerland: IUCN and Grahamstown, South Africa: SAIAB.
- Kristensen, T.K., Stensgaard, A.-S., Seddon, M.B. and McIvor, A. 2009b. The status and distribution of freshwater molluscs (Mollusca). In: Smith, K.G., Diop, M.D., Niane, M. and Darwall, W.R.T. (Compilers). 2009. *The Status and Distribution of Freshwater Biodiversity in Western Africa*. Gland, Switzerland and Cambridge, UK
- Mandahl-Barth, G. 1988. Studies on African Freshwater Bivalves. Danish Bilharziasis Laboratory, Charlottenlund, Denmark. 161 pp.
- Osborn, H.F. and J.C. Bequaert. 1919. The Congo Expedition of the American Museum of Natural History. *Bulletin of the American Museum of Natural History* **39**: xv–xxviii.
- Pilsbury, H.A. and J. Bequaert. 1927. The aquatic mollusks of the Belgian Congo, with a geographical and ecological account of Congo malacology. *Bulletin of the American Museum of Natural History* **53**: 69–602.
- Showers, K.B. 2009. Congo River's Grand Inga hydroelectricity scheme: linking environmental history, policy and impact. *Water History* **1**: 31–58.
- Thieme, M.L., R. Abell, M.L.J. Stiassny, P. Skelton et al. 2005. *Freshwater Ecoregions of Africa and Madagascar: a Conservation Assessment*. Island Press, Washington DC, USA. 431 pp.
- Van Damme, D., Ghamizi, M., Soliman, G., McIvor, A. and Seddon, M.B. 2010. The status and distribution of freshwater molluscs. In: García, N., Cuttelod, A. and Abdul Malak, D. (eds.) 2010. *The Status and Distribution of Freshwater Biodiversity in Northern Africa*. Gland, Switzerland, Cambridge, UK, and Malaga, Spain.

Chapter 5. The status and distribution of dragonflies and damselflies (Odonata) in central Africa

Dijkstra, K.-D.B.¹, Clausnitzer, V.², Mézière, N.³, Kipping, J.⁴ and Schütte, K.⁵

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5.1 Overview of the regional Odonata in relation to the freshwater ecoregions

Equatorial Africa is naturally dominated by almost continuous Guineo-Congolian lowland rainforest, which has a gradual transition of riverine forests and woodland into peripheral savannahs. The highest odonate diversity in tropical Africa is found here (Figure 5.1): all African countries with well over 200 species have a considerable portion of this forest within their borders (Dijkstra and Clausnitzer 2006). Although many species range throughout Africa's forested heart, it can be subdivided into four main areas of endemism (Dijkstra 2007a), of which only the more westerly Upper Guinea lies outside the central Africa assessment region (see Dijkstra *et al.* 2010). The three others are (1) the Lower Guinea, with the Cameroon highlands as its focus, (2) the Congo Basin, and (3) the slope east of the Congo River towards the Albertine Rift. Each area, which agree reasonably with the freshwater ecoregions of Thieme *et al.* (2005), is discussed separately below, as is the large area of more open habitats to the south of the rainforest belt that dominates Katanga and adjacent Angola and Zambia. Central Africa has the richest, but also the least known and probably (currently) least imperilled, odonate fauna in Africa. Therefore this report focuses primarily on what we do and, especially, do not know. Much emphasis is given on

recent discoveries, including collection work conducted as part of the central African freshwater biodiversity assessment and fieldwork by the authors in Cameroon and Gabon (all results otherwise still unpublished). We attempt to provide information on all threatened (or Near Threatened) and Data Deficient species in the region, their status being Least Concern unless indicated.

5.1.1 Lower Guinea

The Northern, Central and Southern West Coastal Equatorial ecoregions together are best known as the Lower Guinea, whose rainforests have the richest odonate fauna in Africa: typical rainforest groups such as Calopterygidae, Chlorocyphidae and *Chlorocnemis* are about twice as species rich here than elsewhere. The region is best characterised by the presence of several presumably relict damselfly genera, some with distinct Madagascan and Neotropical affinities: *Pentaphlebia* (Amphiptyrygidae) has its nearest relative on South America's Guyana Shield. The genus was believed to be endemic to the Cameroon highlands with two species, but a third taxon was discovered recently in south-eastern Gabon and north-western Congo (Mézière and Lambret unpubl.). *Neurolestes trinervis* (Megapodagrionidae) and *Stenocnemis pachystigma* (Platycnemididae) both occur from the Cameroon highlands to the Mayombe Hills of south-western Congo. The

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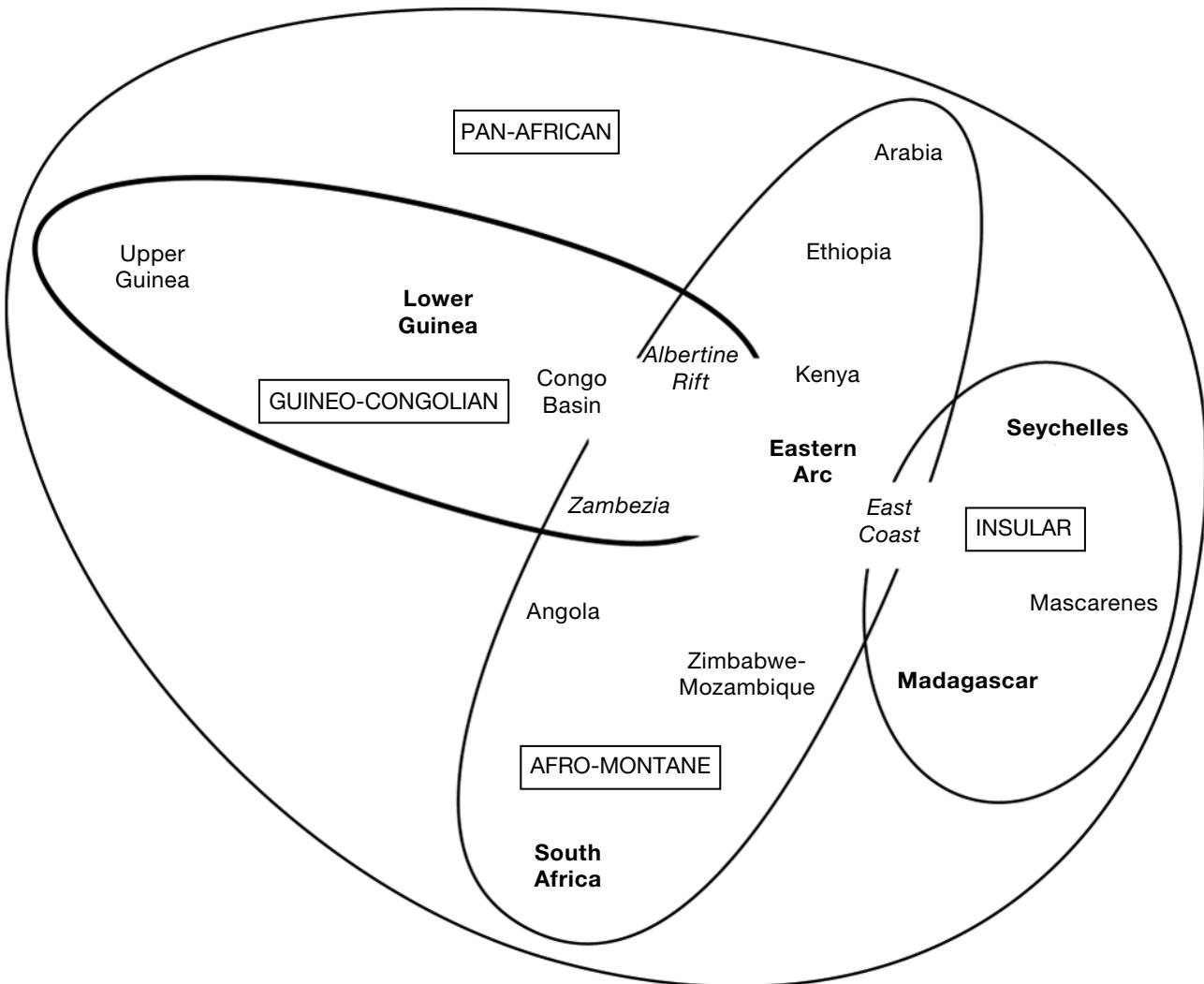
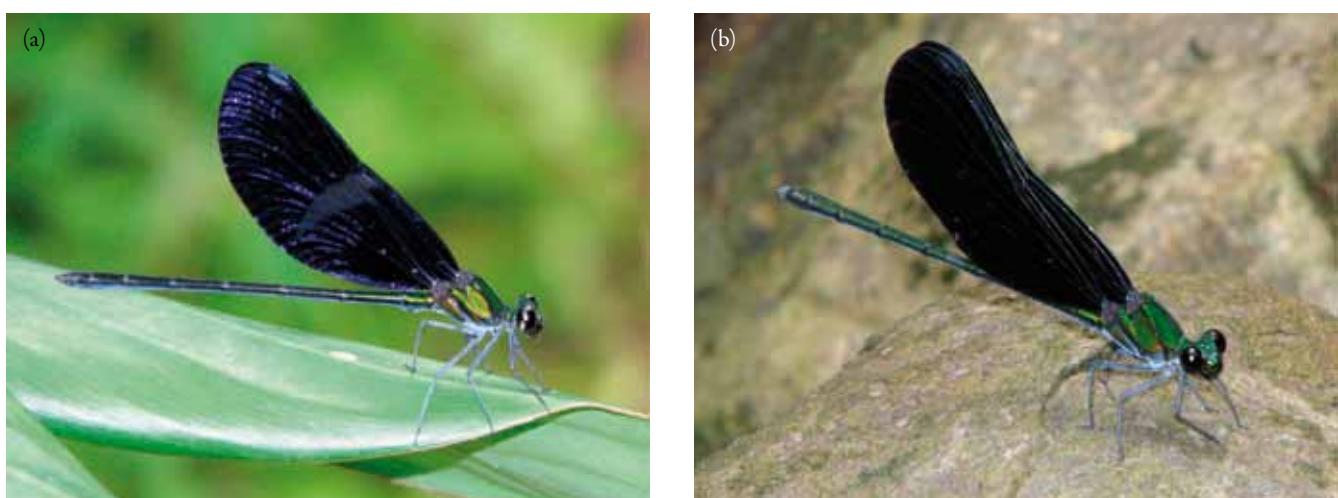


Figure 5.1 Schematic representation of Afrotropical odonate diversity. Each ellipse represents about one-fifth of species richness, the thick-bordered ellipse two-fifths. The name of the fauna represented by each ellipse is given in upper case; discussed regions are given in lower case. Regions in bold font harbour ancient relicts, often in regionally endemic genera, those in italic font have a ‘mixed’ character where faunas intersect. The border between the western and central African assessment regions ran through the Lower Guinean relict region, and that between the central and eastern/southern assessment regions through the Albertine and Zambezian intersection areas. The choice of these borders greatly complicated the assessment of odonate diversity.

Sapho males with broad blue wings are found on many streams and rivers in the Lower Guinea and western Congo Basin. In the centre of this range, specimens have a matt band on the wings and are classified as *S. gloriosa*, while in the periphery (e.g. Cameroon Highlands, Congo Basin) this band is absent and males are identified as *S. orichalcea*. Possibly the two are variants of one species. Photos: © K.-D.B. Dijkstra.





Two characteristic jewel damselflies (Chlorocyphidae) of the Lower Guinean rainforest: (a) *Chlorocypha gracilis*, (b) *Platycypha rufitibia*. Photos: © C. Vanappelghem (a) and J. Kipping (b).

former is closely related to *Nesolestes nigeriensis* (DD) from the Cameroon highlands, which despite the close relationship of both to the Madagascan genus *Nesolestes*, probably represent a second *Neurolestes* species (Kalkman *et al.* 2010). Other characteristic Lower Guinea endemics are: *Sapho gloriosa*, *Chlorocypha gracilis*, *Platycypha rufitibia*, *Chlorocnemis contraria* (VU^{RG}), *Platycnemis rufipes*, *Diastatomma tricolor*, *Phyllomacromia insignis* and *Zygonyx speciosus*.

Northern West Coastal Equatorial: One of the richest odonate faunas in Africa in terms of restricted range species and relicts is centred on the southern end of the Cameroon highlands, on the border of the western and central African assessment areas. This artificial division has hampered the proper assessment of this unique diversity, but many of the endemic species are probably not threatened globally, although they were considered regionally Vulnerable or Endangered in western Africa due to deforestation, especially in Nigeria (Dijkstra *et al.* 2010). This area was studied by the Cameroon Dragonfly Project (Vick 1996, 1998, 1999, 2000, 2002, 2003a, 2003b), and the similar fauna of Bioko is also reasonably well known (Brooks and Jackson 2001; Pinhey 1971c; 1974). Perhaps the defining species of these Cameroon highlands is *Nubiolestes diotima* (VU^{RG}) the only African species of the otherwise Neotropical family Perilestidae. Other characteristic endemics of this area and the adjacent lowlands are *Pentaphlebia stabli* (VU^{RG}), *Africocypha lacuselephantum* (VU^{RG}), *Chlorocypha centripunctata* (NT^{RG}), *Chlorocypha neptunus*, *Sapho puella* (DD), *Umma mesumbei* (NT), *Umma purpurea* (EN^{RG}), *Nesolestes nigeriensis* (DD), *Chlorocnemis eisentrauti* (DD), and unnamed *Chlorocnemis* near *C. pauli* (EN^{RG}), *Elatoneura pruinosa*, *Pseudagrion risi*, *Notogomphus maryae* (DD), *N. moorei*, *Tragogomphus aurivilii* (DD), and *Phyllomacromia caneri*. If the present populations of *Phyllomacromia aeneothorax* are considered specifically distinct from those in the Upper Guinea, as recommended by Dijkstra (2005; Dijkstra *et al.* 2010), this constitutes another endemic. Until recently, *Azuragrion buchholzi* (NT) and *Trithemis hartwigi* (DD) were thought to be confined to standing waters, possibly specifically crater lakes, in Bioko and adjacent Cameroon, but extend to south-eastern Gabon, while *T. hartwigi* was also photographed much further east in east DRC.



Central West Coastal Equatorial: The rainforest of southern Cameroon, mainland Equatorial Guinea and northern Gabon are insufficiently surveyed for Odonata. A notable exception is the Makokou region of north-eastern Gabon (Figure 5.2), that was studied intensively by Legrand (1975, 1977, 1979, 1982, 1984a, 1984b, 1986, 1992, 2002). He described numerous species from this area, some of which have not yet been recorded elsewhere (all DD): *Chlorocypha helena*, *Pseudagrion spinithoracicum*, *Onychogomphus emiliae*, and *Tragogomphus ellioti*. It is likely, however, that all will be found to be more widespread, though possibly confined to (part of) the Lower Guinea, as recent field and collection work yielded the first new records of several other ‘Makokou species’: *Chlorocnemis interrupta* (DD), *Aciagrion brosseti* (DD), *Malgassophlebia westfalli* (DD), *Palpopleura albifrons* and *Tetrathemis fraseri* (DD) were found elsewhere in Gabon, up to 300 km from the type locality, *M. westfalli* and specimens near *Aciagrion balachowskyi* (DD) in southern Cameroon, and *P. albifrons* and *Tetrathemis longfieldae* from several widespread localities in DRC in the collections of the Royal Museum of Central Africa (RMCA) in Tervuren, Belgium. Of other species described from the region, the precise type locality of *Neurogomphus agilis* (DD) was unknown, but it was rediscovered in the Sanaga Delta, Cameroon. Similarly, the origin of *Cornigomphus guineensis* (DD) described from ‘Spanish Guinea’ is unclear, although it may be the same as *Onychogomphus mariannae* (NE) described in *Paragomphus* from Mt Nimba, Guinea, and reported from Makokou by Legrand (1992) (see Dijksta *et al.* 2010). The latter record was erroneously overlooked for the central Africa assessment. *Paragomphus aureatus* (DD) from north-west Gabon and *Prodasineura perisi* (DD) from north-east Rio Muni have not been reported since their descriptions. *Elatoneura josemorai* was described from south-west Rio Muni and extends to adjacent Cameroon and south-western Congo, but its separation from *E. pruinosa* occurring further northern in Cameroon is not well resolved.

Southern West Coastal Equatorial: The southern end of the Lower Guinea, encompassing the southern half of Gabon and the south-west of Congo, is odontologically the least known, although it is probably equally rich as the central and northern parts. This is demonstrated by recent research by Nicolas Mézière

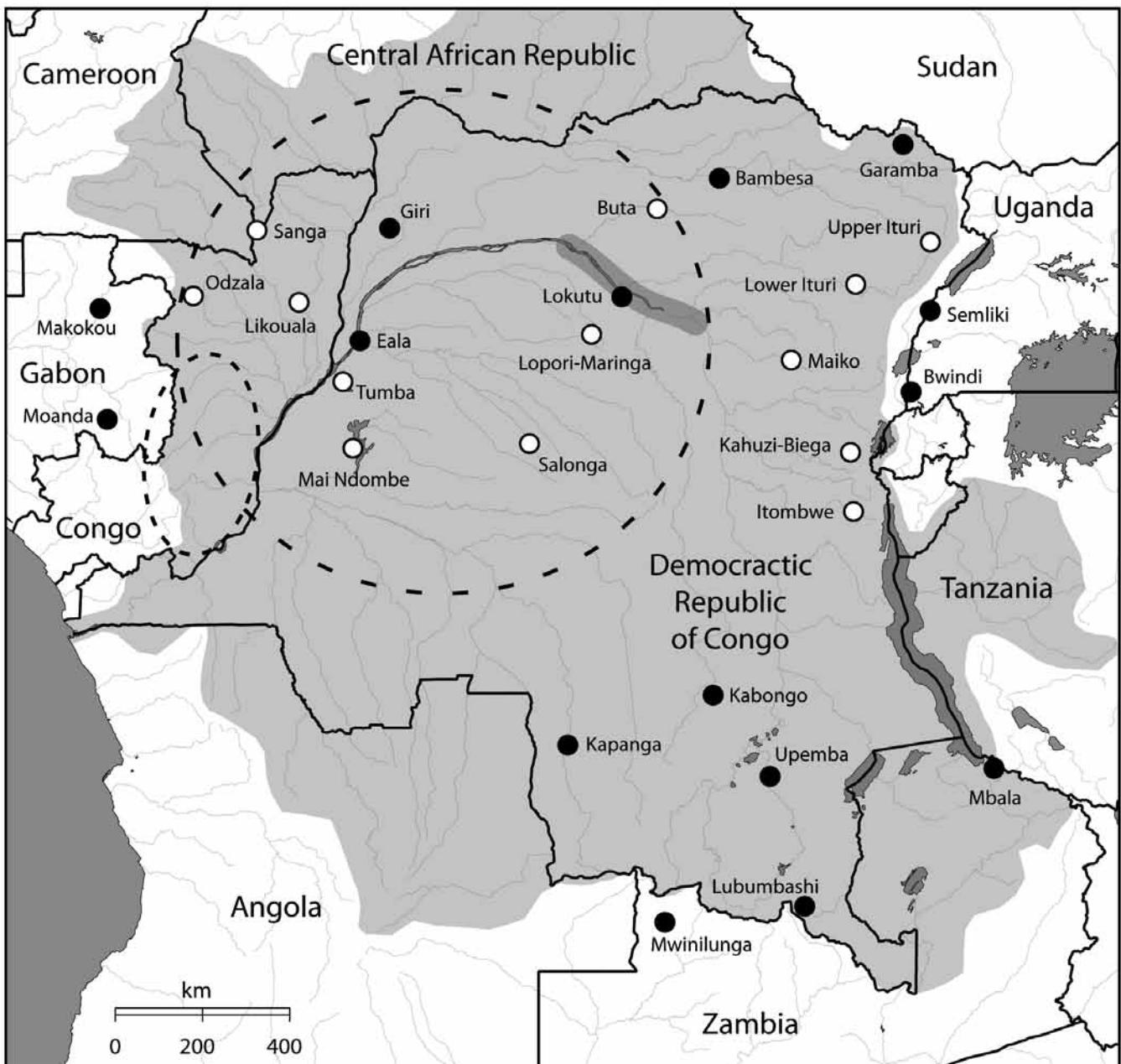


Figure 5.2 Odonatological exploration of the Congo Basin. Legend: Open circles: sites of high conservation priority according to Congo Basin Forest Partnership, none of which have been surveyed for Odonata; Filled circles: sites with reasonable (historic) odonatological data, none of which are CBFP priorities; Pale grey area: Congo River watershed; Large dashed ellipse: approximate extent of 'cuvette centrale', defined as part of basin below 500 m; Small dashed ellipse: approximate extent Batéké Plateau; Dark grey line: route Congo 2010 expedition. Adapted from Dijkstra (2007a).

around Moanda (Figure 5.2) in south-east Gabon: in less than two years, in an area of about 200 by 100 km and between 400 and 700 m altitude, over 170 species have been recorded. Among these are numerous rediscoveries and range extensions of poorly known species, like *Elatoneura morini* (DD), *Aciagrion brosseti* (DD), *Azuragrion buchholzi* (NT), *Notogomphus spinosus*, *Aethiothemis mediofasciata* (DD), *Malgassophlebia westfalli* (DD), *Palpopleura albifrons*, *Tetrathemis fraseri* (DD), *Trithemis hartwigi* (DD), and *T. osvaldae* (DD), all of which should probably be reassessed as LC in light of these finds. The area presents an interesting mix of species thought to be (largely) confined to the Congo Basin (*Chlorocypha aphrodite*, *Platycnemis nyansana*, *Elatoneura incerta*, *E. vrijdaghi*, *Pseudagrion simplicilaminatum*, *P. thenartum*, *Diastatomma*

multilineatum, *Ictinogomphus regisalberti*, *Lestinogomphus congoensis*, *Phyllogomphus annulus*, *Trithemis congolica*, *Trithetrum congoense*, *Zygonyx regisalberti*) and isolated sites of savannah/woodland species generally occurring much further north or south (*Leptogomphus ochraceus*, *Pseudagrion torridum* (NA), *Gomphidia quarrei*, *Lestinogomphus angustus*, *Paragomphus serrulatus* (= *bredoi*), *Nesciothemis nigeriensis*, *Trithemis bifida*). Illustrative of the fauna's diversity and complexity is that several of these species meet their counterparts here from the west African rainforests (*Ictinogomphus fraseri*, *Trithemis basitincta*) or non-forest habitats outside the Congo Basin (*Trithemis aconita*, *Trithetrum navasi*). The research also produced new species of *Pentaphlebia*, *Africocypha*, *Mesocnemis*, *Elatoneura*,

Porpax, *Trithemis*, *Urothemis*, *Zygonyx* and two of *Pseudagrion*. Remarkably, most of the new species are not very localised: the *Mesocnemis* and *Zygonyx* were first discovered during the afternoon excursion of the central African evaluation workshop to the Sanaga River north of Yaoundé (750 km north), while the *Pentaphlebia* and one *Pseudagrion* species were found about 350–400 km south-west in north-western Congo (Philippe Lambret pers. comm.). The *Trithemis* also occurs at Makokou and in extreme south-west Cameroon (625 km north-west). The locally abundant new *Urothemis* had been photographed 26 years earlier 1,500 km east in DRC. This demonstrates how rapidly our knowledge of this rich fauna will expand once further areas are studied. Two more *Pseudagrion* species were described from this ecoregion by Legrand (1987): *P. grilloti* (DD) is only known from the Mayombe Hills in western Congo, but *P. simonae* has been found throughout the ecoregion. Finally, *Neurogomphus angustisigna* (DD) is only known from the holotype from the lower Ogooué River (Pinhey 1971a).

5.1.2 Central Congo Basin

Ever-shifting rivers, swamps, forests, woodlands and savannahs in the Congo Basin create an enormous mosaic of prime odonate habitat in time and space. Africa's heart has always been on a crossroads, between the forests to the west and east in wet periods, and between the savannahs to the north and south in drier times, when sensitive species could survive in presumed forest refuges west and east of the basin and along its rivers. Kingdon (1989) postulated that the basin is an “evolutionary whirlpool” of species diversification, conservation and dispersal, leading to high endemism and diversity. This could be especially true for Odonata, because of their strong ties to freshwater and vegetation structure (e.g. Dijkstra 2006b). Unfortunately our knowledge of the fauna is concentrated in a handful of peripheral sites, sampled mostly in the 1930s to 1960s (Figure 5.2). This data largely comes from the collection of the RMCA, which was treated by Schouteden (1934) and especially Fraser (1949; 1953a; 1953b; 1954a; 1954b; 1955a; 1955b; 1956; 1957; 1958a; 1958b; 1958c; 1958d; 1959), and databased as part of this assessment. Species found in a large part of the basin (but see **Southern West Coastal Equatorial** ecoregion), and largely confined to it, are *Chlorocypha aphrodite*, *Elattoneura centrafricana*, *E. vrijdaghi*, *Prodasineura odzalae*, *Pseudagrion*

New damselfly species discovered recently in south-east Gabon; (a) genera



(a)

simplicilaminatum, *P. thenartum*, *Ictinogomphus regisalberti*, *Phyllogomphus annulus*, *Phyllomacromia maesi*, *P. schoutedeni*, *P. seydeli*, *Lokia circe*, *L. erythromelas*, *Porpax garambensis*, *P. sentipes*, *Trithemis apicalis* (= *Porpacithemis trithemoides*), *T. congolica*, and *Zygonyx regisalberti*.

Sangha: This ecoregion between the Lower Guinea-Congo watershed and the swamp forest of the Congo and Ubangi (see Cuvette Centrale) is very poorly known. Most available information was provided by Aguesse (1966), Carletti (1997), Legrand and Lachaise (1980) and Pinhey (1962). *Elattoneura incerta*, *Prodasineura odzalae* and *Trithemis fumosa* (DD) were described from near Odzala National Park, but *T. fumosa* has since only been reported from near Bangui in the Central African Republic (Pinhey 1971b) and both others from a few sites in DRC and Gabon. In the south-west of the **Sangha** ecoregion, the open grasslands of the Batéké Plateau (Figure 5.2) are wedged between the Lower Guinea and Congo Basin forests. Numerous very clear rivers with forest galleries cut through and run off this sandy plateau, such as the Lékoní and Léfini. Explorations on the plateau's western fringe in south-eastern Gabon, suggest these waters have a distinctive fauna: *Platycypha picta* (DD) and *Pseudagrion bernardi* were known previously only from central Congo, while newly discovered species of *Pseudagrion* and *Elattoneura* may also be endemic.

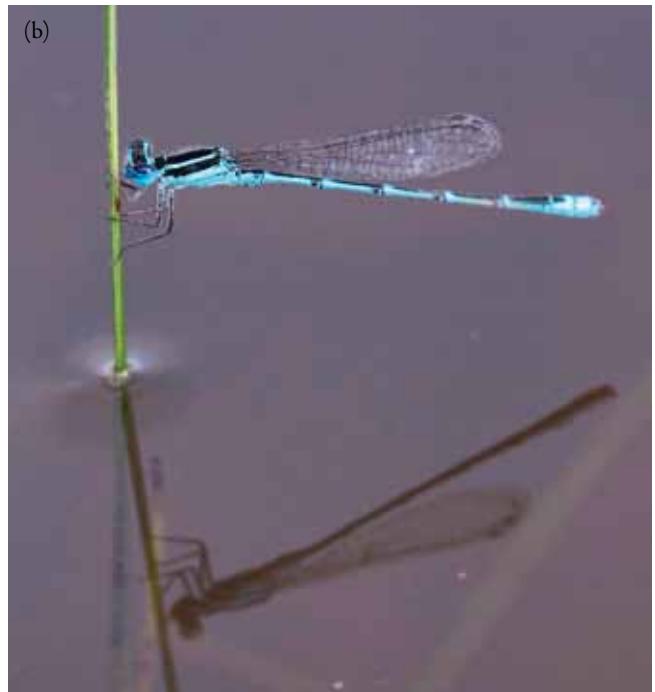
Cuvette Centrale: This saucer-like area below 500 m in the central Congo Basin (Figure 5.2) is a seemingly monotonous forested plain crossed by countless rivers. Ecologically, the lower reaches of the **Sudanic Congo (Oubangui), Tumba** and **Mai Ndombe** ecoregions belong to the ‘cuvette’ as well. Various species appear to be endemic to the region's huge rivers (most notably the Ubangi and middle Congo) like *Neurogomphus chapini*, *N. martininus*, *N. uelensis* (including similar *N. paenuelensis* (DD)), *Paragomphus acuminatus*, and *Zygonoides occidentis*, or at least with the associated forest habitat, like *Agriocnemis stygia* and *Hadrothemis vrijdaghi*. Our knowledge of the fauna largely stems from material in RMCA from two sites. Almost a hundred species were collected at Eala, mainly by J. Ghesquière in 1933–1937, although some of these may be doubted, because *Orthetrum caffrum*, *O. camerunense*, *Proischnura subfurcata*, and *Trithemis furva* favour open highlands. A. Bal collected along the Giri River south of Kungu in 1934–1935, amassing 85

Africocypha, and (b) genera *Pseudagrion*. Photos: © C. Vanappelghem.



(b)

Two species described from the highlands of Cameroon and Bioko: while *Notogomphus moorei* (a) may well be endemic, *Azuragrion buchholzi* (b) has been found more widely. Photos: © C. Vanappelghem (a) and K.-D.B. Dijkstra (b).



Two species described from Makokou in north-east Gabon, but since found to be more widespread: (a) *Aciagrion brosseti*, (b) *Palpopleura albifrons*. Photos: © N. Mézière.



Two characteristic damselflies of Congo Basin streams: (a) *Chlorocypha aphrodite*, (b) *Pseudagrion simplicilaminatum*. Photos: © K.-D.B. Dijkstra.





Two characteristic damselflies of clear sandy rivers of the Batéké Plateau: (a) *Platycypha picta*, (b) *Pseudagrion bernardi*. Photos: © N. Mézière (a) and C. Vanappelghem (b).

species. Together these collections provide the only impression of the typical dragonfly fauna of the cuvette, sharing typical Congolian species such as *Agriocnemis stygia*, *Phyllomacromia maesi*, *Lokia circe*, *L. erythromelas*, *Porpax sentipes*, *Trithemis apicalis*, *T. congolica*, and *H. vrijdaghi*, but also the only records of *Congothemis longistyla*, and most of the few known of *Elattoneura incerta* and *Tetrathemis longfieldae* (see above). *Diastatomma multilineatum*, described from the Giri area, was recently recorded 700 km south-west in south-eastern Gabon. It is still the only known locality for and an unnamed *Chlorocypha* (NE), while *Chlorocypha ghesquierei* (DD) was recorded only at Eala. Rather little is known of the swamps around Lake Mai-Ndombe and Tumba. *Trithetrum congoense* is possibly a characteristic species, known only from near Brazzaville, Eala and Lake Tumba (Dijkstra and Pilgrim 2007) until it was discovered at grassy riverbanks in south-east Gabon. Although geographically in the Kasai ecoregion, Bumbuli, the only known locality of *Paragomphus maynei* (DD), lies in the southern Cuvette: the least explored of one of the most poorly explored parts of Africa. Also the western Cuvette, including the swamp forests of north-east Congo (e.g. along the Likouala River), is entirely unexplored (Figure 5.2). Dijkstra (2007b, 2008) obtained an impression of the central basin's remarkable diversity by recording 86 species within 13 days in a small area around Lokutu. Only 28% were widespread species; the fauna was estimated to number over 125 species.

Two finds near the Congo at Lokutu: (a) *Platycypha eliseva*; (b) *Neurogomphus uelensis*. Photos: © K.-D.B. Dijkstra.



The survey produced two conspicuous new species (both DD), *Mesocnemis saralisa* and *Platycypha eliseva*, and range extensions over thousands of kilometres. *Ceriagrion ignitum* and *Chlorocypha pyriformosa*, for example, had not been found outside western Africa before, the former not even since its description from Ghana (see Dijkstra et al. 2010).

An expedition conducted in April–June 2010 on the Congo, going downstream from Kisangani (route shown in Figure 5.2), yielded many additions: including prior data, 171 species have been found along this 350 km stretch of the river. Many new species were found, including probable new species of *Ceriagrion*, *Prodasineura*, *Aciagrion*, *Notogomphus* and *Paragomphus*, and range extensions were proven for several more. The extensive sympatry of *T. congoense* with *T. navasi*, the only species of the recently erected genus *Trithetrum* (Dijkstra and Pilgrim 2007) is also notable. Despite these efforts, the southern and western Cuvette, including the swamp forests of north-east Congo, remain entirely unexplored.

Uele: This ecoregion incorporates the open habitats on the north-eastern fringe of central Africa. The fauna is poorly known, with two notable exceptions, Bambesa and Garamba National Park (Figure 5.2). The former lies on the northern forest-savannah border and is the locality most often attached to odonates kept

in RMCA, thanks to the efforts of H.J. Brédo, P. Henrard and especially J. Vrijdagh (1932–1940). As a consequence, 21 species were first described from here, although only *Elattoneura vrijdaghi*, *Pseudagrion thenartum*, *Anax congoliath*, *Diastatomma selysi*, *Lestinogomphus congoensis*, *Notogomphus leroyi*, *Paragomphus nigroviridis*, *Phyllomacromia aureozona*, *Ph. schoutedeni*, and *Malgassophlebia bispina* are presently considered valid and have all been found to be widespread. It is possible that material from “Bambesa” came from a much larger part of north-east DRC, as the 143 species obtained are suspected to originate from the savannahs to the north, swamp forests to the south-west and highlands to the south-east. Garamba National Park was surveyed by H. de Saeger in 1949–1954, resulting in records of almost 80 species (Pinhey 1966). Among these are some species that are better known from western Africa, especially in savannah habitats: *Ceriagrion rubellocerinum*, *Pseudagrion emarginatum*, *Phyllomacromia flavimitella*, *Brachythemis wilsoni*, *Nesciothemis nigeriensis*, *Orthetrum latihami*, and *Trithemis kalula*. Garamba is the type locality of *Ph. flavimitella* and *O. latihami*, as well as of *Orthetrum saegeri* and *Porpax garambensis*.

Lower Congo: This region is here taken to include the **Lower Congo Rapids** and **Malebo Pool** ecoregions, which have not been studied specifically for Odonata. The region is characterised by more open habitats, which extend northwards to the Batéké Plateau (see Sangha). As a consequence, the Odonata differ by a greater proportion of open-land species penetrating from the south. Most of these are widespread and avoid dense forest, but among them are three principally ‘Katangan’ species (see below): *Umma electa*, *Phyllomacromia congolica*, and *Zygonyx eusebia*. A potential endemic of this region, *Elattoneura morini* (DD), was described from near Brazzaville (Legrand 1985) and known from a single male in RMCA collected near Kinshasa, but it was found to extend to north-western Congo and south-eastern Gabon (N. Mézière and P. Lambret pers. comm.).

Two species described from Bambesa but since found much more widely. Both were photographed in south-east Gabon: (a) *Elattoneura vrijdaghi*; (b) *Lestinogomphus congoensis*. Photos: © C. Vanappelghem (a) and N. Mézière (b).



5.1.3 Katanga

In the southern half of the Congo Basin, rainforest gives way to woodlands and savannah, and the land gradually slopes up, reaching elevations over 1,000 m. As a consequence, this area, named here after the large southern DRC province that dominates it, has a very different fauna from the rest of central Africa (Figure 5.1). Many species that are typical of eastern and southern Africa occur only here in central Africa and DRC, such as *Chlorocypha consueta*, *Lestes amicus*, *Elattoneura cellularis*, *Africallagma sinuatum*, *Pseudagrion inconspicuum*, *P. makabusiense*, *P. salisburyense*, *Notogomphus praetorius*, *Phyllomacromia monoceros*, *Atoconeura biordinata*, *Bradinopyga cornuta*, *Hadrothemis scabrifrons*, *Orthetrum macrostigma*, *Porpax risi*, *Thermochoria jeannelli*, and *Trithemis pluvialis*. Some of these species also penetrate from the east in the highlands of eastern DRC: *Platycypha caligata*, *Lestes virgatus*, *Agriocnemis gratiosa*, *Pseudagrion hageni*, *P. massaicum*, *P. spernatum*, *Aeshna rileyi*, *Gynacantha villosa*, *Crenigomphus hartmanni* and *Orthetrum machadoi*. Aside from these widespread species, the fauna includes species (largely) confined to the Zambezian area that extends to adjacent Angola, Zambia and in some cases into the Okavango regions of Namibia and Botswana: *Umma electa*, *Chlorocypha frigida*, *C. seydeli*, *Chlorocnemis wittei*, *Aciagrion heterosticta*, *Pseudagrion coeruleipunctum* (DD), *P. fisheri*, *P. greeni* (VURG), *P. rufostigma*, *Diastatomma soror*, *Ictinogomphus dundoensis*, *Phyllomacromia unifasciata*, *Lokia ellioti*, *Neodythemis fitzgeraldi* (DD), *Nesciothemis fitzgeraldi* (DD), *Rhyothemis mariposa*, *Trithemis anomala*, and *Zygonyx atritibiae*.

Kasai: The fauna of south-west Katanga is best known through the efforts of G.F. Overlaet who collected along the Upper Lulua, mainly between Kapanga and Dilolo, in 1918–1937, although mainly 1932–1934. Some 90 species were recorded, including





Two damselflies, restricted to forest streams within the Katanga region of southern DRC and northern Zambia. Both photographed near Ikelenge, north Zambia, a famous collecting site of Pinhey: (a) *Chlorocnemis wittei*, (b) *Umma electa*. Photos: © J. Kipping.

the types of *Microgomphus schoutedeni*, *Phyllomacromia overlaeti*, and *Phyllomacromia seydeli*, and poorly known species like *Chlorocypha seydeli*, *Prodasineura flavifacies* (DD) and *Lestinogomphus congoensis*. Dundo (= Chitato), in the centre of the Kasai ecoregion on the Angola-DRC border, is also the origin of many records (Longfield 1959, Pinhey 1961a, Pinhey 1961b), but their geographic accuracy is doubtful: ‘Dundo’ may refer to the collection held at this town rather than material obtained there. This is especially problematic as several species, some taxonomically dubious, are only known from ‘Dundo’: *Chlorocypha rubriventris* (DD), *Pseudagrion dundoense* (DD), *Ictinogomphus dundoensis*, *Paragomphus machadoi* (DD), and *Lestinogomphus bivittatus* (DD). Of these only *I. dundoensis* has since been found to be quite widespread in swamps from Lake Bangweulu to the Okavango Delta, and ‘Dundo’ is an extreme and probably erroneous outlier.

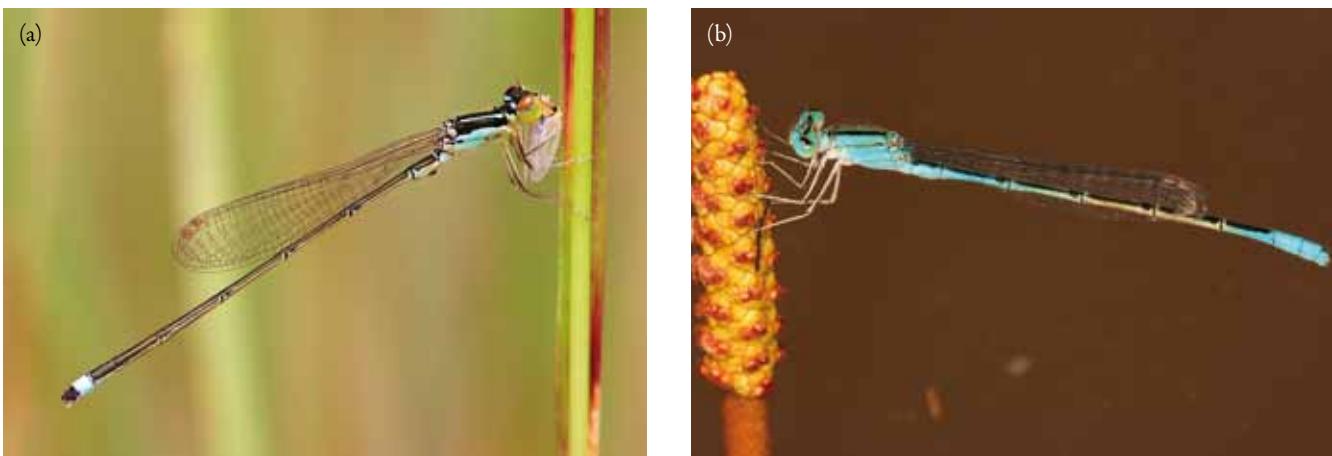
Upper Lualaba: C. Seydel obtained almost 50 species from Kabongo in 1951–1954 (Figure 5.2), including the types of *Chlorocypha seydeli* (only other site Tshibalaka near Kapanga), *Phyllogomphus schoutedeni* (also Lubumbashi), and *Paragomphus interruptus* and *Rhyothemis splendens* (both DD), which have yet to be found elsewhere. G.F. de Witte obtained over 70 species in the huge Upemba National Park (Figure 5.2) in 1945–1949 (Fraser 1955c). *Chlorocnemis wittei* and *Phyllomacromia unifasciata* were described from here, but extend to north Zambia. Of particular interest are two species so far appearing endemic to the park and environs: *Allocnemis mitwabae* is known only from near Lubudi and Mitwaba, while *Pseudagrion symoensii* is confined to the Kundelungu Plateau in the eastern part of the park. *Chlorocypha wittei* is also known only from the park, but was not evaluated due to confusion with the more widespread *C. fabamacula* (Dijkstra unpubl.). Without specific information about threats, these species are (or should be) considered as globally NT.

Bangweulu/Mweru: This region is comparatively well-known, due to the work of J.J. Symoens (Lieftinck 1969; Pinhey 1967) and the earlier efforts of C. Seydel (1923–1959). Although in RMCA alone 145 species are labelled as originating from

Elisabethville/Lubumbashi (Figure 5.2), ambiguous collection data and the absence of records from the well-studied parts of adjacent Zambia (see Pinhey 1984), suggests that especially forest species such as *Phaon camerunensis*, *Umma longistigma*, *U. saphirina*, *Chlorocypha trifaria*, *Chlorocnemis nigripes*, *Elatoneura lliba*, *Ceriagrion annulatum*, *Pseudagrion glaucum* (= *basicornu*), *P. serrulatum*, *Hadrothemis coacta*, *Lokia erythromelas*, *Micromacromia camerunica*, *Thermochoria equivocata* (confused with the locally common *T. jeanneli*), and *Trithemis tropicana* were collected much further afield. *C. annulatum* even has its type locality here, as do *Aciagrion heterosticta*, *Gynacantha immaculifrons* (NA), *Ictinogomphus regisalberti*, *Neurogomphus pallidus* (DD), *Onychogomphus seydeli*, *Phyllomacromia congolica*, and *Aethiothemis bequaerti*. Of these, only *N. pallidus* has not been found elsewhere. The swamps in this region, especially around Lake Bangweulu, form an outpost for species like *Pinheyagrion angolicum*, *Pseudagrion coeleste*, *P. deningi*, *P. helena*, *Anax bangweuluensis* (NT^{RG}), *Diplacodes pumila*, *Trithemis aequalis* and *T. brydeni* (DD), which are more abundant further south, for instance in the Okavango Delta of Botswana. *Lokia gamblesi* (DD) is only known from the holotype male collected at Kisongo on the Katanga-Zambia border.

5.1.4 Albertine Rift and Slope

Most of central Africa is low-lying. The highlands on its western border, reaching their highest point on Mt Cameroon at almost 4,100 m, are rather isolated, but to the south and east the Congo Basin slopes up towards the huge highland area that stretches across eastern Africa from Ethiopia to South Africa. Although an Afro-montane dragonfly fauna (Figure 5.1) is seen especially in the more open habitats of Katanga, central Africa’s forest-clothed highest mountains lie along the Albertine Rift on its eastern border, with the Ruwenzori just reaching over 5,100 m. This slope incorporates the ecoregions of **Upper Congo**, including **Upper Congo Rapids**, and the **Albertine Highlands**, including Ituri, and the eastern portion of the **Cuvette Centrale** ecoregion. Aside from a few widespread montane species occurring very peripherally in central Africa, like *Aeshna ellioti*, these highland have a characteristic Albertine fauna, with endemism in forest



Two damselflies which are known to occur in the swamps of Lake Bangweulu as well as the Okavango Delta of Botswana. (a) *Pinheyagrion angolicum*, (b) *Pseudagrion helena*. Photos: © J. Kipping.

genera such as *Chlorocypha*, *Chlorocnemis*, *Neodythemis* and *Tetrathemis*, as well as in the more montane genera *Notogomphus* and *Atoconeura*. Most knowledge of this fauna comes from Bwindi Impenetrable National Park and other forests in south-west Uganda (e.g. Dijkstra and Kisakye 2004; Dijkstra 2006a; Dijkstra and Vick 2006). Unfortunately, the western slope of the rift, the part covered in the central African assessment, is almost completely unstudied. Nonetheless it seems relevant to discuss all Albertine species here, because these species, or related new species, must occur on the western slope. Many of the species range widely beyond the Albertine Rift highlands, extending throughout the forested highlands east of the Congo, from western Kenya and Tanzania to north-east DRC and down to Katanga. Examples are *Chlorocypha trifaria*, *Chlorocnemis pauli* (NT^{RG}), *Africallagma pseudelongatum*, *Notogomphus leroyi*, *N. lujai*, *Paragomphus lacustris*, *P. viridior*, *Phyllomacromia sylvatica*, *Atoconeura pseudeudoxia*, *Lokia corydoni* (DD) and *Tetrathemis denticauda* (DD). *Pseudagrion rufocinctum* and *Trithemis integra* range from eastern DRC to west Tanzania and east Uganda. However, most Albertine species have not or only marginally been found in the central African assessment area: *Chlorocypha hasta* (NA; western Tanzania), *C. jacksoni* (VU^{RG}), *C. molindica* (EN^{RG}), *C. schmidti* (VU), *C. tenuis* (LC^{RG}; Uvira to western Kenya), *Platycypha pinheyi* (NA;

Lake Tanganyika), *Chlorocnemis superba* (DD; east DRC to western Uganda and Tanzania), *Agriocnemis palaeforma* (NA; papyrus swamps in Uganda), *Tragogomphus* (= *Onychogomphus*) *bwambae* (NA; Semliki Valley), *Neurogomphus wittei* (NA; Lake Tanganyika), *Notogomphus flavifrons* (NA; south-west Uganda), *Onychogomphus styx* (NA; west Tanzania, east Uganda to west Kenya), *Idomacromia jillianae* (NA; south-west Uganda), *Atoconeura eudoxia* (NA; Burundi, Ruwenzori to west Kenya), *Neodythemis munyaga* (NA; south-west Uganda), *N. nyungwe* (NA; Rwanda), *Tetrathemis corduliformis* (DD; Rutshuru and east Uganda to west Kenya) and *T. ruwensoriensis* (NA; Ruwenzori). The taxonomically dubious *Neurogomphus vicinus* is also DD because the position of its type locality Kibombo is ambiguous. Possibly the fauna of the Congo Basin's eastern fringes (Figure 5.2) is similarly rich in species and endemics as that of the Lower Guinea, but we have virtually no information on this.

5.2 Conservation status (IUCN Red List Criteria: Regional scale)

The summary presented here is based on a regional species assessment applying the IUCN Red List Categories and Criteria and Regional Guidelines. For comparison, results from western

Two damselflies found in the forested regions of eastern DRC and adjacent East Africa: (a) *Chlorocnemis pauli*; (b) *Africallagma pseudelongatum*. Photos: © A. Cordero Rivera.



Africa are given in square brackets. The regional Red List status of any species which is endemic to central Africa will be equivalent to its global status. Because most species are widespread and/or are tolerant to some habitat degradation, only 12 (2.6%) of the species assessed in central Africa are regionally threatened, with a further six (1.3%) assessed as Near Threatened [9.4% and 1% respectively of 287 species in western Africa]. The remaining 96% of species are generally widespread and (therefore) of Least Concern, also because extensive forests still stand in the region. However, the extensive habitat degradation in the region is a

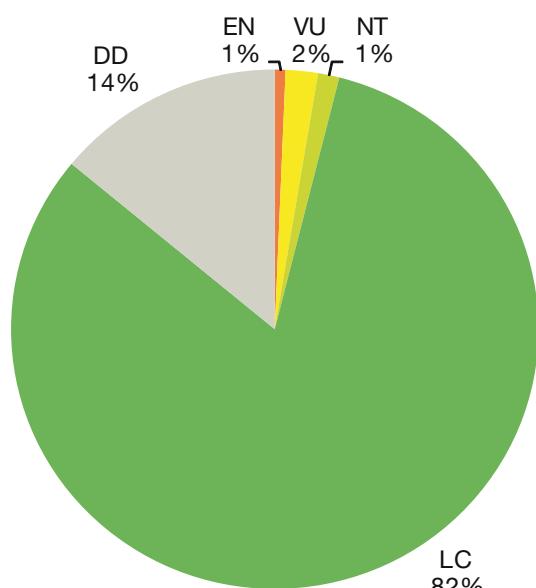
Table 5.1 The number of Odonata species in each regional Red List Category in the central African region.

Regional Red List Category	Number of Species	Number of Regional Endemics
Extinct	0	0
Regionally Extinct	0	0
Extinct in the Wild	0	0
Critically Endangered	0	0
Threatened Categories	3	0
Endangered		
Vulnerable		
Near Threatened		
Least Concern		
Data Deficient		
Not Applicable		
Total*	457	93

* The total figure does not include NA (Not Applicable) species.

All species assessed as regionally threatened that are endemic to the region are also globally threatened.

Figure 5.3 The proportion of Odonata species in each Regional Red List Category in the central African region. IUCN Red List Status: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient.



threat whose impacts must be continuously monitored. Ninety-three species are endemic (20.4%), of which only two (2.2%) are deemed under threat [24.6% of 61]. Moreover, 14.0% of all species [13.9%], as well as 45% of the endemics [31%], is considered too poorly known for an assessment of threat. Altogether, 17.9% of all central African species [24.4%] and 50% of its endemics [61%] require further attention (particularly research) because they are either threatened, Near Threatened or poorly known (DD). The comparison with western Africa is relevant because it is the only other region with extensive rainforest and associated endemism (Figure 5.1). The degree of endemism there is similar (21.3%), but the proportion of threatened species is notably higher, especially among the endemics. This difference may be slightly exacerbated by the higher Data Deficiency among central African endemics, but the main cause is the much greater fragmentation of western African rainforests.

5.3 Patterns of species richness

In very broad lines, odonate diversity in Africa peaks on the equator, with the richest assemblages in rainforest habitats (Dijkstra and Clausnitzer 2006). That the pattern in central Africa is more patchy (Figure 5.4a) is probably largely the effect of poor sampling in large but probably rich parts of south-east Cameroon, south-west Gabon, west and north Congo, north-west Angola and especially most of DRC, particularly the central and poorly accessible parts. The diversity of endemic species, which constitute one fifth of the fauna, shows a rather different pattern, with a strong concentration of endemism in the northern Congo Basin (Figure 5.4b). However, the delimitation of the central African assessment region runs right through three regions of endemism: (1) Lower Guinea, shared with western Africa; (2) Albertine Rift, with eastern Africa; (3) Zambezia, with southern Africa. The range-restricted species in those areas are therefore not classified as central African endemics, although they are highly localised and sometimes threatened. Indeed, the only concentration of threatened species in central Africa (Figure 5.4c) is in the Lower Guinea, especially the highlands on the Cameroon-Nigeria border. Thus the central concentration of endemism in Figure 5.4b mainly shows where most species confined within the region's borders overlap (mid-domain effect), although the Congo Basin is also the fourth main area of endemism in central Africa (see Figure 5.1). Data Deficiency is virtually pandemic, with concentrations ironically in species-rich areas that have been comparatively well-researched (Figure 5.4d), because from there multiple species were described for which no new information has been obtained since.

5.4 Major threats to dragonflies

Central Africa has the richest and, as yet, least threatened odonate fauna in the continent. This is because the region is largely very rich in water and still extensively forested. The Congo Basin, for example, contains the second-largest intact rainforest area in the World, and one-quarter of Africa's freshwater. Through the

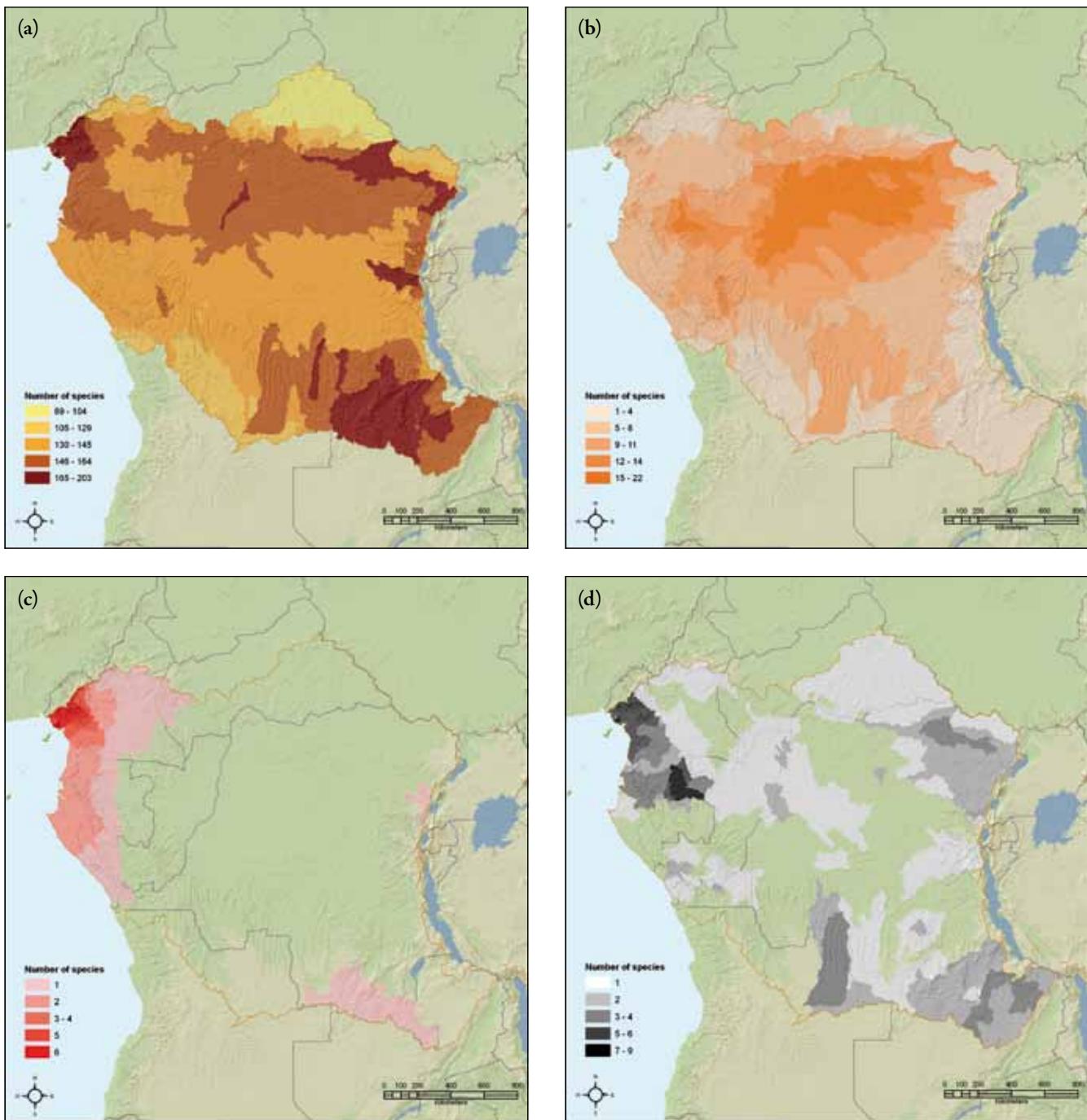
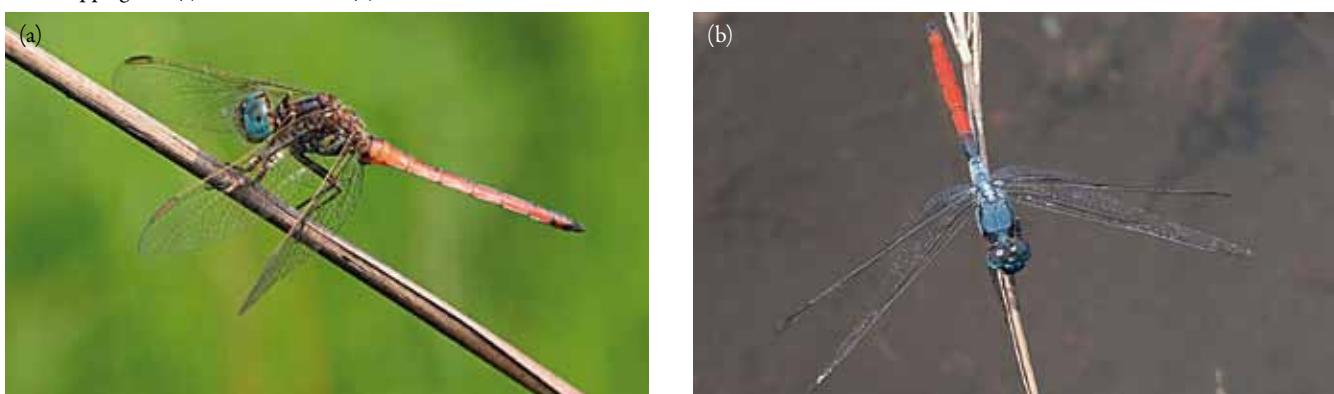


Figure 5.4 Richness of (a) all Odonata species, (b) endemics, (c) threatened, and (d) Data Deficient species in central Africa, based on known and inferred distribution mapped to river sub-catchments.

Two localised libellulids discovered recently in south-east Gabon: (a) *Aethiothemis mediofasciata*, (b) *Nesciothemis nigeriensis*. Photos: © C. Vanappelghem (a) and N. Mézière (b).



assessment process the major threats to the Odonata of central Africa can be quantified in terms of proportion of species affected by each threat. Odonata may be sensitive to any changes in the flow, oxygen and temperature regimes of the waterways they inhabit. Figure 5.5 shows that habitat loss is by far the greatest threat to odonates, impacting half of all species and 91% of threatened species. Habitat loss due to agriculture affects 25% of all species, and 58% of threatened species, and deforestation, 43% of all species and 25% of threatened species. As human populations grow explosively, the general alteration of the natural landscape (especially through deforestation, urbanisation and agricultural encroachment) and the subsequent alteration of water bodies (e.g. by erosion, eutrophication and siltation) is the main threat to Odonata in central Africa and indeed the tropics worldwide. Aside from land and water, energy is gaining prominence as a tropical resource: the feasibility of the Grand Inga scheme, which could generate over twice the power of China's Three Gorges Dam, and REDD (Reduced Emissions from Deforestation and Degradation) in central Africa depends on the Congo Basin's environmental health.

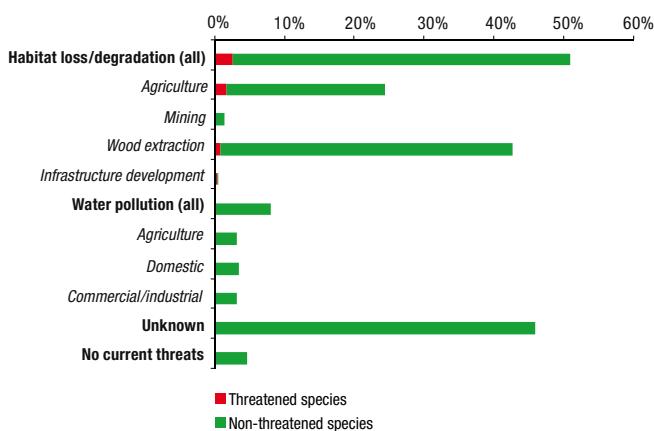


Figure 5.5 Percentage of Odonata species affected by each threat. Note that many species have more than one threat listed.

This photo was taken in 1983 north-east of Kalima near Kindu, eastern DRC. *Tribemis hartwigi* was known previously from only four sites on Bioko and adjacent Cameroon, almost 2,000 km away. It was recently found to be abundant in SE Gabon. Photo: © C. Vanappelghem.



Further threats are much more localised, such as water pollution, and the effects of mining. Given the likely increase in development in the area, these are a potentially increasing problem throughout central Africa. There are also 46% of species where the threats are unknown which reflects the high levels of species assessed as Data Deficient. Only 5% of species are thought to have no threats, all of which are assessed as Least Concern.

5.5 Conservation recommendations

5.5.1 Conservation measures

Habitat degradation: For now, most central African endemic dragonflies appear to survive in the fragments of natural forest that remain. Because deforestation has lead to the demise of virtually all forest in the region, the survival of the remnants, especially the large tracts in DRC, is vital.

Damming large rivers: The impact of dams, at least downstream, can be reduced if a natural water regime with normal seasonal fluctuations is retained. Otherwise breeding habitats and life cycles of dragonflies and other aquatic fauna will be seriously disturbed.

Mining: Where mining takes place it is of the utmost importance that minimal damage to the watershed is ensured by leaving broad zones around water bodies (rivers, inundation zones) untouched. Also minimising the outflow of mining water into the river systems will reduce the possible negative effect of those activities.

5.5.2 Research action required

Having the continent's richest but least known odonate fauna, all of central Africa requires more surveys. Huge areas, such as northern Angola, eastern Cameroon, eastern Central African Republic and large parts of DRC have no records at all. However, the three greatest priorities, with the expectation of the discovery of many new species, lie in the Congo Basin (Figure 5.2):

1. Western Cuvette, including Odzala, Sanga and Likouala areas.
2. Southern Cuvette, including Tumba, Mai Ndombe, Lopori Maringa and Salonga areas.
3. Western Albertine Slope, including Ituri, Maiko, Kahuzi-Biega and Itombwe areas.

Targeted surveys to determine the status and ecologies of (potentially) threatened species should be undertaken in this understudied region. A study of the impact of mining, e.g. in Katanga, on stream systems and their dragonflies would be insightful.

5.6 References

- Aguesse, P. 1966. Contribution à la faune de Congo (Brazzaville)
Mission A. Villiers et A. Descarpentries XXI. Odonates.

- Bulletin de l'Institut fondamental d'Afrique noire* (A) **28**:783–797.
- Brooks, S.J. and Jackson, K.A. 2001. The Odonata of Bioko, Republic of Equatorial Guinea, with the description of fan-shaped setae on early instar Libellulidae larvae. *Odonatologica* **30**:29–38.
- Carletti, B. 1997. *Odonatofauna della Repubblica del Congo (Africa Equatoriale)*. Tesi di Laurea in Scienze Naturali, Facoltà di Scienze Matematiche, Fisiche e Naturali, Università degli Studi Firenze: 1–188.
- Dijkstra, K.-D.B. 2005. The identity of some widespread and variable *Phyllomacromia* species, with a revised grouping of the genus (Anisoptera: Corduliidae). *Odonatologica* **34**:11–16.
- Dijkstra, K.-D.B. 2006a. The *Atoconeura* problem revisited: taxonomy, phylogeny and biogeography of a dragonfly genus in the highlands of Africa (Odonata, Libellulidae). *Tijdschrift voor Entomologie* **149**:121–144.
- Dijkstra, K.-D.B. 2006b. Taxonomy and biogeography of *Porpax*, a dragonfly genus centred in the Congo Basin (Odonata, Libellulidae). *Tijdschrift voor Entomologie* **149**:71–88.
- Dijkstra, K.-D.B. 2007a. *Demise and rise: the biogeography and taxonomy of the Odonata of tropical Africa*. PhD Thesis, Leiden University 1–204.
- Dijkstra, K.-D.B. 2007b. Dragonflies and damselflies (Odonata) of Lokutu. In: Butynski, T.M. and McCullough, J. (eds.), *A rapid biological assessment of Lokutu, Democratic Republic of Congo*. RAP Bulletin of biological assessment, **46**:21–36.
- Dijkstra, K.-D.B. 2008. The Systematist's Muse – two new damselfly species from 'Elisabetha' in the Congo Basin (Odonata: Chlorocyphidae, Platycnemididae). *Zoologische Mededelingen* **82**:15–27.
- Dijkstra, K.-D.B. and Clausnitzer, V. 2006. Thoughts from Africa: how can forest influence species composition, diversity and speciation in tropical Odonata? In: Cordero Rivera, A. (ed.), *Forests and dragonflies*. Pensoft Publishers, Sofia 127–151.
- Dijkstra, K.-D.B. and Kisakye, J.J. 2004. *Idomacromia jillianae* sp. nov. from Uganda (Odonata: Corduliidae). *International Journal of Odonatology* **7**:459–466.
- Dijkstra, K.-D.B. and Pilgrim, E.M. 2007. *Trithetrum*, a new genus of African dragonflies formerly placed in *Sympetrum* (Odonata, Libellulidae). *Journal of Afrotropical Zoology* **3**:77–81.
- Dijkstra, K.-D.B., Tchibozo, S.L. and Ogbogu, S.S. 2010. Chapter 5. The status and distribution of dragonflies and damselflies (Odonata) in western Africa. In: Smith, K.G., M.D. Diop, M. Niane and W.R.T. Darwall (eds.) *The Status and Distribution of Freshwater Biodiversity in Western Africa*, pp. 41–55. IUCN.
- Dijkstra, K.-D.B. and Vick, G.S. 2006. Inflation by venation and the bankruptcy of traditional genera: the case of *Neodythemis* and *Micromacromia*, with keys to the continental African species and the description of two new *Neodythemis* species from the Albertine Rift (Odonata: Libellulidae). *International Journal of Odonatology* **9**:51–70.
- Fraser, F.C. 1949. Gomphidae from the Belgian Congo (Order Odonata). *Revue de Zoologie et de Botanique Africaines* **42**:101–138.
- Fraser, F.C. 1953a. New genera and species of Libellulines from the Belgian Congo. *Revue de Zoologie et de Botanique Africaines* **48**:242–256.
- Fraser, F.C. 1953b. A new giant dragonfly from the Belgian Congo. *Revue de Zoologie et de Botanique Africaines* **48**:301–305.
- Fraser, F.C. 1954a. New and rare species of Zygoptera from the Belgian Congo. *Revue de Zoologie et de Botanique Africaines* **50**:269–276.
- Fraser, F.C. 1954b. The origin and relationships of the odonate fauna of the Belgian Congo. *Annales du Musée du Congo Belge* (N.S. Sciences zoologiques) **1**:368–370.
- Fraser, F.C. 1955a. Four new species of Odonata from the Belgian Congo. *Revue de Zoologie et de Botanique Africaines* **52**:17–54.
- Fraser, F.C. 1955b. New species and new additions to the Odonata of the Belgian Congo. *Revue de Zoologie et de Botanique Africaines* **51**:33–42.
- Fraser, F.C. 1956. *Pseudagrion superbum*, *Gynacantha flavipes* and *Gynacantha immaculifrons*, three new species of Odonata from the Belgian Congo. *Revue de Zoologie et de Botanique Africaines* **54**:382–387.
- Fraser, F.C. 1957. Some further notes on the Odonata of the Belgian Congo. *Revue de Zoologie et de Botanique Africaines* **55**:338–346.
- Fraser, F.C. 1958a. *Chlorocypha Seydeli*, a new species of Dragonfly from the Belgian Congo. *Revue de Zoologie et de Botanique Africaines* **57**:109–112.
- Fraser, F.C. 1958b. *Malgassophlebia bispina*, a remarkable new Libelluline from the Belgian Congo. *Revue de Zoologie et de Botanique Africaines* **57**:317–320.
- Fraser, F.C. 1958c. Odonata new to the Belgian Congo with the description of the male of *Porpacithemis dubia* Fraser and of another new species belonging to the same genus. *Revue de Zoologie et de Botanique Africaines* **58**:39–42.
- Fraser, F.C. 1958d. *Zygonyx prodigiosa*, a new species of Dragonfly from the Belgian Congo (Order Odonata). *Revue de Zoologie et de Botanique Africaines* **58**:263–266.
- Fraser, F.C. 1959. A new species of *Chlorocypha* and some notes on the synonymy of other species of Odonata from the Belgian Congo. *Revue de Zoologie et de Botanique Africaines* **60**:307–312.
- Kalkman, V.J., Choong, C.Y., Orr, A.G. and Schütte, K. 2010. Remarks on the taxonomy of Megapodagrionidae with emphasis on the larval gills. *International Journal of Odonatology* **13**:109–117.
- Kingdon, J. 1989. *Island Africa*. Princeton University Press, Princeton 1–287.
- Legrand, J. 1975. Contribution à la faune du Gabon, Odonates: 1re Note. *Annales de la société entomologique de France* (N.S.) **11**:679–696.
- Legrand, J. 1977. Deux *Tetrathemis* Brauer nouveaux du Gabon et la larve de l'un d'eux (Anisoptera: Libellulidae). *Odonatologica* **6**:245–251.
- Legrand, J. 1979. *Palpopleura albifrons*, n. sp., nouveau Diastatopidinae de la forêt gabonaise (Odonata Libellulidae). *Revue française d'Entomologie* (N.S.) **1**:179–181.

- Legrand, J. 1982. Deux nouveaux *Aciagrion* du Gabon (Odonata, Zygoptera, Coenagrionidae). *Revue française d'Entomologie* (N.S.) 4:161–164.
- Legrand, J. 1984a. Trois nouveaux Zygoptères forestiers du Gabon oriental et une synonymie nouvelle (Chlorocyphidae, Protoneuridae, Coenagrionidae). *Odonatologica* 13:237–244.
- Legrand, J. 1984b. Un deuxième *Idomacromia* de la forêt gabonaise: *I. liefitincki* spec.nov. (Anisoptera: Corduliidae). *Odonatologica* 13:113–117.
- Legrand, J. 1985. *Elattonoeura* afrotropicaux nouveaux ou peu connus (Odonata, Protoneuridae). *Nouvelle Revue d'Entomologie* (N.S.) 2:159–168.
- Legrand, J. 1986. *Malgassophlebia westfalli* spec. nov., nouveau Tetratheminae afrotropical des forêts du Gabon oriental: imagos, larves, notes biologiques et discussion sur le genre (Anisoptera: Libellulidae). *Odonatologica* 15:97–105.
- Legrand, J. 1987. Deux nouveaux *Pseudagrion* forestiers afrotropicaux (Odonata, Zygoptera, Coenagrionidae). *Revue française d'Entomologie* (N.S.) 9:77–82.
- Legrand, J. 1992. Nouveaux Gomphidae afrotropicaux. Descriptions préliminaires. (Odonata, Anisoptera). *Revue française d'Entomologie* (N.S.) 14:187–190.
- Legrand, J. 2002. Un nouveau *Tragogomphus* d'Afrique équatoriale: *T. ellioti* spec. nov. (Anisoptera: Gomphidae). *Odonatologica* 31:193–197.
- Legrand, J. and Lachaise, M. 1980. Contribution à la faune du Congo (Brazzaville) Mission A. Villiers et A. Descarpentries. *Bulletin de l'Institut fondamental d'Afrique noire* (A) 42:586–593.
- Liefitinck, M.A. 1969. Odonata Anisoptera. *Hydrobiological survey of the Lake Bangweulu Luapula River basin* 14:1–61.
- Longfield, C. 1959. The Odonata of N. Angola. Part II. *Publicações Culturais Companhia de Diamantes de Angola* 45:13–42.
- Pinhey, E. 1961a. A collection of Odonata from Dundo, Angola. With the description of two new species of Gomphids. *Publicações Culturais Companhia de Diamantes de Angola* 56:71–78.
- Pinhey, E. 1961b. Some dragonflies (Odonata) from Angola; and descriptions of three new species of the family Gomphidae. *Publicações Culturais Companhia de Diamantes de Angola* 56:79–86.
- Pinhey, E. 1962. Some records of Odonata collected in Tropical Africa. *Journal of the Entomological Society of South Africa* 25:20–50.
- Pinhey, E. 1966. Odonata. *Exploration du Parc National de la Garamba* 45:1–114.
- Pinhey, E. 1967. Odonata Zygoptera. *Hydrobiological survey of the Lake Bangweulu Luapula River basin* 14:1–43.
- Pinhey, E. 1971a. Contribution à la faune du Gabon. Mission A. Villiers, 1969. Odonates. *Bulletin de l'Institut fondamental d'Afrique noire* (A) 33:959–968.
- Pinhey, E. 1971b. Odonata collected in République Centrafricaine by R. Pujol. *Arnoldia Rhodesia* 5(18):1–16.
- Pinhey, E. 1971c. Odonata of Fernando Po Island and of neighbouring Cameroons Territory. *Journal of the Entomological Society of South Africa* 34:215–230.
- Pinhey, E. 1974. Odonata of the Northwest Cameroons and particularly of the islands stretching southwards from the Guinea Gulf. *Bonner zoologische Beiträge* 25:179–212.
- Pinhey, E. 1984. A checklist of the Odonata of Zimbabwe and Zambia. *Smithersia* 3:1–64.
- Schouteden, H. 1934. Catalogues raisonnés de la faune entomologique du Congo Belge. Pseudonéuroptères – Odonates. *Annales du Musée du Congo Belge, Zoologie* 3:1–84.
- Thieme, M.L., Abell, R., Stiassny, M.L.J., Skelton, P., Burgess, N., Lehner, B., Dinerstein, E., Olson, D., Teugels, G. and Kamdem-Toham, A. 2005. *Freshwater Ecoregions of Africa and Madagascar: a Conservation Assessment*. Island Press, Washington DC, USA.
- Vick, G.S. 1996. *Umma mesumbei* spec. nov., with records of some other dragonfly species from the South-West province of Cameroon (Zygoptera: Calopterygidae). *Odonatologica* 25:109–220.
- Vick, G.S. 1998. Notes on some damselfly larvae from Cameroon (Zygoptera: Perilestidae, Amphipterygidae, Platycnemididae). *Odonatologica* 27:87–98.
- Vick, G.S. 1999. A checklist of the Odonata of the South-West province of Cameroon, with the description of *Phyllogomphus corbetae* spec. nov. (Anisoptera: Gomphidae). *Odonatologica* 28:219–256.
- Vick, G.S. 2000. *Mesumbethemis takamandensis* gen. nov., spec. nov., a new genus and species of the Tetrathemistinae from Cameroon, with a key to the African genera or the subfamily (Anisoptera: Libellulidae). *Odonatologica* 29:225–237.
- Vick, G.S. 2002. *Preliminary biodiversity assessment of the odonate fauna of the Takamanda Forest Reserve, Cameroon*. IDF-Report 4:1–10.
- Vick, G.S. 2003a. *Biodiversity assessment of the odonate fauna of the Takamanda Forest Reserve, Cameroon*. SI/MAB Series 8: 73–82.
- Vick, G.S. 2003b. Notes on the genus *Notogomphus* Selys, 1858 in Cameroon with the descriptions of two new species (Anisoptera: Gomphidae). *Odonatologica* 32:47–60.

Chapter 6. The status and distribution of freshwater crabs

Cumberlidge, N.¹

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6.1 Overview of the central African freshwater crab fauna

The entire Afrotropical zoogeographical region (Africa and Madagascar) hosts 134 species of freshwater crabs in 20 genera and two families; Potamonautesidae Bott, 1970, and Potamidae Ortmann, 1896 (Cumberlidge 1999, 2009a; Cumberlidge and Sternberg 2002; Daniels *et al.* 2006; Cumberlidge *et al.* 2008; Cumberlidge *et al.* 2009; Yeo *et al.* 2008). Central Africa includes about a quarter (26%) of this Afrotropical fauna, with 38 species of freshwater crabs in five genera (*Erimetopus*, *Louisea*, *Sudanonautes*, *Potamonemus*, and *Potamonautes*) that all belong to a single family (Potamonautesidae) (Table 6.1) (Bott 1955; Cumberlidge 1999; Cumberlidge *et al.* 2008, Cumberlidge *et al.* 2009). The region's freshwater crab fauna is highly endemic at the species level, whereby 30 (79%) species and one genus (*Erimetopus*) are endemic (Bott 1955; Cumberlidge 1999; Cumberlidge and Reed 2004).

Central Africa's freshwater crab fauna is the most diverse in Africa, exceeding even that of eastern Africa (35 species, three genera) (Bott 1955; Cumberlidge 1997, 1998, 2009a,b; Corace *et al.* 2001; Cumberlidge and Vannini 2004; Reed and Cumberlidge 2004,

2006a; Darwall *et al.* 2005; Cumberlidge and Dobson 2008), western Africa (25 species, six genera) (Bott 1955; Cumberlidge 1999; Cumberlidge *et al.* 2002; Cumberlidge and Boyko 2000), southern Africa (19 species, one genus) (Cumberlidge and Tavares 2006; Cumberlidge and Daniels 2008), and Madagascar (only 15 species, but seven genera) (Cumberlidge and Sternberg 2002; Reed and Cumberlidge 2006b; Cumberlidge *et al.* 2008; Cumberlidge and Meyer 2009). Although some of the nine species of *Platythelphusa* that are endemic to Lake Tanganyika (Cumberlidge *et al.* 1999; Marijnissen *et al.* 2004) have a small part of their range on the Zambian shore of the lake within the central African region, they are not included in this report because they have already been assessed as part of the eastern Africa assessment (Darwall *et al.* 2005).

6.1.1 Freshwater crab distribution and freshwater ecoregions

Distribution data have been derived from specimen records but are still likely to be incomplete. Although a majority of the species from central Africa are quite well known, there are still a number that are either known only from the type locality or

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Table 6.1 List of the species of freshwater crabs found in central Africa, with the important threats to the species, and a summary of their conservation status.

Species	Regional Distribution	IUCN Red List Category	IUCN Red List Criteria	Main Threats
<i>Erimetopus brazzae</i>	C	LC		3
<i>Erimetopus vandenbrandeni</i>	C	DD		4
<i>Louisea balssi</i>	C	EN	B1ab(i,ii,iii,iv,v)	1
<i>Louisea edeaensis</i>	C	EN	B1ab(i,ii,iii,iv,v)	1
<i>Potamonautes acristatus</i>	C	DD		4
<i>Potamonautes adeleae</i>	C	DD		4
<i>Potamonautes adenatus</i>	C	DD		4
<i>Potamonautes ballayi</i>	C	LC		3
<i>Potamonautes bayonianus</i>	C/S	LC		3
<i>Potamonautes congoensis</i>	C	LC		3
<i>Potamonautes dybowskii</i>	C	LC		3
<i>Potamonautes gonocristatus</i>	C/E	EN	B1ab(i,ii,iii,v)	1
<i>Potamonautes langi</i>	C	LC		3
<i>Potamonautes lirrangensis</i>	C/E/S	LC		3
<i>Potamonautes loashiensis</i>	C	LC		3
<i>Potamonautes lueboensis</i>	C	DD		4
<i>Potamonautes margaritarius</i>	C	LC		3
<i>Potamonautes minor</i>	C	LC		3
<i>Potamonautes paecilei</i>	C	LC		3
<i>Potamonautes perparvus</i>	C	LC		3
<i>Potamonautes principe</i>	C	LC		3
<i>Potamonautes punctatus</i>	C	DD		4
<i>Potamonautes regnieri</i>	C	DD		4
<i>Potamonautes schubotzi</i>	C	DD		4
<i>Potamonautes semilunaris</i>	C	DD		4
<i>Potamonautes stanleyensis</i>	C	LC		3
<i>Potamonautes walderi</i>	C	LC		3
<i>Potamonemus asylos</i>	C	DD		4
<i>Potamonemus mambilorum</i>	C	LC		1
<i>Potamonemus sachsi</i>	C/W	VU	B1ab(iii)+2ab(iii)	1
<i>Sudanonautes africanus</i>	C/W	LC		3
<i>Sudanonautes aubryi</i>	C/W	LC		3
<i>Sudanonautes chavanesii</i>	C	LC		3
<i>Sudanonautes faradjensis</i>	C	LC		3
<i>Sudanonautes floweri</i>	C/W/E	LC		3
<i>Sudanonautes granulatus</i>	C/W	LC		3
<i>Sudanonautes orthostylis</i>	C	DD		4
<i>Sudanonautes sangha</i>	C	DD		4

Regional distribution: C – Central Africa, W – Western Africa, S – Southern Africa, E – Eastern Africa. IUCN Red List Categories: EN – Endangered, VU – Vulnerable, LC – Least Concern, DD – Data Deficient. Threat codes: 1 – Habitat destruction, 2 -Pollution, 3 – No major threats identified, 4 – Threat status unknown.

from only a few localities, and further collections are necessary to ascertain their actual distribution. Species diversity is highest in the rivers and streams of the moist lowland forested regions of the Congo River basin, but in general, freshwater crab distribution patterns do not conform closely to the majority of the 22 freshwater ecoregions found in the central African region (Figure 1.2) (Thieme *et al.* 2005; Abell *et al.* 2008). Only five of these ecoregions have endemic species of freshwater crabs: (1) **Sao Tome, Principe, and Annobon** that includes two of the Gulf of Guinea Islands where *P. margaritarius* (endemic to Sao Tome) and *P. principe* (endemic to Principe) occur; (2) the **Lower Congo Rapids** in the DRC (where *E. vandenbrandeni* is endemic), and (3) the **Northern Gulf of Guinea Drainage** in Cameroon (where *L. balssi*, *P. mambilorum*, and *S. orthostylis* are endemic). The remaining two ecoregions with endemic species of freshwater crabs are (4) **Sangha**, which includes the rivers and streams of the lowland forests of Congo, south east Cameroon, and western Central African Republic (where *S. sangha* and *P. regnieri* are endemic), and (5) the **Southern Gulf of Guinea Drainage** in southern Cameroon (where *L. edeaensis* is endemic). All remaining ecoregions in central Africa exhibit little correspondence between freshwater crab distribution patterns and ecoregion boundaries.

The 15 ecoregions in the extensive Congo River drainage basin have rich freshwater crab communities but none include any

species that are endemic to these ecoregions. For example, the **Central Cuvette** ecoregion in the DRC is home to 11 species of *Potamonautes* and four species of *Sudanonautes*, while the neighbouring **Sudanic Congo-Oubangi** ecoregion in the Central African Republic and northern DRC is home to six species of *Potamonautes*, four species of *Sudanonautes*, and one species of *Erimetopus*. This high species diversity continues south into the forested Congo basin in the **Kasai** ecoregion of southern DRC, where 12 species of *Potamonautes* and one species of *Erimetopus* are found. A second region of high species diversity includes the forested rivers and streams of the **Upper Congo** ecoregion in the DRC (where there are eight species of *Potamonautes* and one species of *Sudanonautes*) and in the mountain systems of the **Albertine Highlands** ecoregion in the eastern DRC (where nine species of *Potamonautes* occur). The forested **Uele** ecoregion supports three species of *Potamonautes* and two species of *Sudanonautes*, while there are four species of *Potamonautes*, two species of *Sudanonautes*, and one species of *Erimetopus* in the **Lower Congo** ecoregion. The least diverse areas are all small ecoregions with unusual habitats and are all in the DRC but none of the species found there are endemic to these ecoregions. For example, **Malebo Pool** has one species of *Erimetopus*, **Tumba** has two species of *Potamonautes*, and there are four other ecoregions (the **Lower Congo Rapids**, **Bangweulu-Mweru**, **Lake Tanganyika** drainage streams, and **Mai N'Dombe**) where the crab fauna consists of a single species of *Potamonautes*.

Sudanonautes aubryi, LC, at Nkoelon, a small village just on the western border of the Campo Maan National Park on the border to Equatorial Guinea. Photo: © Jens Kipping.



The forested **Northern Gulf of Guinea Drainage-Bioko** ecoregion in the west coastal equatorial region is highly diverse with seven species of *Sudanonautes*, three species of *Potamonemus*, and one species of *Louisea*. The **Sangha** ecoregion provides important moist lowland forest habitat for freshwater crabs that supports five species of *Sudanonautes* and one species of *Potamonauta* (Cumberlidge and Bokyo 2000). The **Western Equatorial Crater Lakes** ecoregion in Cameroon has no endemic species but is home to three species of *Potamonemus*, two species of *Sudanonautes*, and one species of *Louisea*.

6.2 Conservation status (IUCN Red List Criteria: Regional scale)

The conservation status of central Africa's freshwater crab fauna was assessed by Cumberlidge *et al.* (2009) using the IUCN Red List Categories and Criteria at the global scale (IUCN 2003) and individual species assessments can be found at the IUCN Red List site (www.iucn.redlist.org). Although the available data were sufficient to make valid assessments of the conservation status of most central African species there is still a need to collect more comprehensive information for 12 (32%) of the 38 species that were assessed by Cumberlidge *et al.* (2009) as DD (Table 6.2, Figure 6.1a) because of a lack of data on distribution and population levels. The DD species are *E. vandenbrandeni*, *P. acristatus*, *P. adeleae*, *P. adentatus*, *P. lueboensis*, *P. punctatus*, *P. regnieri*, *P. schubotzi*, *P. semilunaris*, *Potamonemus asylos*, *S. orthostylis* and *S. sangha*) from DRC, Cameroon, and Congo. The relatively high proportion of DD species (32%) reflects the general lack of specimens available from the region, a scarcity that continues to fuel uncertainty about the distribution of these little-known species (Bott 1955; Cumberlidge 1999). The majority of the 26 assessed species of central African freshwater crabs (22 species, 84%, Figure 6.1b) were judged to be LC, and most live

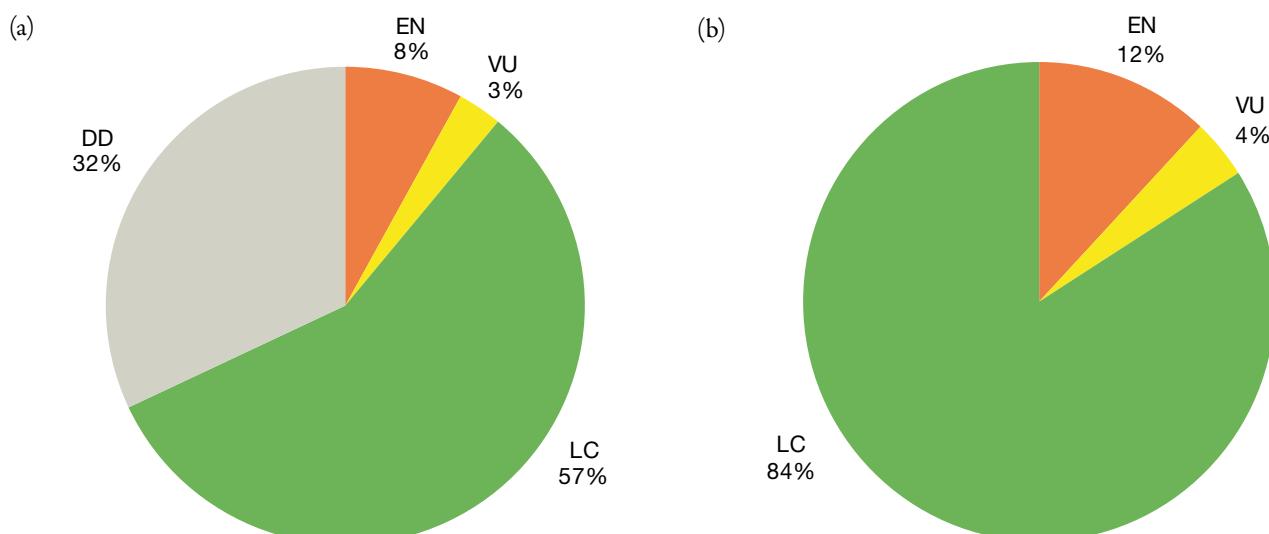
in rivers, marshy lowlands, or mountain streams in the forested parts of the region (Cumberlidge 1999; Cumberlidge *et al.* 2009). Four (16%) of the 26 assessed species were listed in a threatened category either as VU (*P. sachsi*) or EN (*L. balssi*, *L. edeaensis* and *P. gonocristatus*) (Figure 6.1b and Table 6.2). The main threats to these species were identified as agricultural development and its associated aquatic habitat degradation and pollution (Table 6.1). The low proportion of species in a threatened category (16%) could well prove to be an underestimate if any of the DD species are later found to be threatened (Cumberlidge *et al.* 2009). No species of freshwater crabs from central Africa could be confirmed Extinct or Extinct in the Wild. The majority of the DD species are from the DRC (*E. vandenbrandeni*, *P. acristatus*, *P. adeleae*, *P. adentatus*, *P. lueboensis*, *P. punctatus*, *P. schubotzi* and *P. semilunaris*) and it is of great concern that most of these have not been found in recent years. However, a species cannot be formally assessed as threatened (or even as Extinct) until exhaustive surveys probing its disappearance have been carried out.

Table 6.2 The number of crab species in each regional Red List Category in the central African region.

	Regional Red List Category	Number of Species	Number of Regional Endemics
Threatened Categories	Critically Endangered	0	0
	Endangered	3	2
	Vulnerable	1	0
	Near Threatened	0	0
	Least Concern	22	16
	Data Deficient	12	12
Total		38	30

Note: All species assessed as regionally threatened that are endemic to the region are also globally threatened (from Cumberlidge *et al.* 2009).

Figure 6.1 The proportion (%) of freshwater crab species in each regional IUCN Red List Category in central Africa (Cumberlidge *et al.* 2009). (a) All 38 species from the region, (b) the 26 non-DD species from the region that were assessed. IUCN Red List Categories: EN – Endangered, VU – Vulnerable, LC – Least Concern, DD – Data Deficient.



6.2.1 Species assessed as Endangered

Louisea balssi Balss's Crab (EN B1ab(i,ii,iii,iv,v))

This small and difficult to identify species is known only from just four specimens that were most recently collected over 100 years ago from two localities in forested streams in the Bamenda Highlands of south-west Cameroon in the **Northern Gulf of Guinea Drainage-Bioko** ecoregion. The original specimens have been given different taxonomic names over the years and *L. balssi* is the latest arrangement (Cumberlidge 1994, 1999). There have been several zoological expeditions to this area of Cameroon since 1909, but these have not focused on collecting this species and no new specimens have been found to date. *Louisea balssi* was assessed as EN because it is only known from two localities, has a likely extent of occurrence of less than 5,000 km², and its area of occupancy, habitat, and the number of individuals may be in decline given that it has not been seen for over a century (and could even prove to be Extinct) (Cumberlidge 2008b). In addition, threats to its rainforest habitat are ongoing due to human population increases, deforestation, and increased agriculture in Cameroon. No conservation measures are in place for this species and it is not found in a protected area (Cumberlidge *et al.* 2009).

Louisea edeaensis Edea crab (EN B1ab(i,ii,iii,iv,v))

This small species is known only from just three specimens most recently collected a hundred years ago from forested streams in two localities (Edea and Yabassi) in south-west Cameroon (in the **Northern Gulf of Guinea Drainage-Bioko**, and the **Southern Gulf of Guinea Drainage** ecoregions). This taxon was formally described almost 60 years after it was collected

as *Globonautes macropus edeaensis* (Bott 1969), and later as *L. edeaensis* by Cumberlidge (1999). There have been several zoological expeditions to this area of Cameroon since 1910, but these have not focussed on collecting this species. *Louisea edeaensis* was assessed as EN because it is only known from two localities, has a likely extent of occurrence of less than 5,000 km², and its extent of occurrence, area of occupancy, habitat, and number of individuals may be in decline given that it has not been seen in 100 years (and could even prove to be Extinct) (Cumberlidge 2008c). Threats to its rainforest habitat are ongoing due to human population increases, deforestation, and increased agriculture in Cameroon, and it is not found in a protected area (Cumberlidge *et al.* 2009).

Potamonautes gonocristatus (EN B1ab(i,ii,iii,v))

Bott (1955) originally described this taxon as the subspecies *Potamonautes (Lobopotamonautes) perparvus gonocristatus*, but Cumberlidge (2009c) later recognised this taxon as the valid species, *Potamonautes gonocristatus*. This species was assessed as EN because of its restricted extent of occurrence and because all individuals are found in just five localities, all at altitudes between 1,000 and 2,200 m above sea level in the highlands of eastern DRC, and its range, although restricted, does extend into the East African region (Cumberlidge 2008d). The lack of recent new material from anywhere in its range for over 30 years and its poor representation in museum collections implies a low population size. Threats to its rainforest habitat are ongoing due to human population increases, deforestation, increased agriculture, and political instability in the eastern DRC. No conservation measures are in place for this species and it is not found in a protected area (Cumberlidge *et al.* 2009).

Sand extraction from the Sanaga River, Cameroon. Photo: © Kevin Smith.



6.2.2 Species assessed as Vulnerable

Potamonemussachsi, Sachs's Stream crab (VUB1ab(iii)+2ab(iii))
Potamonemus sachsi is found in the Bamenda highlands in southwest Cameroon, and its range, although restricted, does extend into the western African region in the neighbouring Obudu plateau in south-east Nigeria (Cumberlidge 1999). The climate of these highland areas is cool and humid, and supports a tropical montane vegetation, including extensive grasslands drained by streams and rivers that flow south into the Gulf of Guinea. These crabs live under boulders in stretches of streams shaded by overhanging vegetation and forest canopy. The estimated extent of occurrence is less than 20,000 km² and the estimated area of occupancy is less than 2,000 km² due to its restriction to the wetland habitats within its range, and because it is known from fewer than 10 localities (Cumberlidge 2008e). Threats to this species include a decline in the extent and quality of its stream habitat from deforestation associated with farming and human population increases. No conservation measures are in place for this species and it is not found in a protected area (Cumberlidge *et al.* 2009).

6.2.3 Species assessed as Least Concern

Twenty-two species of central African freshwater crabs in four genera were assessed by Cumberlidge *et al.* (2009) as LC. These species are: *E. brazzae*, *P. ballayi*, *P. bayonianus*, *P. congoensis*, *P. dybowskii*, *P. langi*, *P. lirrangensis*, *P. loashiensis*, *P. minor*, *P. paecilei*, *P. perparvus*, *P. principe*, *P. margaritarius*, *P. stanleyensis*, *P. walderi*, *Potamonemus mambiliorum*, *S. africanus*, *S. aubryi*, *S. chavanesii*, *S. faradjensis*, *S. floweri*, and *S. granulatus*. Central Africa is home to 23 out of the more than 70 species of *Potamonautes* that are found throughout Africa, and 14 of the central African species of this genus are LC, eight are DD, and one (*P. gonocristatus*) is EN. Two of these LC species, *P. margaritarius* and *P. principe*, are found on the Gulf of Guinea islands of Sao Tome and Principe respectively, where both are island endemics (Cumberlidge *et al.* 2002; Cumberlidge 2008a). Six of the eight species of *Sudanonautes* found in central Africa are widespread throughout the region, while the other two species, *S. orthostylis* and *S. sangha*, each have a restricted distribution. Only one of the three species of *Potamonemus* (*P. mambiliorum*) (Cumberlidge and Clark 1992) was assessed as LC, while the other two species, *P. sachsi* and *S. asylos*, are less well known, more restricted in their distribution, and were assessed as VU and DD respectively. One of the two species of *Erimetopus* (*E. brazzae*) was assessed as LC, while the other species in this genus, *E. vandenbrandeni*, is less well known, more restricted in its distribution, and assessed as DD (Cumberlidge *et al.* 2009).

6.2.4 Species assessed as Data Deficient

Twelve central African species of freshwater crabs belonging to four genera were assessed by Cumberlidge *et al.* (2009) as DD: *E. vandenbrandeni*, *P. acristatus*, *P. adeleae*, *P. adentatus*, *P. lueboensis*, *P. punctatus*, *P. regnieri*, *P. schubotzi*, *P. semilunaris*, *Potamonemus asylos*, *S. orthostylis*, and *S. sangha*. These species

were listed as DD in view of the absence of recent information on their extent of occurrence, habitat, ecological requirements, population size, population trends, and long-term threats. It is of great concern that many of these species are known only from a few individuals collected many years ago, and that no new specimens have been found recently.

6.3 Patterns of species richness

Central Africa has a rich, highly diverse, and distinctly recognisable freshwater crab fauna where 30/38 species (79%) are found exclusively in central Africa from Cameroon to the DRC (Table 6.1), and only eight species (*S. africanus*, *S. aubryi*, *S. floweri*, *S. granulatus*, *P. gonocristatus*, *P. lirrangensis*, *P. bayonianus*, and *Potamonemus sachsi*) occur outside of the region (Cumberlidge 1999). The distributional range of the four species of *Sudanonautes* that extend outside the region includes either western or eastern Africa, while that of *P. lirrangensis* extends into eastern Africa as far south as Malawi, and that of *P. bayonianus* into southern Africa (Table 6.1; Cumberlidge and Daniels 2008). The taxonomic diversity of the central African region at the genus level (five genera, 36 species, one subfamily) is higher than that of southern Africa (one genus 19 species, one subfamily), northern Africa (two genera, three species, two families), eastern Africa (three genera, 35 species, two subfamilies) but lower than that of western Africa (six genera, 33 species, two subfamilies) and Madagascar (seven genera, 15 species, one subfamily). Species diversity within the central African region depends on vegetation cover and altitude, with the highest number of species occurring in rainforest ecosystems, especially in highland areas. The ecoregions with the lowest species richness (all in a single genus, *Potamonautes*) are found in the vast region to the south of the Congo River where there is either one species (**Congo Rapids, Bangweulu, Mai N'Dombe, Malebo Pool**), two species (**Tumba**), or three species (**Upper Lualuba**).

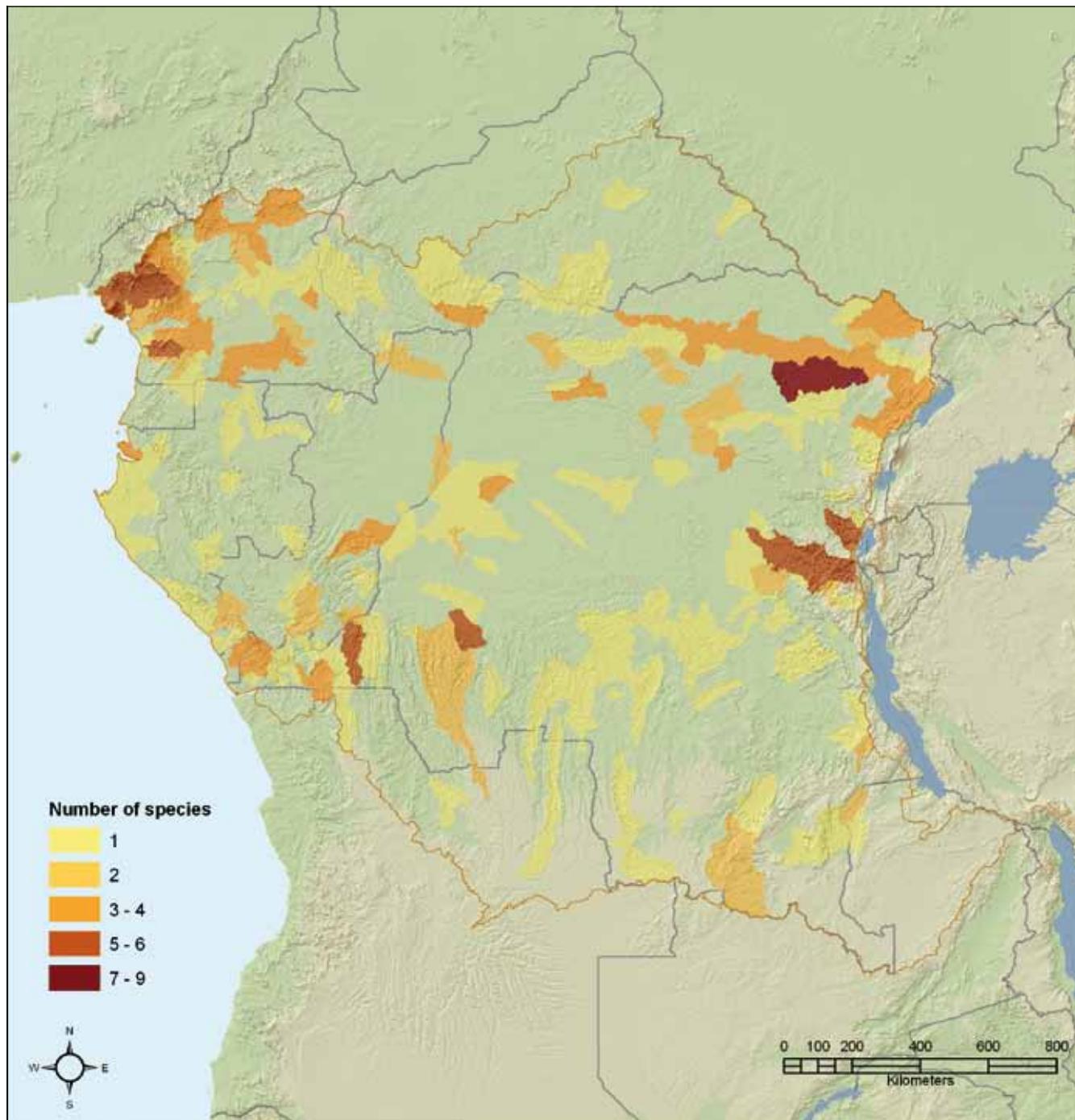
6.3.1 All freshwater crab species

The composition of the freshwater crab fauna in the tropical rainforests of central Africa is not uniform and changes from the Atlantic Coast in the west across to the Rift Valley in the east. The distribution patterns reveal two major subdivisions. Each of these subdivisions supports a distinct group of freshwater crab species (Figure 6.2). These subdivisions are: (1) the northern coastal part of the central African region north of the Congo River (that includes Cameroon, Gabon, Congo, Central African Republic, Cabinda, and parts of the northern DRC) which is dominated by *Sudanonautes*, and is most diverse in Cameroon (where *Louisea* and two species of *Potamonemus* are endemic); and (2) the southern part of the region that comprises the majority of the Congo River Basin south of the river (that includes the DRC, plus northern Zambia, and northern Angola) that is dominated by species of *Potamonautes* and is most diverse in the **Cuvette Centrale** ecoregion of central Congo (where *Erimetopus* is endemic).

Distribution patterns considered at the genus level indicate that three out of the five central African freshwater crab genera have relatively restricted ranges and two of these are endemic to the region. For example, *Louisea* is found only in south-west Cameroon, and *Erimetopus* is found only in the DRC from Malebo Pool to the Lower Congo rapids. In contrast, two freshwater crab genera (*Potamonautes* and *Sudanonautes*) include species that are endemic to central Africa. Twenty out of the 22 central African species of *Potamonautes* are endemic to the region (*P. acristatus*, *P. adeleae*, *P. adentatus*, *P. ballayi*, *P. congoensis*, *P. dybowskii*, *P. langi*, *P. loashiensis*, *P. lueboensis*, *P. margaritarius*, *P. minor*, *P. paecilei*, *P. perparvus*, *P. principe*, *P. punctatus*, *P. regnieri*, *P. schubotzi*, *P. semilunaris*, *P. stanleyensis*, and *P. walderi*), and most of these have a relatively restricted distributional range, while *P. lirrangensis*

extends into eastern Africa, and *P. bayonianus* is also found in southern Africa (Cumberlidge and Daniels 2008). Similarly, four species of *Sudanonautes* (*S. faradjensis*, *S. chavanesii*, *S. orthostylis*, and *S. sangha*) have a relatively restricted distributional range, while *S. africanus*, *S. aubryi*, *S. floweri*, and *S. granulatus* each have a wider distribution extending well outside of the region. Interestingly, there are no species of *Sudanonautes* found south of the Congo River, nor are there any species of this genus in northern Zambia, northern Angola, Principe, or Sao Tome (although there are two species on Bioko) (Cumberlidge 2008a). In conclusion, the distributional data indicate that there is a high degree of endemism in central Africa's freshwater crab fauna both at the species level (79%) and the genus level (40%), but this is not the case at the family level where all taxa belong to the Potamonautesidae (Cumberlidge *et al.* 2008).

Figure 6.2 Freshwater crab species richness in central Africa, mapped to river sub-catchments.



Finally, at the species level, the DRC hosts the most species (24 out of 38, 63%) and most of these are endemic to the region. Cameroon is the second most speciose country in the central African region (with 12 out of 38 species, 32%) and a rate of endemism of 33%.

Cameroon is probably the most thoroughly surveyed country in the region, which no doubt accounts for the recent increase in species descriptions and new distribution records there, while the freshwater crab faunas of the other central African countries have only been lightly sampled by comparison. Nevertheless, three areas in central Africa stand out as freshwater crab 'biodiversity hotspots'; that is, areas with a high number of crab genera and species, most of which are endemic and have a very restricted range (Cumberlidge and Clark 1992; Cumberlidge 1993, 1994, 1999). These areas of species richness are in the Lower Guinea rainforests of south-west Cameroon and along the Congo River from Kinshasa to Kisangani in eastern DRC (Figure 6.2). Conversely, the areas of central Africa with the lowest species richness lie in the southern DRC south of the Congo River. This general pattern of species-rich faunas in the rainforests of Lower Guinea and central and eastern Congo, and low species richness in the Congo basin south of the river is probably real, rather than an artefact resulting from a lack of knowledge. The low species richness in the southern DRC is unexpected and hard to explain. This pattern may be attributable to periods of past drier

climates that led to the loss of the forest and to its replacement by savannah or desert in this part of Africa. Nevertheless, it is likely that at least some of this paucity may be due to under-sampling. Further exploration is needed throughout central Africa where it is probable that the species count for the freshwater crab fauna of the region will increase substantially as taxonomic discrimination improves and collection efforts intensify.

6.3.2 Threatened species

Four species of freshwater crabs have been assessed as belonging to one of the threatened categories (Cumberlidge *et al.* 2009). Two EN species and one VU species are from the highlands of Cameroon, notably the rainforests around Bamenda and the lowland forests of south-western Cameroon, while one of the EN species is from the highland rainforests of the eastern DRC (Figure 6.3).

6.3.3 Restricted range species

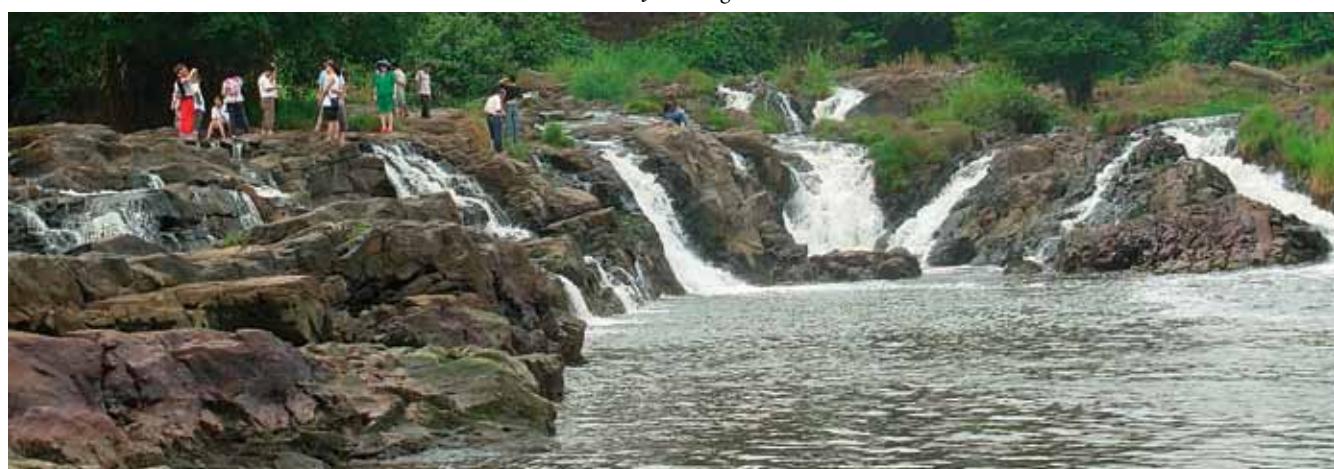
Species with restricted ranges are irregularly distributed in the region. Excluding DD species, seven species of freshwater crab from central Africa have a restricted range (less than 20,000 km²), and three of these are found in the Gulf of Guinea drainage, two are from the Gulf of Guinea islands, one occurs in the central Congo basin, and one in the forested highlands of the eastern DRC (Table 6.3). There is reason to believe that the

Table 6.3 Species of freshwater crabs of central Africa restricted to single river basins, excluding those considered to be Data Deficient.

Species	RL Category	Range (km ²)	# Loc	PA	Zone
<i>Potamonemus sachsi</i>	VU	< 20,000	<10	N	GG
<i>Erimetopus brazzae</i>	LC	< 20,000	<10	N	CC
<i>Louisea balssi</i>	EN	< 5,000	3	N	GG
<i>Louisea edeaensis</i>	EN	< 5,000	2	N	GG
<i>Potamonautes gonocristatus</i>	EN	< 5,000	<10	N	EC
<i>Potamonautes margaritarius</i>	LC	< 800	<5	N	GGI
<i>Potamonautes principe</i>	LC	< 120	<5	N	GGI

RL = IUCN Red List Category: EN – Endangered, VU – Vulnerable, LC – Least Concern; Range = estimation of species distribution range based on distribution polygon of all known specimens; #Loc = Number of discontinuous localities from which the species was collected; PA = found in a protected area; Y – yes, N – no; Forest Zone codes: GG – Gulf of Guinea forests, GGI – Gulf of Guinea islands, CC – Central Congo forests, EC – Eastern Congo forests.

Tourists on a visit to the Lobe waterfalls, Kribi, Cameroon. Photo: © J.P. Ghogue.



limited distributions of these seven species are not just the result of a lack of knowledge or under collection, because these species have not shown up in other localities where they may be expected to occur during survey work in central Africa over the years. Any disruption of the forested habitats of these species (either from development or political unrest) could potentially impact them because four of these restricted range species are assessed as threatened (Table 6.1). Any species with a restricted range is potentially vulnerable to extreme population fragmentation and could suffer a rapid decline and even extinction in a relatively short time should dramatic changes in land-use suddenly affect its habitat. It is therefore of immediate concern that seven (27%) of the region's 26 crab species that could be assessed are known from

distribution ranges of less than 20,000 km² (and some of these have an estimated range of 5,000 km² or less, Table 6.3). Despite the danger of population fragmentation the current population levels of stenotopic species assessed as LC were estimated to be stable because they have been collected recently and because there are no identifiable immediate threats that would impact the health of those streams and endanger their long-term existence. The reasons for the restricted ranges of the stenotopic species are largely unknown, but it is thought to be more likely that they have speciated relatively recently in response to isolation in a specialised (marginal) habitat or island colonization, rather than their being the remnant populations of formerly widespread species now in decline (Cumberlidge 2008a).

Figure 6.3 Threatened freshwater crab species richness in central Africa, mapped to river sub-catchments.



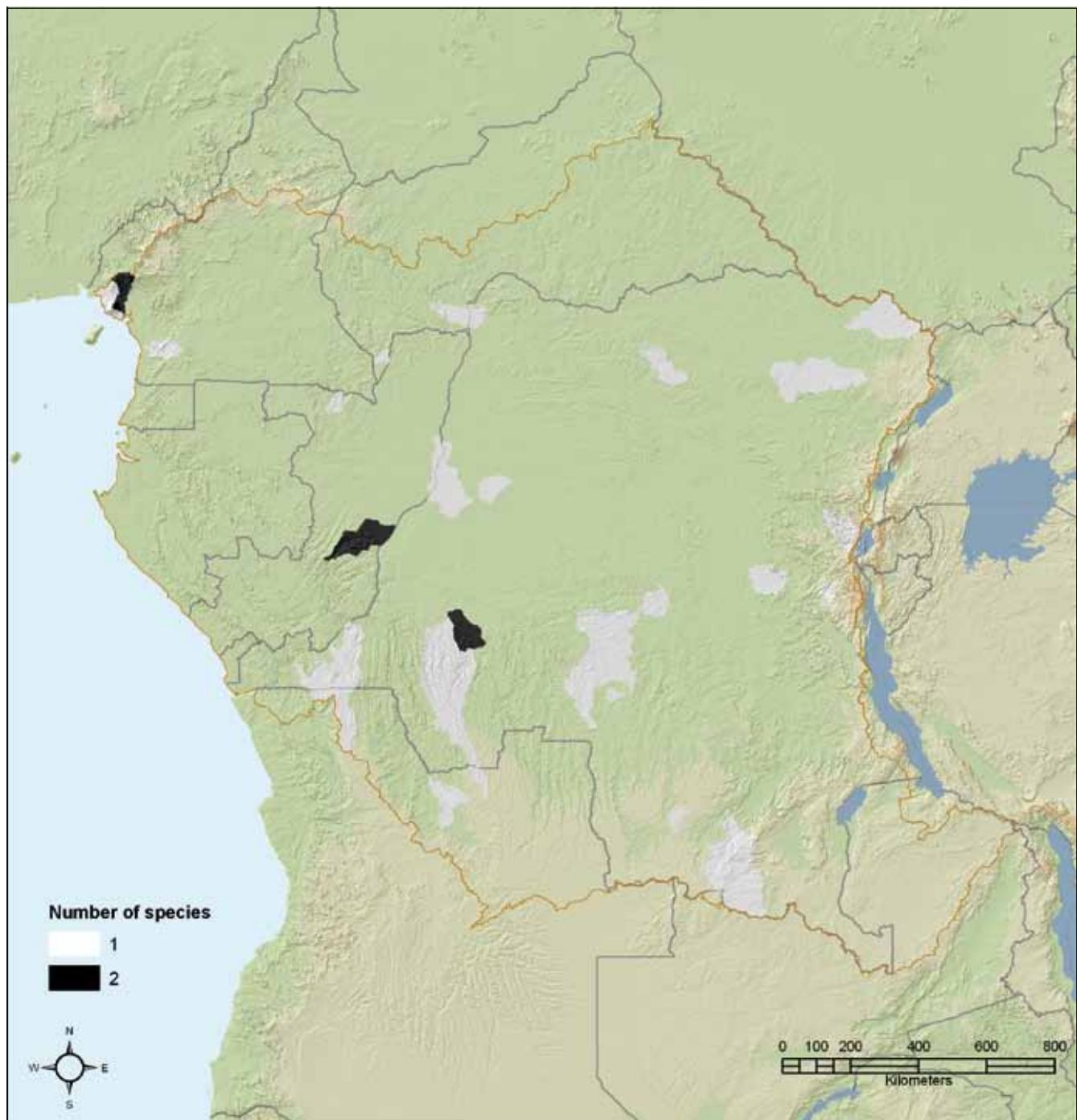
Extension work on the Edea hydro-electric dam. Photo: © J.P. Ghogue



6.3.4 Data Deficient species

The 12 DD species of freshwater crabs from the central African region belong to four genera and are from all parts of the region (Figure 6.4; Cumberlidge *et al.* 2009). Seven of these species (*E. vandenbrandeni*, *P. acristatus*, *P. adeleae*, *P. adentatus*, *P. lueboensis*, *P. punctatus*, and *P. schubotzi*) are from the Congo River in the DRC (Bott 1955; Cumberlidge and Tavares 2006), one is from the eastern DRC (*P. semilunaris*), and four (*P. regnieri*, *P. asylos*, *S. orthostylis*, and *S. sangha*) are from outside of the Congo basin in southern Cameroon, Gabon, and Congo. The DD status is due to insufficient information either on their taxonomic distinction (*E. vandenbrandeni*), or because they are known from either only one or only a few localities (*P. regnieri*, *P. schubotzi*,

Figure 6.4 Distribution of data deficient freshwater crab species, mapped to river sub-catchments.



S. orthostylis and *S. sangha*). It is possible that in some cases the DD status may be due to under-sampling. Further research is needed on all of these species that may prove to be restricted range endemics that are vulnerable to habitat loss.

6.4 Major threats to freshwater crabs

The main threats to the freshwater crabs of central Africa are habitat loss due to deforestation resulting from human population and agricultural expansion (Figure 6.5).

6.4.1 Natural predators

Freshwater crabs are among the most important invertebrates inhabiting central African fresh waters and these large and conspicuous crustaceans are present in almost all freshwater habitats from mountain streams to large lowland rivers and smaller water bodies (Rathbun 1921; Bals 1936; Bott 1955; Cumberlidge 1999). Freshwater crabs are important members of freshwater communities in the aquatic ecosystems because these crustaceans form an integral part of the food chain in these river systems. For example, crabs are the largest macro-invertebrates in African aquatic ecosystems and are vital components of the diet of a number of predators. For example, freshwater crabs are eaten by yellow-necked otters, water mongooses, African civets, kites, egrets, herons, giant kingfishers, monitor lizards, and crocodiles. It is vital to the health of these ecosystems that fishery managers consider measures that specifically include the conservation and sustainable use of local populations of river crabs.

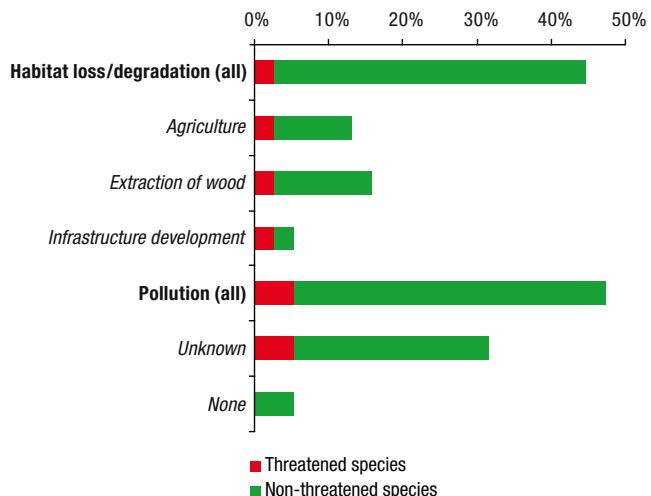


Figure 6.5 Threats to freshwater crab species in central Africa.

6.4.2 Pollution

Pollutants from mining activities for diamonds, gold, and coltan (a mineral used in creating capacitors) in eastern DRC and from organic wastes from leaking sewage systems in urban areas in central Africa can accumulate in rivers and other freshwater bodies. These pollutants impact freshwater crab populations because these crustaceans are benthic feeders that ingest other invertebrates and detritus that may contain high levels of contaminants. Immediate attention should be given to the improvement of the water quality in these areas not least because the bioaccumulation of metals in crabs could pose an increasing problem for the health of people that may eat them.

An abandoned factory in Mfouati (Republic of the Congo), where waste was pumped straight into the river. Photo: © Victor Mamonokene.



6.4.3 Threats to the forests of the Congo and Gulf of Guinea drainage

Threats to the endemic species of the forests of the Congo and Gulf of Guinea drainage include habitat destruction in the form of deforestation driven by timber extraction, increasing agriculture, the demands of increasing industrial development, the alteration of fast flowing rivers for the creation of hydroelectric power, and the drainage of wetlands for farming and other uses (Figure 6.5). Destruction of the equatorial forests of central Africa is further exacerbated by deep forest access made possible by logging roads. Other threats that result in deforestation and habitat destruction include political unrest and refugees. The impact of refugees on an area can include deforestation and soil erosion that contributes environmental damage to freshwater ecosystems. Potential future threats to aquatic communities in rivers associated with cities and towns in central Africa include pollution by sewage and industrial and general waste. Some agricultural pesticides used by farmers may prove to be lethal to freshwater crabs but more research needs to be carried out. All of the above combine to increase the overall level of threat to range-restricted endemic species of freshwater crabs, and the careful management of central Africa's forests and water resources in the future will have the biggest impact on their long-term survival.

Fires on hillsides near Inga, lower section of Congo river, Democratic Republic of Congo. Fires are deliberately set to clear vegetation so it is easier to hunt small mammals, and so that the land can be planted for agriculture (e.g., cassava maize) Photo: © Robert Schelly.



6.4.4 Taxonomic issues

The evolving taxonomy of freshwater crabs may prove to be a challenge for conservation planning in the future because although a lot of progress has been made recently, some taxa that are currently assumed to be widespread and common may prove to be complexes of several distinct cryptic taxa, each with specific ecologies and distributions requiring direct conservation action. Two such possibilities are *P. lirrangensis* and *S. granulatus* that are both currently assessed as LC primarily on account of their wide distributional ranges. However the distribution patterns of both species consist of many relatively isolated subpopulations that show a great deal of morphological variation, and further investigations may show *S. granulatus* and *P. lirrangensis* to be species complexes, as is probably the case for *P. perlatus* in South Africa (Daniels *et al.* 2002).

6.5 Conservation recommendations

The biology and distribution patterns of the freshwater crabs of central Africa are becoming better known as are the potential threats to their long-term survival. With four (15%) species of the 26 non-DD species of freshwater crabs from central Africa

Table 6.4 Number of species, genera, and ecoregions in each central African country, with the forest zone marked. C – Congo basin forest, GG – Gulf of Guinea drainage forest, GI – Gulf of Guinea islands.

Country	No. Species / No. Genera per Country	No. Ecoregions per Country	Forest Zone
DRC	24 / 3	15	C
Cameroon	13 / 4	5	GG
Congo	11 / 3	2	GG/C
Gabon	8 / 2	2	GG
Central African Republic	4 / 2	1	GG/C
Equatorial Guinea/Bioko	3 / 1	1	GI
Sao Tome, Principe	2 / 1	1	GI
Angola (Cabinda)	1 / 1	1	GG
Zambia	1 / 1	1	C
Angola	1 / 1	12	C

currently assessed as being at risk of global extinction, the region's largely endemic freshwater crab fauna appears to be a concern. Nevertheless, it is hoped that conservation recovery plans for threatened species will be developed for those species identified to be in need of conservation action through the Red List assessment process (Cumberlidge *et al.* 2009; Collen *et al.* 2009).

The conservation of many species of freshwater crabs depends primarily on the preservation of areas of natural habitat large enough to maintain water quality. Although it is not yet known exactly how sensitive African freshwater crabs are to polluted or silted waters, there is evidence from Asia that similar crabs are not likely to survive when exposed to these factors (Ng and Yeo 2007). Development, agriculture and exploitation of natural products are necessary realities in developing economies, but compromises may have to be made if freshwater crab species are not to be extirpated in the future. Judicious and careful use of resources is unlikely to cause species extinctions as long as water drainages are not heavily polluted or redirected, that some forest and vegetation cover is maintained, and protected areas are respected (Cumberlidge *et al.* 2009).

Common species of central African freshwater crabs assessed as LC have a wide distribution in the rivers, wetlands, and mountain streams of the region and so far have proved to be relatively tolerant of changes in land-use affecting aquatic ecosystems. It is encouraging that these more adaptable species in lowland rivers and streams that are already disturbed and visibly polluted in parts. Loss of natural vegetation and pollution as a result of land development and agriculture is, however, likely to affect the lowland rivers, and many of the wholly aquatic species that live there could be vulnerable. Even species assessed as LC could suffer catastrophic declines should there be abrupt changes in land development, hydrology, or pesticide-use regimes. It is not known how the highland taxa will cope with habitat disturbance and pollution, but considering their specialised habitat requirements it is likely that most of these species will not adapt as readily as the more widespread lowland species. In many countries with

a rapid pace of development, often only a fine line separates a species assessed as LC from one assessed as VU, or a VU species from one that is assessed as EN. Development projects could have a dramatic impact on species of freshwater crabs with specific habitat requirements and a restricted distribution. Conservation activities should therefore be aimed primarily at preserving the integrity of sites and habitats while at the same time closely monitoring key freshwater crab populations.

The 12 species of freshwater crabs from central Africa that were judged to be DD are primarily the result of insufficient field surveys. The scarcity of available specimens is in a large part due to the long-term poor security situation in parts of the DRC, and little is known of the habitat needs, population trends, or threats to these species. For example, *E. vandenbrandeni* came to light only recently during examination of unidentified museum specimens. When more information has been gathered, all 12 DD species will probably prove to have a relatively restricted distribution and will likely prove to be endemic to the river basin where they are found.

The conservation assessment of freshwater crabs in central Africa represents a first step toward the identification of threatened species within the region and toward the development of a conservation strategy for endemic species. The restricted range of many species of freshwater crabs from central Africa, together with the on-going human-induced loss of habitat in many parts of the region are primary causes for concern for the long-term survival of this fauna. Central Africa's freshwater crabs have a high degree of endemism with many species living in specialised habitats such as river rapids, lowland marshes, forested highlands, and islands. Additional research is recommended to determine the minimum effective size and design of protected areas for freshwater species such as crabs.

Significant areas of this vast region still remain insufficiently explored and new species of freshwater crabs are sure to be discovered as collection efforts in the remote areas intensify and taxonomic

skills become more refined. Although taxonomic knowledge has advanced considerably recently, and museum collections of freshwater crabs have improved, a great deal of work still needs to be done. There is a need for further surveys to discover new species, refine species distributions, define specific habitat requirements, describe population levels and trends, and identify specific threats to central Africa's important and unique freshwater crab fauna.

6.6 References

- Abell, R., Thieme, M.L., Revenga, C., Bryer, M., Kottelat, M., Bogutskaya, N., Coad, B., Mandrak, N., Balderas, S.C., Bussing, W., Stiassny, M.L.J., Skelton, P., Allen, G.R., Unmack, P., Naseka, A., Ng, R., Sindorf, N., Robertson, J., Armijo, E., Higgins, J.V., Heibel, T.J., Wikramanayake, E., Olson, D., López, H.L., Reis, R.E., Lundberg, J.G., Pérez, M.H.S. and Petry, P. 2008. Freshwater Ecoregions of the World: A New Map of Biogeographic Units for Freshwater Biodiversity Conservation. *BioScience* **58**(5):403–414.
- Balss, H. 1936. Beiträge zur Kenntnis der Potamonidae (Süßwasserkrabben) des Kongobietes. *Revue de Zoologie et de Botanique Africaines* **28**(2):165–204.
- Bott, R. 1955. Die Süßwasserkrabben von Afrika (Crust., Decap.) und ihre Stammesgeschichte. *Annales du Musée du Congo belge, (Tervuren, Belgique,) C-Zoologie* **3**,**3**(1):209–352.
- Bott, R. 1959. Potamoniden aus West-Afrika (Crust., Dec.). *Bulletin de l'Institut français d'Afrique noire* **21**, série A(3):994–1008.
- Bott, R. 1969. Präadaptation, Evolution und Besiedlungsgeschichte der Süßwasserkrabben der Erde. *Natur und Museum* **99**: 266–275.
- Bott, R. 1970. Betrachtungen über die Entwicklungsgeschichte und Verbreitung der Süßwasser-Krabben nach der Sammlung des Naturhistorischen Museums in Genf/Schweiz. *Revue suisse de Zoologie* **77**(2):327–344.
- Collen, B., Ram, M., Dewhurst, N., Clausnitzer, V., Kalkman, V., Cumberlidge, N. and Baillie, J.E.M. 2008. Broadening the coverage of biodiversity assessments. In: J.-C. Vié, C. Hilton-Taylor and S.N. Stuart (eds.) *The 2008 Review of The IUCN Red List of Threatened Species*. IUCN Gland, Switzerland.
- Corace, R.G., Cumberlidge, N. and Garms, R. 2001. A new species of freshwater crab from Rukwanzi, East Africa. *Proceedings of the Biological Society of Washington* **114**:178–187.
- Cumberlidge, N. 1993. Two new species of *Potamonemus* Cumberlidge and Clark, 1992, (Brachyura, Potamoidea, Potamonautesidae) from the rain forests of West Africa. *Journal of Crustacean Biology* **13**(3):571–584.
- Cumberlidge, N. 1994. *Louisea*, a new genus of fresh-water crab (Brachyura, Potamoidea, Potamonautesidae) *Globonautes macropus edeaensis* Bott, 1969 from Cameroon. *Proceedings of the Biological Society of Washington* **107**(1):122–131.
- Cumberlidge, N. 1997. The African and Madagascan freshwater crabs in the Museum of Natural History, Vienna (Crustacea: Decapoda: Brachyura: Potamoidea). *Annalen des Naturhistorischen Museums in Wien* **99B**:571–589.
- Cumberlidge, N. 1998. The African and Madagascan freshwater crabs in the Zoologische Staatssammlung, Munich (Crustacea: Decapoda: Brachyura: Potamoidea). *Spixiana* **21**(3): 193–214.
- Cumberlidge, N. 1999. *The freshwater crabs of West Africa. Family Potamonautesidae*. Faune et Flore Tropicales 35, Institut de recherche pour le développement (IRD, ex-ORSTOM), Paris, 1–382.
- Cumberlidge, N. 2008a. Insular species of Afrotropical freshwater crabs (Crustacea: Decapoda: Brachyura: Potamonautesidae and Potamidae) with special reference to Madagascar and the Seychelles. *Contributions to Zoology* **77**(2):71–81.
- Cumberlidge, N. 2008b. *Louisea balssi*. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. <www.iucnredlist.org>. Downloaded on 12 February 2010.
- Cumberlidge, N. 2008c. *Louisea edeaensis*. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. <www.iucnredlist.org>. Downloaded on 12 February 2010.
- Cumberlidge, N. 2008d. *Potamonautes gonocristatus*. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. <www.iucnredlist.org>. Downloaded on 12 February 2010.
- Cumberlidge, N. 2008e. *Potamonemus sachsi*. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. <www.iucnredlist.org>. Downloaded on 12 February 2010.
- Cumberlidge, N. 2009a. Chapter 27, Freshwater Crabs and Shrimps (Crustacea: Decapoda) of the Nile Basin. In: H. J. DUMONT (ed.), *The Nile. Origin, environments, limnology and human use*. Monographiae Biologicae, **89**: 547–561. (Springer, New York).
- Cumberlidge, N. 2009b. A revision of the freshwater crabs of Mt Kenya and the Aberdare Mountains, Kenya, East Africa (Brachyura: Potamoidea: Potamonautesidae). *Zootaxa*, **1981**: 29–42.
- Cumberlidge, N. and Boyko, C.B. 2000. Freshwater crabs (Brachyura: Potamoidea: Potamonautesidae) from the rainforests of the Central African Republic. *Proceedings of the Biological Society of Washington* **3**(2), 406–419.
- Cumberlidge, N. and Clark, P.F. 1992. A new genus and species of freshwater crab from Cameroon, West Africa (Crustacea, Brachyura, Potamoidea, Potamonautesidae). *Bulletin of the British Museum of Natural History (Zoology)*, London **58**(2):149–156.
- Cumberlidge, N. and Daniels, S.R. 2008. A conservation assessment of the freshwater crabs of southern Africa (Brachyura: Potamonautesidae). *African Journal of Ecology* **46**:74–79.
- Cumberlidge, N. and Dobson, M. 2008. A new species of freshwater crab (Crustacea: Decapoda: Brachyura: Potamonautesidae) from western Kenya. *Proceedings of the Biological Society of Washington*, **121**(4):468–474.
- Cumberlidge, N. and Meyer, K.S. 2009. A new species of *Foza* Reed and Cumberlidge, 2006, from northern Madagascar (Decapoda, Brachyura, Potamoidea, Potamonautesidae), with a redescription of *F. goudotii* (H. Milne Edwards, 1853) comb. n., and comments on *Skelosophusa prolixa* Ng and Takeda, 1994. *ZooKeys* **18**:77–89.
- Cumberlidge, N. and Reed, S.K. 2004. *Erimetopus vandenbrandeni* (Balss, 1936) n. comb., with notes on the taxonomy of the

- genus *Erimetopus* Rathbun, 1894 (Brachyura: Potamoidea: Potamonautesidae) from Central Africa. *Zootaxa* **422**:1–27.
- Cumberlidge, N. and R. v. Sternberg. 2002. A taxonomic revision of the freshwater crabs of Madagascar (Decapoda: Potamoidea: Potamonautesidae). *Zoosystema* **24**(1):41–79.
- Cumberlidge, N. and Tavares, M. 2006. Remarks on the freshwater crabs of Angola, southcentral Africa, with the description of *Potamonautes kensleyi*, new species (Brachyura: Potamoidea: Potamonautesidae). *Journal of Crustacean Biology* **26**:248–257.
- Cumberlidge, N. and Vannini, M. 2004. Ecology and taxonomy of a tree living freshwater crab (Brachyura: Potamoidea: Potamonautesidae) from Kenya and Tanzania, East Africa. *Journal of Natural History* **38**:681–693.
- Cumberlidge, N., Clark, P.F. and Baillie, J. 2002. A new species of freshwater crab (Brachyura: Potamoidea: Potamonautesidae) from Príncipe, Gulf of Guinea, Central Africa. *Bulletin of the British Museum of Natural History (Zoology)*, London **68**(1):13–18.
- Cumberlidge, N., Daniels, S.R. and Sternberg, R.v. 2008. A revision of the higher taxonomy of the Afrotropical freshwater crabs (Decapoda: Brachyura) with a discussion of their biogeography. *Biological Journal of the Linnean Society* **93**:399–413.
- Cumberlidge, N., Marijnissen, S.A.E. and Thompson, J. 2007. *Hydrothelphusa vencesi*, a new species of freshwater crab (Brachyura: Potamoidea: Potamonautesidae) from southeastern Madagascar. *Zootaxa* **1524**: 61–68.
- Cumberlidge, N., Sternberg, R. v., Bills, I.R. and Martin, H.A. 1999. A revision of the genus *Platythelphusa* A. Milne-Edwards, 1887 from Lake Tanganyika, East Africa (Decapoda: Potamoidea: Platythelphusidae). *Journal of Natural History*, **33**:1487–1512.
- Cumberlidge, N., Ng, P.K.L., Yeo, D.C.J., Magalhaes, C., Campos, M.R., Alvarez, F., Naruse, T., Daniels, S.R., Esser, L.J., Attipoe, F.Y.K., Clotilde-Ba, F.-L., Darwall, W., McIvor, A., Ram, M. and Collen, B. 2009. Freshwater crabs and the biodiversity crisis: importance, threats, status, and conservation challenges. *Biological Conservation* **142**:1665–1673.
- Daniels, S.R., Stewart, B.A., Gouws, G., Cunningham, M. and Matthee, C.A. 2002. Phylogenetic relationships of the southern African freshwater crab fauna (Decapoda: Potamonautesidae: Potamonautes) derived from multiple data sets reveal biogeographic patterning. *Molecular Phylogenetics and Evolution* **25**:511–523.
- Daniels, S.R., Cumberlidge, N., Pérez-Losada, M., Marijnissen, S.A.E. and Crandall, K.A. 2006. Evolution of Afrotropical freshwater crab lineages obscured by morphological convergence. *Molecular Phylogenetics and Evolution* **40**:227–235.
- Darwall, W., Smith, K., Lowe, T. and Vié, J.-C. 2005. *The Status and Distribution of Freshwater Biodiversity in Eastern Africa*. IUCN SSC Freshwater Biodiversity Assessment Programme. IUCN, Gland, Switzerland and Cambridge, UK. viii + 36 pp.
- IUCN 2003. *Guidelines for Application of IUCN Red List Criteria at Regional Levels: Version 3.0*. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.
- Marijnissen, S., Schram, F., Cumberlidge, N. and Michel, E. 2004. Two new species of *Platythelphusa* A. Milne-Edwards, 1887 (Decapoda, Potamoidea, Platythelphusidae) and comments on the taxonomic position of *P. denticulata* Capart, 1952 from Lake Tanganyika, East Africa, *Crustaceana*, **77**(5):513–532.
- Ng, P.K.L. and Yeo, D.C.J. 2007. Malaysian freshwater crabs: conservation prospects and challenges. In: Chua, L. (ed.), *Proceedings of the Seminar on the Status of Biological Diversity in Malaysia and Threat Assessment of Plant Species in Malaysia*, 28–30 June 2005. *Forest Research Institute Malaysia, Kepong*, pp. 95–120.
- Ortmann, A. 1896. Das system der Decapoden-Krebse. *Zool. Jahrb. (Syst.)* **9**:409–453.
- Rathbun, M.J. 1921. Brachyuran Crabs of the Belgian Congo. *Bulletin of the American Museum of Natural History*, **43**: 379–474.
- Reed, S.K. and Cumberlidge, N. 2004. Notes on the taxonomy of *Potamonautes obesus* (A. Milne-Edwards, 1868) and *Potamonautes calcaratus* (Gordon, 1929) (Brachyura: Potamoidea: Potamonautesidae) from eastern and southern Africa. *Zootaxa* **1262**: 1–139.
- Reed, S.K. and Cumberlidge, N. 2006a. Taxonomy and biogeography of the freshwater crabs of Tanzania, East Africa (Brachyura: Potamoidea: Potamonautesidae, Platythelphusidae, Deckeniidae). *Zootaxa* **418**:1–137.
- Reed, S.K. and Cumberlidge, N. 2006b. Foza raimundi, a new genus and species of potamonautesid freshwater crab (Crustacea: Decapoda: Potamoidea) from northern Madagascar. *Proceedings of the Biological Society of Washington* **119**:58–66.
- Thieme, M.L., Abell, R.A., Stiassny, M.J.L., Skelton, P.A. and Lehner, B. 2005. *Freshwater ecoregions of Africa and Madagascar: A conservation assessment*. Island Press, Washington DC, USA.
- Yeo, D.C.J., Ng, P.K.L., Cumberlidge, N., Magalhães, C., Daniels, S.R. and Campos, M.R. 2008. Global diversity of crabs (Crustacea: Decapoda: Brachyura) in freshwater. *Hydrobiologia* **595**:275–286.

Chapter 7. The status and distribution of freshwater plants of central Africa

Ghogue, J.-P¹

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The Africa freshwater ecoregions were primarily based on fish distributional data (Thieme *et al.* 2005; Abell *et al.* 2008). Defined as conservation units (Dinerstein *et al.* 1995), these ecoregions can not be taken as indicative for plants, as fishes and aquatic plants' distribution and ecological requirements do not necessarily overlap. Boundaries of these ecoregions are clearly different from White's phytocoria for the region (White 1983). These are instead floristic regions based on richness of their endemic floras at a species level. For practical reasons, while dealing with ecoregions and to allow further discussions, we will relay on White's phytocoria instead of freshwater bioregions.

7.1 Phytogeographical delineation

The central Africa assessment region derived from the watershed-based Pan Africa Freshwater Biodiversity Assessment (Figure 1.1) includes all or part of eight countries and encompasses six phytocoria (Figure 7.1; White 1983; Linder 2005): The Guineo-Congolian regional centre of endemism (I), the Zambezian regional centre of endemism (II), the Sudanian regional centre of endemism (III), the Afromontane archipelago-like regional centre

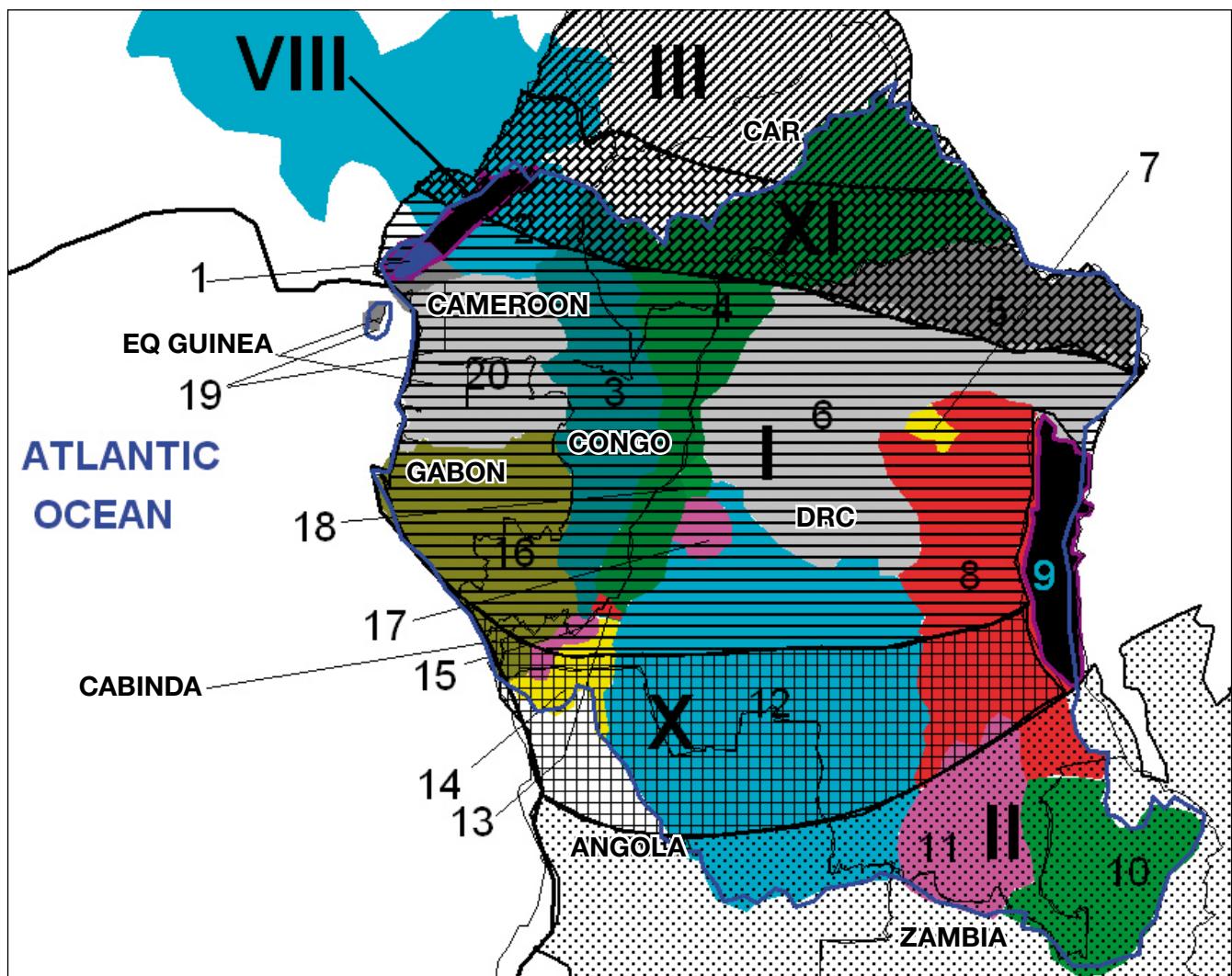
of endemism (VIII), the Guinea-Congolia/Zambezia regional transition zone (X) and the Guinea-Congolia/Sudania regional transition zone (XI). The region is mainly within the Congo basin although many rivers in the north, especially southern Cameroon (e.g., the Sanaga, Nyong, Ntem and Lokoundje Rivers) open directly to the Atlantic ocean, forming the "Atlantic basin" (Letouzey 1985).

7.2 Overview of the central African flora

As for many parts of the continent, no regional Flora exists to date for the whole of central Africa. The *Flore d'Afrique Centrale* (formerly *Flore du Congo et du Rwanda et du Burundi*) series includes the Democratic Republic of Congo (DRC), Rwanda and Burundi only. The *Flora Zambeziaca* includes Mozambique, Malawi, Zambia, Rhodesia and Botswana and therefore covers just a small area of north-east Zambia within the central Africa region. The remaining floras of the region are national such as *Flore du Cameroun*, *Flore du Gabon*, *Flora de Guinea Ecuatorial* and the *Conspectus florae Angolensis*. All the above mentioned series are family (systematic)-based and none of them is complete. Typical thematic floras are nearly absent. Despite the publication of many

¹ The National Herbarium of Cameroon, PO Box 1601, Yaoundé – Cameroon.

Figure 7.1 Map of the central African Freshwater Ecoregions (Thieme *et al.* 2005) and the contours of the African phytochoria (White 1983). Map: © J.P. Ghogue.



A. Phytochoria

- I. Guineo-Congolian regional centre of endemism
- II. Zambezian regional centre of endemism
- III. Sudanian regional centre of endemism
- VIII. Afromontane archipelago-like regional centre of endemism
- X. Guinea-Congolia/Zambezia regional transition zone
- XI. Guinea-Congolia/Sudania regional transition zone
- Countries border
- Contour of the Afromontane archipelago-like Regional Centre of Endemism
- Contour of the Central African freshwater assessment area

B. The Ecoregions

1. Western Equatorial Crater Lakes
2. Lower Niger – Benue
3. Sangha
4. Sudanic Congo – Oubangui
5. Uele
6. Cuvette Centrale
7. Upper Congo Rapids
8. Upper Congo
9. Albertine Highlands
10. Bangweulu – Mweru
11. Upper Lualaba
12. Kasai
13. Malebo Pool
14. Lower Congo
15. Lower Congo Rapids
16. Ogooué – Nyanga – Kouilou – Niari
17. Mai Ndombe
18. Tumba
19. Northern Gulf of Guinea Drainages – Bioko
20. Southern Gulf of Guinea Drainages

books (e.g. Chevalier 1913; Pellegrin 1924; Exell 1944; Silans 1958; Grandvaux Barbosa 1970; etc.), Checklists (Cheek 2004; Sosef *et al.* 2006; Onana *et al.* 2010) and many other publications, the current knowledge of the central African flora is still patchy.

Exclusively aquatic plants families are comparatively few. Most of the aquatic plants belong to families including also true terrestrial plants. Also, many aquatic plants can survive for a more or less long period on true terrestrial station.

This study was based on the definitions of aquatic plants established by Cook (1996, 2004) and we primarily based our investigation on a compiled list of aquatic plants families provided by the project. The 49 families included in our assessment are listed in Table 7.1.

7.2.1 The Guineo-Congolian regional centre of endemism

The Guineo-Congolian floristic region slightly extends into western Africa and is by far the most important in terms of wetlands species diversity, as it encloses more than half of the 20 freshwater ecoregions attributed to central Africa. There are about 8,000 vascular plant species in this phytogeographic region, of which more than 80% are endemic (White 1983).

Before deforestation became widespread, the greater part of this region was covered with rainforest and swamp forests (including riparian forests). The swamp forests are very different floristically, but are interconnected by a complex series of intermediates. Although occurring in the whole region, swamp forests are most extensively developed in the Zaire basin (White 1983).

Fifteen freshwater ecoregions are included in this phytogeographic region. They are:

Lower Niger – Benue: This ecoregion, made of tropical and subtropical floodplain rivers and wetland complexes, is mostly

represented in western Africa. In central Africa, it covers part of the Adamawa in Cameroon. Just to name a few, the true freshwater plants of this ecoregion are *Caldesia reniformis*, *Wiesneria schweinfurthii*, *Crinum natans*, *Aponogeton vallisnerioides*, *Dicraeanthus africanus*, *Ledermannella cristata*, *Ledermannella linearifolia*, *Ledermannella sanagaensis*, *Ledermannella thalloidea*, *Letestuella tisserantii*, *Macropodiella pellucida*, *Saxicolella laciniata* and *Tristicha trifaria*.

Sangha: Permanent swamps increasingly dominate the landscape in the central and southern portions of the ecoregion. Periodically inundated swamp forest, large expanses of dense evergreen and deciduous rainforest and savannahs characterize the terrestrial landscape of the ecoregion. Some freshwater plants species of this ecoregion are: *Hygrophila uliginosa*, *Aponogeton troupinii*, *Aponogeton vallisnerioides*, *Anubias heterophylla*, *Lasimorpha senegalensis*, *Pistia stratiotes*, *Eclipta prostrata*, *Nesaea crassicaulis*, *Nesaea radicans* and *Rotala serpiculoides*.

Sudanic Congo – Oubangi: Aquatic plants are rather poorly represented in this ecoregion. This might be due to the under collection effort in CAR and in the two Congos. The few aquatic plants in this ecoregion include *Ranalisma humile*, *Utricularia gibba*, *Utricularia inflexa*, *Nymphoides forbesiana*, *Letestuella tisserantii* and *Heteranthera callifolia*.

Cuvette Centrale: The vegetation of the ecoregion is primarily tropical rainforest. The following freshwater plants are found within this ecoregion: *Ranalisma humile*, *Crinum jagus*, *Grangea maderaspatana*, *Eclipta prostrata*, *Utricularia gibba*, *Utricularia foliosa*, *Utricularia inflexa*, *Utricularia gibba* and *Utricularia benjaminiiana*.

Upper Congo Rapids: The vegetation of this ecoregion consists of primarily high tropical rainforest. The following freshwater plants are found in this ecoregion: *Crinum natans*, *Adenostemma perrottetii*, *Eclipta prostrata*, *Enydra fluctuans*, *Eichhornia natans*, *Eichhornia crassipes* and *Potamogeton octandrus*.

Table 7.1 List of the 49 families of freshwater plants species assessed in central Africa.

1	ACANTHACEAE	14	CRASSULACEAE	27	JUNCAGINACEAE	40	POLYGONACEAE
2	ALISMATACEAE	15	CYPERACEAE	28	LABIATAE	41	PONTEDERIACEAE
3	AMARANTHACEAE	16	DROSERACEAE	29	LEMNACEAE	42	POTAMOGETONACEAE
4	AMARYLLIDACEAE	17	ELATINACEAE	30	LENTIBULARIACEAE	43	PRIMULACEAE
5	APONOGETONACEAE	18	ERIOCAULACEAE	31	LOMARIOPSISIDACEAE	44	RANUNCULACEAE
6	ARACEAE	19	EUPHORBIACEAE	32	LYTHRACEAE	45	SCROPHULARIACEAE
7	AZOLLACEAE	20	GRAMINEAE	33	MARSILEACEAE	46	THELYPTERIDACEAE
8	CABOMBACEAE	21	HAEMODORACEAE	34	MENYANTHACEAE	47	TYPHACEAE
9	CAMPANULACEAE	22	HALORAGACEAE	35	NAJADACEAE	48	UMBELLIFERAE
10	CANNACEAE	23	HYDROCHARITACEAE	36	NYMPHAEACEAE	49	XYRIDACEAE
11	COMMELINACEAE	24	HYDROPHYLACEAE	37	ONAGRACEAE		
12	COMPOSITAE	25	ISOATACEAE	38	PLANTAGINACEAE		
13	CONVOLVULACEAE	26	JUNCACEAE	39	PODOSTEMACEAE		

Upper Congo: Riverine forests and swamps border the slow-flowing reaches. The terrestrial landscape undergoes a transition from savannah in the south to high equatorial forest in the north. The following freshwater plants are found in this ecoregion: *Crinum jagus*, *Crinum natans*, *Nymphaea maculata*, *Nymphaea nouchali*, *Eichhornia crassipes*, *Eichhornia natans*, *Heteranthera callifolia* and *Dopatrium macranthum*.

Kasai: With the exception of swamp forests in the lowermost river reaches, the vegetation of the ecoregion is primarily savannah with gallery forests lining the river valleys. The freshwater plants found in this ecoregion include *Limnophyton angolense*, *Lasimorpha senegalensis*, *Grangea maderaspatana*, *Utricularia subulata*, *Rotala fontinalis*, *Nymphoides forbesiana*, *Nymphaea nouchali*, *Eichhornia natans* and *Potamogeton thunbergii*.

Polygonum acuminatum is one of the most common plants in wetlands and has a wide distribution. Photo: © J.P. Ghogue.



Ledermannia linearifolia (VU). Lobe waterfalls, 10 km South Kribi. This area is a famous tourist destination as the Lobe river goes directly into the sea through a series of waterfalls. It is unfortunately an important Podostemaceae collecting site in central Africa. Photo: © J.P. Ghogue.

Malebo Pool: The ecoregion is defined by the extent of the Malebo Pool of the Congo River, located directly north of Kinshasa, spanning the border of the ROC and the DRC. The following freshwater plants species occur in the Malebo Pool: *Eclipta prostrata*, *Lasimorpha senegalensis*, *Pistia stratiotes*, *Utricularia appendiculata*, *Utricularia gibba*, *Utricularia foliosa*, *Utricularia inflata*, *Utricularia reflexa*, *Utricularia subulata*, *Nymphoides forbesiana*, *Buchnera capitata* and *Lindernia diffusa*.

Lower Congo: The terrestrial vegetation is a mixture of dense Guinean-Congolian moist forest and Guinean-Congolian grasslands. The freshwater plants of this ecoregion include: *Caldesia reniformis*, *Eclipta prostrata*, *Grangea maderaspatana*, *Utricularia benjaminiana*, *Utricularia gibba*, *Utricularia reflexa*,

Ledermannia cf. cristata (VU). Memve'ele Waterfalls at Ebianemeyong near Nyabessan. Photo: © J.P. Ghogue.



Dicraeanthus zehnderi (CR) is only known from the Sanaga waterfalls at Edea and is one of the most threatened freshwater plant species in central Africa. Its range has been considerably reduced by a dam constructed about 30 years ago (now less than 100 m²). With the recent dam extension works, this species might be lost. Photo: © J.P. Ghogue.

Nymphoides forbesiana, *Najas graminea*, *Eichhornia natans* and *Heteranthera callifolia*.

Lower Congo Rapids: As the Congo River descends toward the Atlantic Ocean, the gallery forests line the rivers and tree-savannah vegetation covers the landscape. Some freshwater plants of this ecoregion include: *Crinum jagus*, *Eclipta prostrata*, *Grangea maderaspatana*, *Utricularia benjaminiana*, *Utricularia inflexa*, *Utricularia pubescens*, *Utricularia reflexa*, *Utricularia spiralis*, *Najas graminea*, *Nymphaea maculata* and *Eichhornia natans*.

Ogooué - Nyanga - Kouilou - Niari: The waters of this rainforest ecoregion are exceptionally rich in freshwater species. The following freshwater plants are found in this ecoregion: *Hypoestes potamophila*, *Crinum natans*, *Utricularia subulata*, *Nymphoides forbesiana*, *Nymphaea lotus*, *Ludwigia abyssinica*, *Persicaria senegalensis* and *Bacopa crenata*.

Mai Ndombe: Here *Crinum natans* is present as freshwater plant species, and naturally this ecoregion needs more collection effort as the freshwater aquatic plants are rather poorly mentioned.

Tumba: This ecoregion is defined by Lake Tumba and its adjacent swamp forests and lies near the equator within the DRC. The lake is surrounded by seasonal and permanent swamps and connects with the Congo River near its confluence with the Oubangui River. *Utricularia appendiculata*, *Utricularia benjaminiana* and *Utricularia subulata* are present as freshwater plants species in this ecoregion.

Northern Gulf of Guinea Drainages – Bioko: The ecoregion is located within an evergreen rainforest zone and includes parts of the Cameroonian highlands and mountain forests on Bioko. The following freshwater plants species are found in this ecoregion: *Crinum purpurascens*, *Pistia stratiotes*, *Struchion sparganophora*, *Monopsis stellaroides*, *Nymphaea lotus*, *Ludwigia octovalvis* and *Tristicha trifaria*.

Eleocharis acutangula (DD). This photograph was taken at a swamp near Douala, on the Edea – Douala highway in Cameroon. Photo: © J.P. Ghogue.



Southern Gulf of Guinea Drainages: In relation to plants, the southern Gulf of Guinea drainages ecoregion is the most well known of the whole central Africa biodiversity assessment area: most of the existing floras and checklists have been published within this ecoregion. Its membership with the generally rich Guineo-Congolian phytocoria might explain its high number of freshwater plants. They include: *Staurogyne letestuana*, *Ranalima humile*, *Crinum purpurascens*, *Pistia stratiotes*, *Monopsis stellaroides*, *Utricularia subulata*, *Rotala welwitschii*, *Nymphoides indica*, *Najas marina*, *Nymphaea maculata*, *Ludwigia stenoraphe*, *Zehnderia microgyna*, *Polygonum acuminatum* and *Heteranthera callifolia*.

7.2.2 The Afromontane Archipelago-like Regional Centre of Endemism

This high altitude phytocorion made of Afromontane and Afroalpine communities, is distributed throughout the African continent and is mostly represented in the east (Ethiopia, Kenya and Tanzania), south-central (south-east DRC) and South Africa (Cap Peninsula). This formation also extends from western Africa to Cameroon, where it forms the western limit of the assessment area. In the Afromontane Regional Centre of Endemism there are at least 4,000 vascular plant species, of which around 3,000 are endemic or nearly endemic (White 1983). Two of the central African freshwater ecoregions fit into this phytocoria: the **Western Equatorial Crater Lakes** in Cameroon and the **Albertine Highlands** in the DRC.

Western Equatorial Crater Lakes: The general vegetation in the ecoregion consists of sub-montane forests between 900 and 1,800 m, and at higher elevations a mixture of montane elements including distinct montane forests and patches of montane grasslands, bamboo forests, and subalpine communities. The high altitude of this ecoregion gives birth to rapid rivers and waterfalls on volcanic rocks, therefore the true aquatic plants are dominated by the members of Podostemaceae family

Stonesia ghoguei (CR). This plant is known so far from the Tello waterfalls only, from an area less than 5 m². The area is intensively grazed by cattle and is frequently visited by tourists. Photo: © J.P. Ghogue.





Dicraeanthus africanus (NT) at Mpume waterfalls at Makak. This is the largest Podostemaceae in central Africa (its flexible stem can grow more than one metre). Its distribution sporadically extends from Cameroon to Gabon. Photo: © J.P. Ghogue.

known to be exclusively associated to rapid waters. They are *Ledermannia onanae*, *Ledermannia variabilis* and *Macropodiella pellucida*.

Albertine Highlands: Vegetation varies across the ecoregion with elevation. Wet rainforest and semi-deciduous forest grow below the plateaus (elevation between 1,500–2,000 m asl), whereas the vegetation is primarily woody savannah at higher elevations on the plateaus. The following freshwater plants are found in this ecoregion: *Burnatia enneandra*, *Caldesia reniformis*, *Adenostemma perrottetii*, *Carduus nyassanus*, *Crassocephalum picridifolium*, *Crassocephalum picridifolium*, *Eclipta prostrata*, *Ethulia conyzoides*, *Lemna paucicostata*, *Nymphoides brevipedicellata*, *Nymphaea maculata*, *Nymphaea nouchali* and *Potamogeton schweinfurthii*.

7.2.3 The Guinea-Congolia/Sudania regional transition zone

This phytocoria, which separates the Guineo-Congolian and the Sudanian Regions, extends across Africa from Senegal to Western Uganda. The natural vegetation of this formation is various types of forests, however it has largely been destroyed by fire and cultivation, and is now mostly secondary and secondary wooded grasslands. This transitional zone is a mixture of about 2,000 species from Guineo-Congolian and Sudanian formations, or linking species with even wider distribution (White 1983). It encloses four of the central African ecoregions: **Lower Niger – Benue, Sangha, Sudanic Congo – Oubangi** and **Uele**. Except for **Uele**, the other three ecoregions extend into the Guineo-Congolian Regional centre of endemism which has been treated already in section 7.2.1.

Uele: A mosaic of Afromontane forest, gallery forest, wooded savannah, and grassland blankets the northern highlands of the **Uele** ecoregion. Savannas range from dense woodland to virtually treeless grassland. The freshwater landscape is dominated by the following plants species: *Wiesneria schweinfurthii*, *Crinum jagus*, *Aponogeton vallisnerioides*, *Enydra fluctuans*, *Utricularia*



Ottelia ulvæfolia. This picture was taken in a stream near Bipindi. Photo: © J.P. Ghogue.

subulata, *Rotala stagnina*, *Nymphoides forbesiana*, *Nymphaea lotus*, *Nymphaea nouchali* and *Monochoria brevipetiolata*.

7.2.4 Zambezian Regional Centre of Endemism

This phytocoria extends from Atlantic Ocean in the west almost to the Indian Ocean in the east. It is the second largest phytocoria in Africa after the Sahara. The Zambezian Regional Centre of Endemism is characterized by the particular Zambezian vegetation (dry forest, woodland, thickets and grassland). It also probably has the richest and most diversified flora, and certainly shows the widest range of vegetation types. There are at least 8,500 vascular plant species of which c. 54% are endemic (White 1983). Within the central African assessment area, this phytocoria includes four ecoregions: **Upper Congo, Kasai, Bangweulu-Mweru, and Upper Lualaba**. The **Upper Congo** and **Kasai** overlap many phytocoria and have already been described above. The remaining ecoregions are described below.

Bangweulu-Mueru: This ecoregion is situated in the south-eastern corner of the DRC and north-eastern Zambia. The ecoregion is a component of the southern headwaters of the Congo River and include permanent swamps and shallow lakes of the Bangweulu-Mueru system. The following freshwater plants are found in this ecoregion: *Wiesneria schweinfurthii*, *Pancratium tenuifolium*, *Aponogeton vallisnerioides*, *Pistia stratiotes*, *Grangea maderaspatana*, *Triglochin bulbosa*, *Utricularia stellaris*, *Rotala serpiceoloides*, *Nymphoides tenuissima*, *Najas pectinata*, *Nymphaea nouchali* and *Ludwigia leptocarpa*.

Upper Lualaba: The Upper Lualaba ecoregion lies within the Democratic Republic of Congo in the south-eastern portion of its Shaba Province and is dominated by a series of lakes. Among others, the following freshwater plants species are found in this ecoregion: *Wiesneria filifolia*, *Aponogeton vallisnerioides*, *Genlisea angolensis*, *Utricularia welwitschii*, *Rotala myriophylloides*, *Nymphoides brevipedicellata*, *Nymphoides forbesiana*, *Nymphoides indica*, *Nymphoides rautanenii*, *Najas*

graminea, *Potamogeton octandrus*, *Potamogeton schweinfurthii* and *Potamogeton thunbergii*.

7.2.5 The Guinea-Congolia/Zambezia regional transition zone

This transition zone separates the Guineo-Congolian and Zambezian regions and extends from the Atlantic Ocean to the Lake Tanganyika. There are about 2,000 vascular plant species, and very few of these are endemic. The greater part of this zone is today occupied by secondary grassland and wooded grassland dominated exclusively by Zambezian species (White 1983).

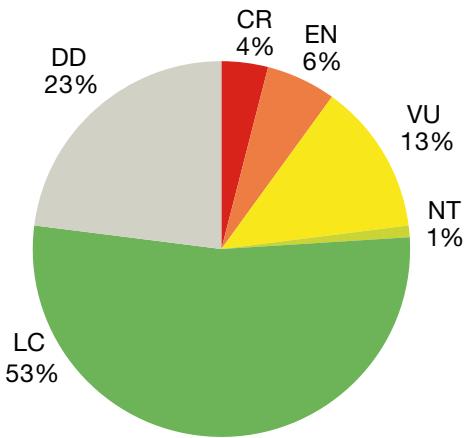
In the central Africa assessment area, this phytochorion covers four freshwater ecoregions: **Upper Congo, Kasai, Lower Congo and Lower Congo Rapids**. All of them overlap with the Guineo-Congolian phytochoria and have therefore been already described in the previous sections.

7.3 Conservation status (IUCN Red List Criteria: Regional scale)

A total of 435 freshwater plant species were initially identified within the central Africa region. Forty-three of these fell into the Not Applicable (NA) category and are not included in analyses. The regional Red List status of the remaining 392 species are given in Figure 7.2.

Fifty-three percent (209) of freshwater plants in central Africa are assessed as Least Concern (LC). A further six species (1%) are categorised as Near Threatened. Threats to freshwater biodiversity are mostly human induced and central Africa is generally under populated. Where present, the threat affects mostly the large rivers and large urban cities.

Figure 7.2 The proportion of aquatic plant species in each regional Red List Category in the central Africa region.
IUCN Red List Category: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient.



Eighty-nine (23%) of the species are not sufficiently documented to be given a conservation status, and are assessed as Data Deficient (DD). This is largely a result of species' under-collection or/and the difficulty of access to biological information (i.e. many museum collection have not been digitised and the information that they hold is generally unavailable).

Finally, 23% (88) of all freshwater plants assessed in central Africa are threatened. Most of the ecoregions supporting higher numbers of threatened species belong entirely or partially to the Guineo-Congolian Regional Centre of Endemism. The Guineo-Congolian phytochoria has long been recognized for its high level of endemism, most of its endemic species characterized by very restricted range, making them particularly susceptible to threats (such as pollution, uncontrolled exploitation and industrialization). A good demonstration of this is given by the Podostemaceae family constituting 29% of all threatened freshwater plants species in central Africa (Figure 7.3). Podostemaceae are submerged rheophytic herbs, growing in waterfalls and river-rapids. Their Area of Occupancy is generally narrow as they often occur in a single river and sometimes in only one waterfall.

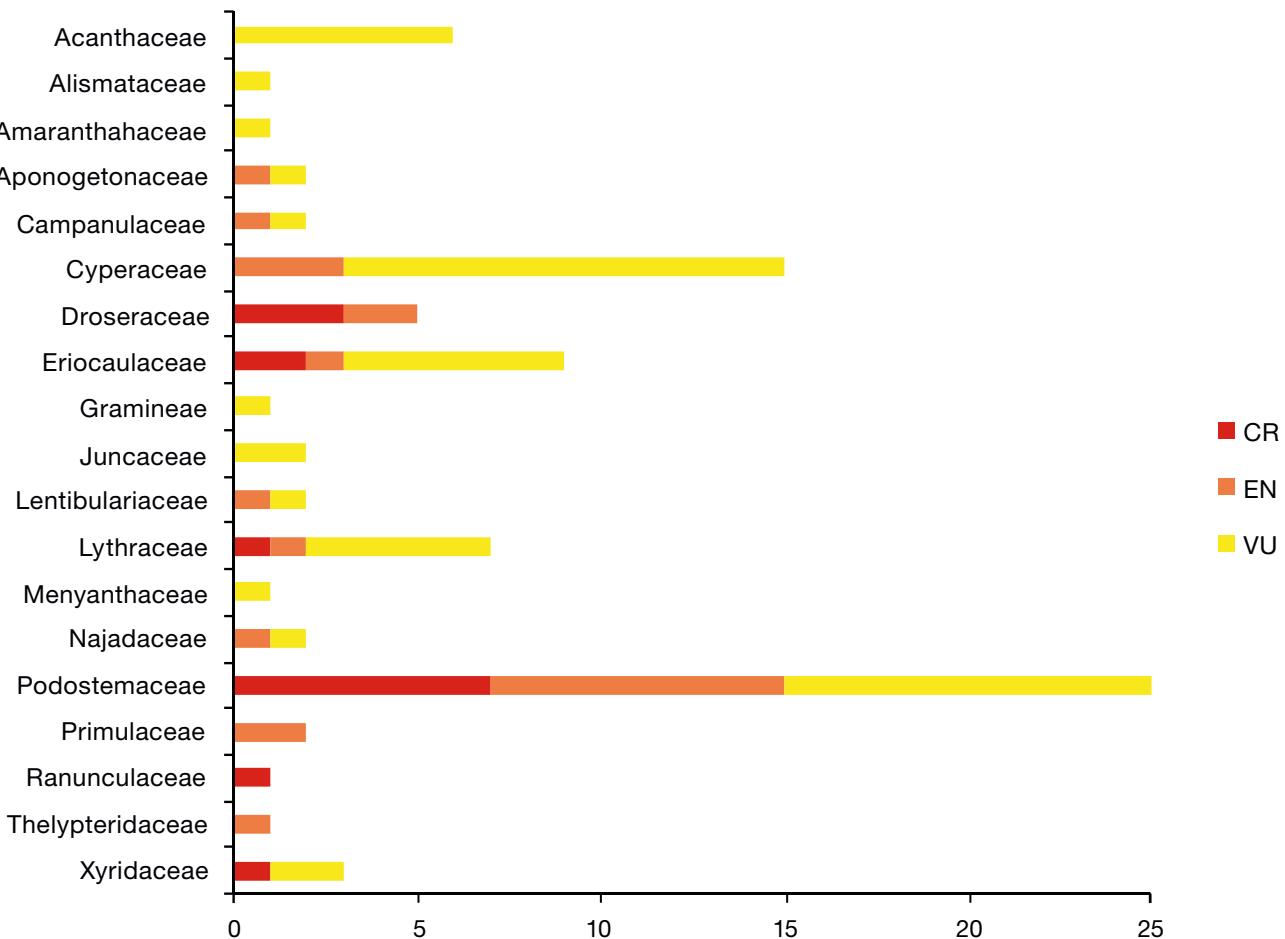
Twenty-one families contain threatened species, and Figure 7.3 shows the total number of threatened species per family by threat Category. For the reasons already mentioned, the Podostemaceae family is the most represented in terms of threatened species and for all threat categories (29%), followed by the Cyperaceae (16%), the Eriocaulaceae (10%) and the Lythraceae (7%).

Five ecoregions have no threatened species at all. They are the **Upper Congo Rapids, the Albertine Highlands, Malebo Pool, Mai Ndombe and Tumba**. It is possible that in relation to plants, these generally narrow ecoregions are not large enough to constitute separate systems on their own. Also, all of them fall within DRC, where in general plants have been under collected.

Ipomoea aquatica Forsk. (Convolvulaceae). Here in University Lake at Yaoundé. Photo: © J.P. Ghogue.



Figure 7.3 Total threatened freshwater plant species in central Africa by families. A further 30 aquatic families have no threatened species within central Africa. IUCN Red List Categories: CR – Critically Endangered, EN – Endangered, VU – Vulnerable.



7.4 Freshwater plant diversity patterns and endemism in central Africa

Over the past decades, there has been renewed emphasis on locating centres of species richness or endemism, in attempts to optimize conservation strategies (Beentje *et al.* 1994; Linder 2001). For freshwater plants in central Africa, these two parameters, associated with regional threat level, will be highly relevant to the global prioritization of conservation efforts.

7.4.1 Freshwater plant diversity

The Mount Cameroon area is the most diverse in tropical Africa (Figure 7.4). This area includes Mt. Cameroon itself, the Korup forest and south to Libreville. The area immediately to the south, reaching to the Angolan border and inland to Kinshasa, is only slightly less diverse (Linder 2001). The ecoregions with the highest biodiversity are the **Southern** and **Northern Gulf of Guinea Drainages**, the **Western Equatorial Crater Lakes** and **Lower Niger Benue**. They all belong to the Guineo-Congolian Regional Centre of Endemism and their two related transitional zones, the Sudania and the Zambesia. They encompass four countries, mainly Cameroon south of the Adamawa, but also Gabon, Equatorial Guinea and western Republic of Congo. Some other small patches of high freshwater plants diversity are found in the

Malebo Pool, partly in the **Lower Congo** and **Upper Lualaba**, south west Kasai and to a lesser extent the Congo valley at the border between the two Congos.

7.4.2 Freshwater plant endemism

The rainforest centres from central to western Africa have long been recognized as centres of endemism (Linder 2001). Of these centres, the lower Guinea (Cameroon to Gabon) is regarded as having the highest number of endemic species. The endemic patterns of freshwater plants in central Africa generally follow that of the general vegetation (Figure 7.5). The ecoregions with the highest endemism are the same as for plant diversity, that is, the **Southern** and **Northern Gulf of Guinea Drainages**, the **Western Equatorial Crater Lakes**, **Lower Niger Benue** and to a lesser extent **Sangha**. This shows as stated by Linder (2001), that in central Africa, plant diversity and endemism are not truly independent. The ecoregions with highest endemism equally all belong to the Guineo-Congolian Regional Centre of Endemism and their two related transitional zones, the Sudania and the Zambesia.

Sixty species (15.3%) out of the 392 freshwater plants assessed are endemic to central Africa. Therefore, their regional red list assessment represents that of their global assessment.

Only 8% of those endemic plants are of Least Concern (Figure 7.6). This supports the previous statement that in the assessment area, there is a relationship between endemism and threat, with 70% of endemic species currently under global threat. Twenty-two percent (22%) of them have been assessed as Data Deficient. It is therefore urgent to collect more data in order to have a clear view of their true conservation status.

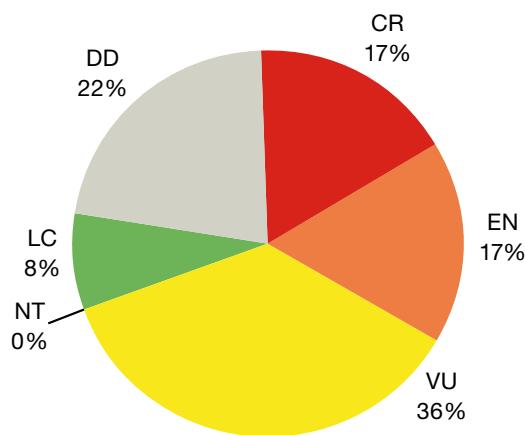
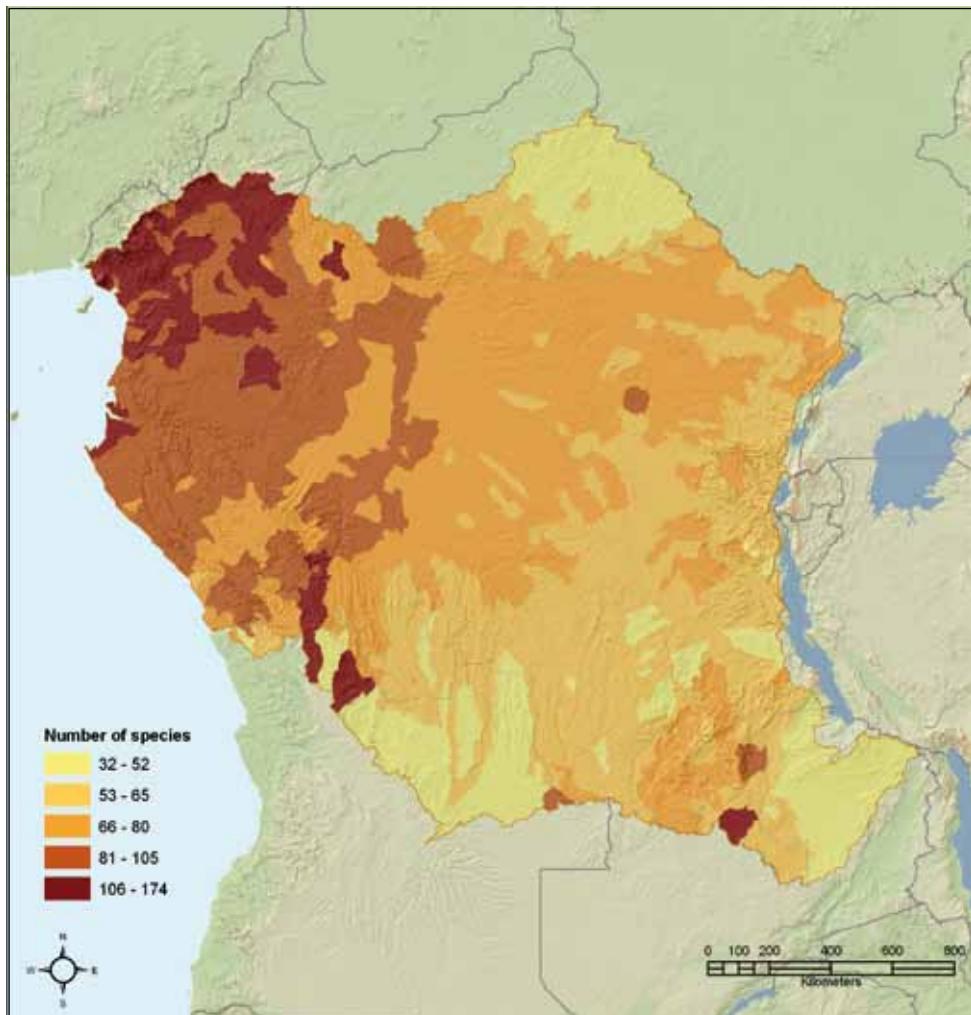


Figure 7.6 Red List Categories of freshwater plants endemic to central Africa. IUCN Red List Category: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient.

Figure 7.4 Patterns of species richness of aquatic plants of central Africa, mapped to river sub-catchments.



7.5 Major threats to central Africa freshwater plants

The eternal problem of conservation is the incidence of regions of high biodiversity with regions with high human impact. Such biogeographic regions with a significantly high biodiversity which is subjected to human threat are termed ‘hotspots’. An index combining biodiversity and human impact has helped to redefine Africa’s hotspots of biodiversity (Küper *et al.* 2004). One of these hotspots covers (totally or partially) the **Southern and Northern Gulf of Guinea Drainages**, the **Western Equatorial Crater Lakes**, the **Lower Niger Benue** and in a lesser extent the **Sangha**. There is an evident overlap between the patterns of species richness and those of threatened species (Figure 7.7). Therefore, the freshwater plants diversity hotspot in central Africa should cover Cameroon south of Adamawa and east of the Cameroon system, the whole of Gabon and Equatorial Guinea and finally north west of the Republic of Congo (Figure 7.8).

The most significant threats to freshwater or wetland plant species in central Africa are human induced (Figure 7.9). Almost all categories of human activity induced threats to freshwater plants have been encountered in this assessment, including water and land pollution, human settlement, infrastructure development,

Figure 7.9 Percentage of aquatic plants species affected by threat categories in central Africa. Note that many species have more than one threat listed.

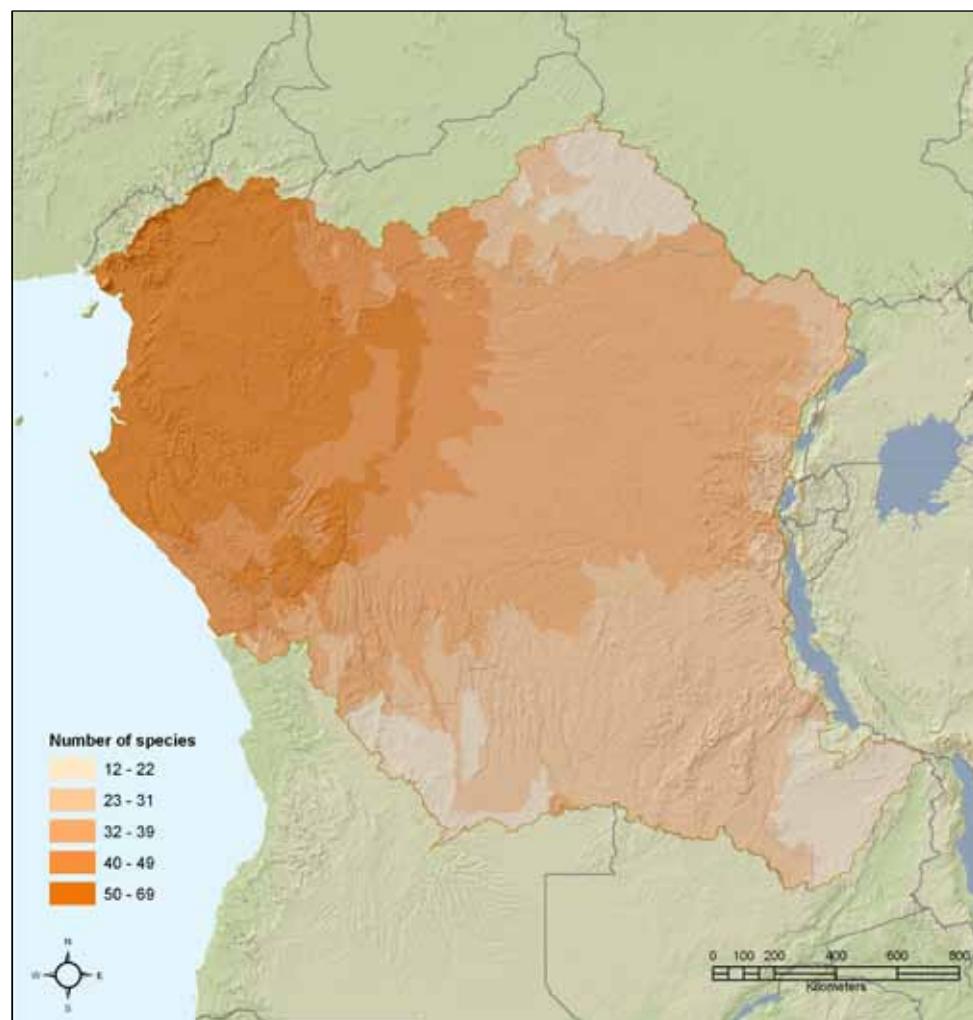
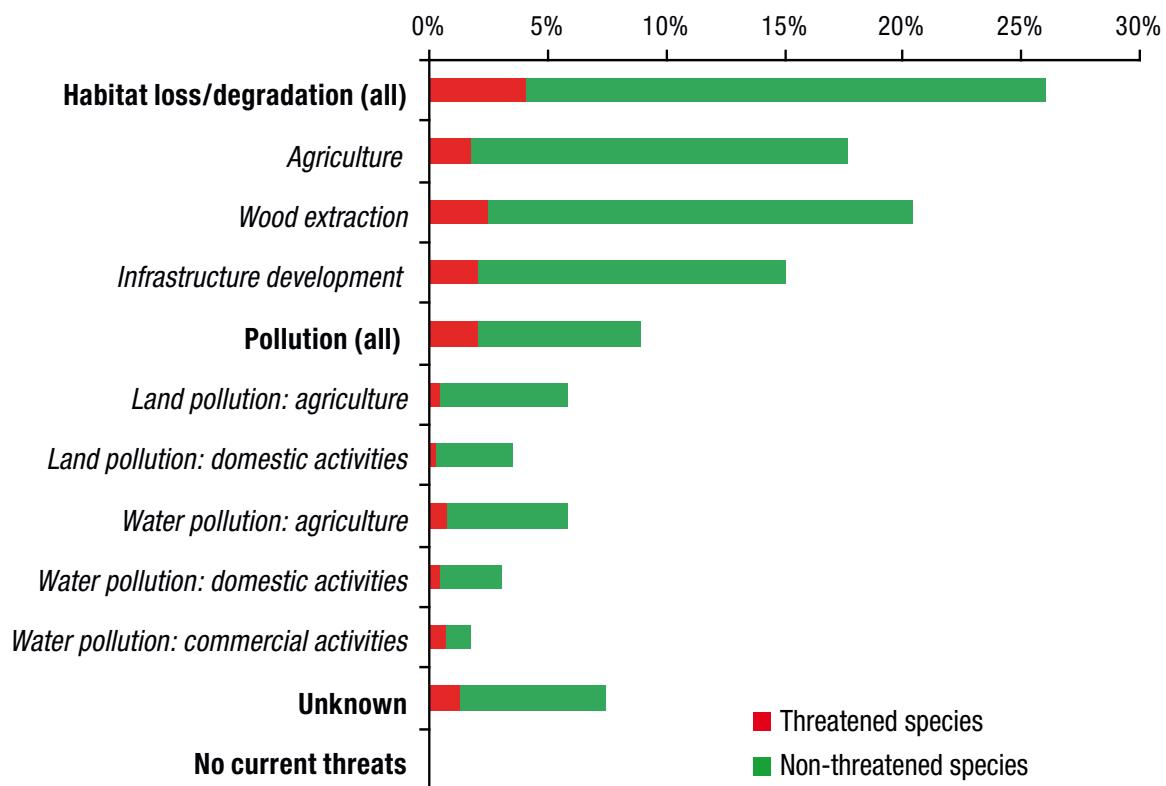


Figure 7.5 Endemic aquatic plants species richness in the central Africa region, mapped to river sub-catchments.

dam construction and agriculture, often leading to habitat degradation and loss.

7.5.1 Habitat degradation

7.5.1.1 Industrialization

Where environmental protection laws and regulations are absent, or for any reason are not implemented, waste waters and factory effluents, from mining as well as chemical industries such as soap and dye industries, enter directly or indirectly into nearby waterways. These waste waters and associated domestic waste waters cause the eutrophication of wetlands (small streams, rivers, lakes, marshes, swamps etc.). This can lead to the introduction and establishment of alien and native invasive species (see 7.5.2.1). In central Africa, the case is common in industrial cities such as Douala, Kinshasa, Brazzaville and Libreville.

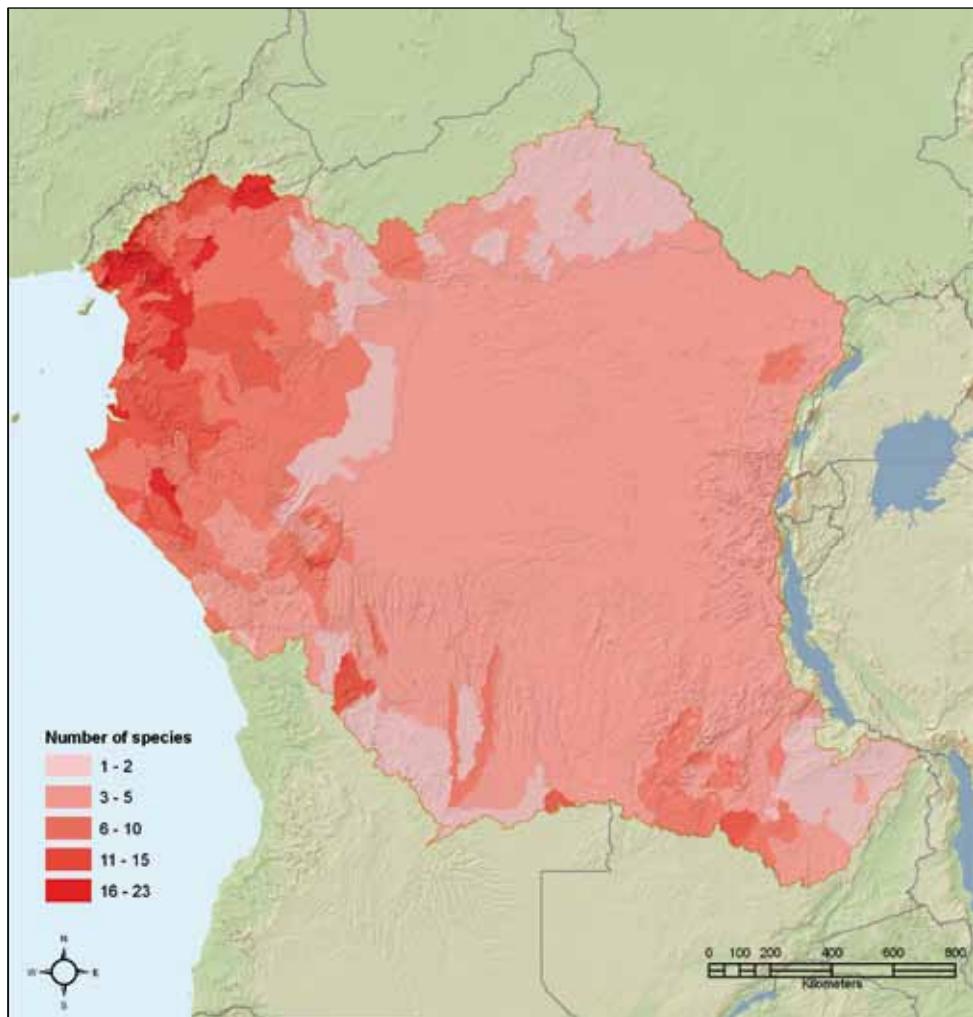
7.5.1.2 Urbanization

In most of the large towns and cities of central Africa, high human density is usually associated with intensive land use, and land's occupation laws and regulations are not always respected. Uncontrolled land occupation and exploitation is leading to an increasing problem of domestic waste handling and management.



Irrigation pipes in the highlands of Bafou (near Bamboutos Mountains). Photo: © J.P. Ghogue.

Figure 7.7 Threatened aquatic plants species richness in the central Africa region, mapped to river sub-catchments.



7.5.1.3 Agriculture

Agro-industry and market gardening can have long term harmful impacts on water quality and therefore affect freshwater biodiversity. These activities lead generally to water and land pollution. Both industrial agriculture and market gardening utilise high volumes of chemical fertilizers and pesticides, and are very demanding of water for irrigation, especially during the dry season.

After many years of market gardening with its negative impact on the environment, the composition of water in the rivers is strongly affected (Ghogue *et al.* 2010). For example, for many decades, intensive market gardening has been used in the highlands of western Cameroon, and industrial agriculture has been going-on in the lowlands south-west of same country around Limbe town (including rubber, banana, and oil palm plantations). Recently, the survey of very promising waterfalls and rapids showed no trace of Podostemaceae in these areas.

7.5.2 Habitat loss

Habitat loss in many cases is human induced and thus is similar to habitat degradation. There are multiple processes leading to habitat loss including the following:

7.5.2.1 Introduced species

Invasive plants can eventually lead to the total coverage of water bodies, supported by continuing habitat pollution. In such conditions, the reduction of species richness and diversity can reach 90% (Hejda *et al.* 2009). In central Africa, *Pistia stratiotes*, *Eichhornia crassipes*, *Cyperus papyrus* and to a lesser extent

Lasimorpha senegalensis are the most important aliens responsible for water surface coverage and therefore biodiversity loss.

7.5.2.2 Human settlement

The establishment of new settlements and the expansion of existing townships often take place to the detriment of wetlands habitat. Swamps and other wet areas are dug, drained or filled for dwelling houses, industry establishment, agriculture or creation of recreation facilities (lawns, golf pitches and other recreation fields). The rivers shores are “done up” and waterproofed with concrete. Also, river courses are canalised and river banks concreted as part of flood defence works. Moreover, inadequate reforestation and plantation development will lead to increased water loss, resulting in dryer soils unsuitable for wetland species.

7.5.2.3 Infrastructure development

For transport reasons, many industries are developed along rivers, often leading to the disappearance of the original wetland vegetation. Good examples of this in central Africa are given by the Wouri River at Douala (Cameroon) and the Congo River at Brazzaville (Congo) and Kinshasa (DRC).

Dams are considered a solution to the serious energy shortages in central Africa, and there are many existing or proposed dams in almost all countries. Dams have been shown to have the potential for large impacts on freshwater plants, such as the Central Amazonian dams in South America (Quiroz *et al.* 1997). In Cameroon, eight endemic species are seriously threatened in two waterfalls of the Sanaga River (the Edea and Nachtigal falls); the former is already dammed and there is an advanced project of dam construction on the second. These species are *Dicraeanthus zehnderi*

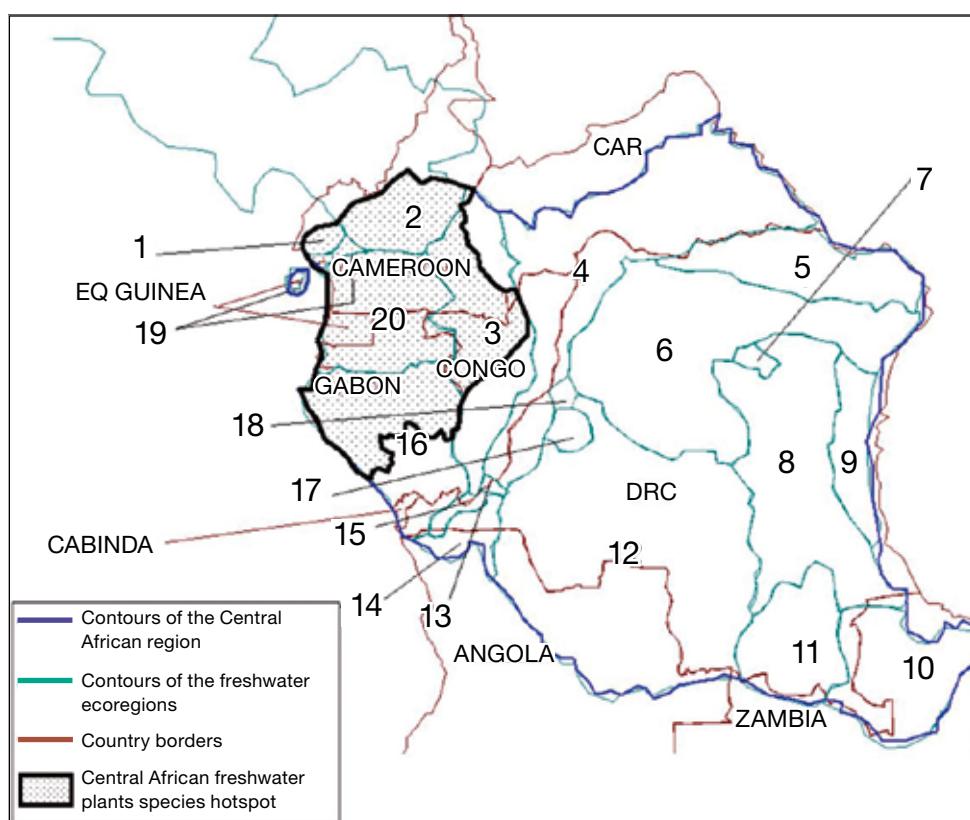


Figure 7.8 Map of the central African freshwater plant diversity hotspot, resulted from the superposition of the patterns of high diversity and threat.

(CR), *Winklerella dichotoma* (CR), *Zehnderia microgyna* (CR), *Ledermannella sanagaensis* (CR), *L. schlechteri* (EN), *L. thalloidea* (CR), *Leiothylax quangensis* (EN) and *Letestuella tisserantii* (EN). The first four species are endemic to the Sanaga River. The regional assessment for the conservation status of these species was carried out before the ongoing extension work on the Edea dam, which is expected to have further impacts on these species.

Polluted wetland around Nanga Eboko (East Cameroon), probably by a dyeing industry upstream. Note the deep black colour of the water.
Photo: © J.P. Ghogue.



Cyperus papyrus, photographed in Yaoundé. This African native grows rapidly making it one of the most invasive plants of eutrophic wetlands. Photo: ©J.P. Ghogue.”



7.6 Utilisation of freshwater plants

The economic importance of freshwater plants in central Africa is considerable. Many aquatic plants have dietary and medicinal importance (accounting for 21% and 24% of utilised species respectively) for humankind as well as animals, and all parts of the plants can be used (tuberous stems and leaves). They also

Lemna paucicostata. Growing in a small stream at Yaoundé. This stemless floating plant is one of the best indicators of generally stagnant water's pollution. Photo: © J.P. Ghogue.



have cultural and spiritual importance, and are also used to produce ornaments and tools.

Twenty-nine out of a total of 50 (58%) freshwater plants families, comprising 89 species, have known uses. The most represented in term of number of plant species are Acanthaceae, Cyperaceae, Asteraceae, Araceae, Aponogetonaceae and Podostemaceae. About 45% of these species are totally aquatic (e.g. *Burnatia enneandra*, *Aponogeton abyssinicus*, *Lasimorpha senegalensis*, *Eclipta prostrata*, *Dicraeanthus africanus*, *Persicaria senegalensis*, *Eichhornia crassipes*, *Typha capensis* and *Xyris anceps*), while the remaining are wetland species. The most used central African freshwater plants are: *Cyperus papyrus* (VU), *Xyris anceps* (LC), *Pistia stratiotes* (introduced) and *Lasimorpha senegalensis* (LC).

7.7 Conservation recommendations

The proportion of Vulnerable species in central Africa is relatively high (13%). This is an alarm indicating that immediate action must be taken to deal with the factors /conditions resulting in the degradation and destruction of the habitats of freshwater plants, in order to avoid increasing the proportion of Endangered species (6%) or that of already Critically Endangered species (4%). Where applicable, if the threat pressure is maintained, the

species within the NT category might easily be upgraded to more threatened categories.

7.7.1 Data quality and availability

In all analyses on the central African freshwater plants, a key bias might result from the data quality. In fact, 23% of all species were assessed as Data Deficient. Once these species are better collected and documented, the updated data might change our current knowledge about the conservation status of the whole central African freshwater flora. For example, DRC is by far the largest country in central Africa, but important parts of the country lacks reliable data (Figure 7.11). Therefore, all conservation efforts in the country should take this fact into consideration. Our advice at this point is that more freshwater plants collection and documentation is urgently carried out in DRC.

The data availability is also a serious problem to freshwater biodiversity assessment in central Africa, because many historical collections are generally inaccessible. There are ongoing international projects aiming to solve this problem: The API (African Plants Initiative) aims to reproduce efficiently a set of images and associated informations of the type specimens of the African flora kept in northern and southern herbaria and to make them accessible through appropriate electronic and other means for use by everyone for scholarly purposes (Smith 2004).

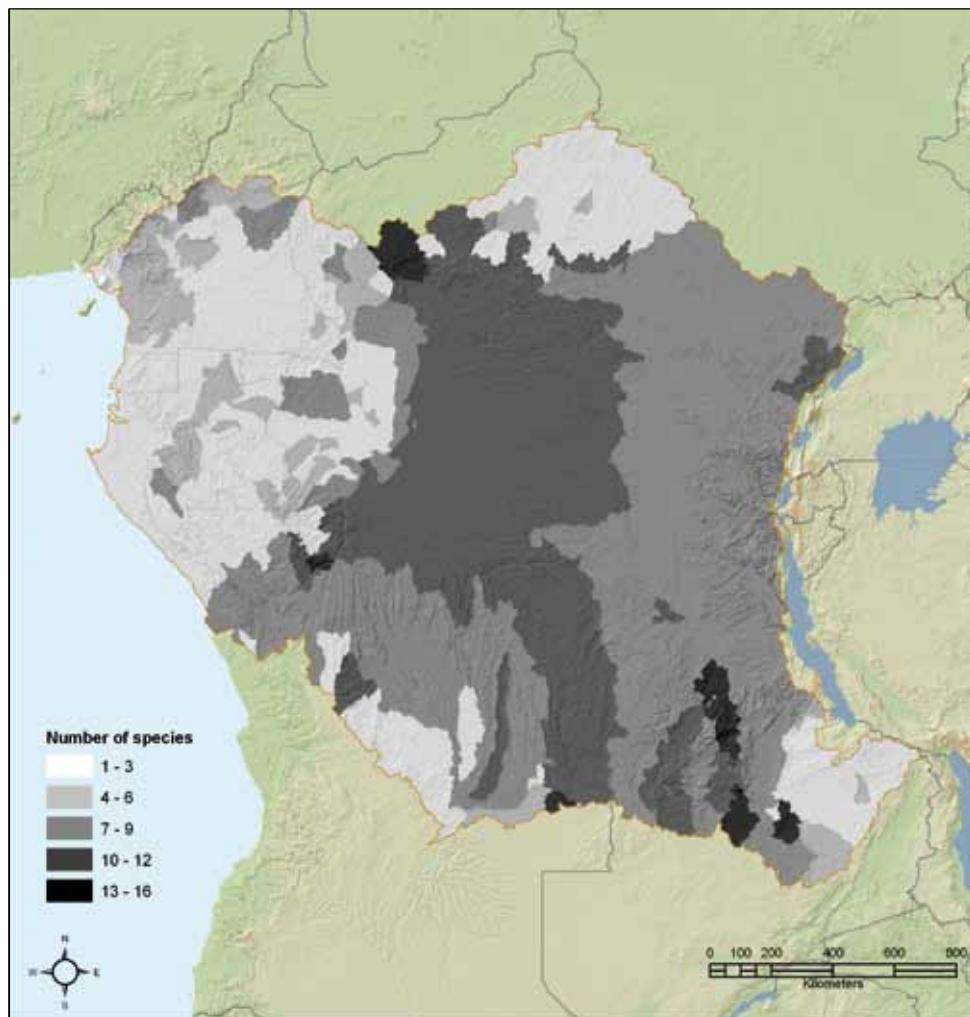


Figure 7.11 Data Deficient aquatic species richness in the central Africa region, mapped to river sub-catchments. Note that the Guineo-congolian's ecoregions have been relatively better explored and documented than those of DRC.

Also, GBIF is an international organization that is working to make the world's biodiversity data accessible everywhere in the world. GBIF and its many partners work to mobilize the data, and to improve search mechanisms, data and metadata standards, web services, and the other components of an internet-based information infrastructure for biodiversity. At this point, we encourage worldwide data holding institutions and individuals to join these initiatives to make the central African biodiversity information more accessible.

Thirteen (13) out of the 89 Data Deficient species are endemic to central Africa. They are *Adhatoda bolomboensis*, *Drosera elongata*, *Uapaca laurentii*, *Utricularia microcalyx*, *Xyris* species (*bampsii*, *densa*, *gossweilera*, *imitatrix*, *kundelungensis*, *kwangolana*, *lejolyana*, *popeana*, and *sanguinea*). It is therefore imperative that more data is collected for these species as many of them could already be seriously threatened.

7.7.2 Human welfare and conservation.

The human population of central Africa (this concerns the countries included in the watershed-based central Africa used in the frame of this study) is estimated to 148–152 million, with a mean population density of about 18–19 inhabitants/km² (PRB 2009, World Atlas

2010). Compared with other regions of the world and even with some countries, this population is rather low. In such conditions, the human's pressure on biodiversity in natural habitat is expected to be normally low. Nevertheless, the most important threat to freshwater or wetland plant species in central Africa has shown to be human induced. This is explained by the fact that about 74% of the population of the subregion live on less than 2\$US/day (PRB 2009) and there is a relationship between poverty and biodiversity loss (Adams *et al.* 2004; Fisher and Christopher 2007). Our recommendation at this point is addressed to governments of central Africa, as well as all decision makers, national and international stakeholders in the subregion: The current economical and financial policies should be revised and improved to ensure a better welfare of the population in central Africa.

7.7.3 Threats

The superposition of freshwater plant diversity patterns with threat patterns helped us delineating the contours of a freshwater phytodiversity hotspot in central Africa (Figure 7.8). This area is approximately one fifth of the whole central African area, but contains more than 70% of threatened freshwater plants. Our recommendation at this point is that freshwater conservation projects are immediately encouraged in this phytodiversity hotspot.

Macropodiella heteromorpha (VU). Here held by Hortense, guide and canoe driver on the Ntem River. The plant is collected at Memve'ele waterfalls at Ebianemeyong near Nyabessan. All the freshwater plants of these famous waterfalls are seriously threatened by an ongoing project of dam construction at the site. Photo: © J.P. Ghogue.



The most significant threats to freshwater plant species in central Africa are human induced, especially in the large rivers and in large urban cities. The following recommendations are made for governments, donors and stakeholders, directly or indirectly through conservation project makers:

- During the process of dam construction, prior to the project, Environmental Impact Assessments (EIA) must be carried out and the recommendations of the assessment report fully implemented. The experts carrying out the EIA should remember that there are plants living within the stream, and adequate technical measures should be planned to protect floral biodiversity before starting any construction work.
- For the already existing dams, a revised EIA should be urgently ordered and carried out in order to re-evaluate the impact of the dam on the biodiversity and the recommendations resulting from the assessment must be implemented.
- Agro-industry and market gardening in the long term reduce the water quality and therefore affect the freshwater biodiversity. Chemical fertilizers and pesticides should be restricted, and applied to crops only if absolutely essential.
- Town planning and land occupation in large urban cities should be sustained by strict laws, especially to reduce domestic waste issues, and be always supervised by qualified professionals.

Lower Itimbiri, DRC. Photo: © K.-D. Dijkstra



- The non-existence or the non-implementation of environmental protection laws and regulations allows industrial wastes to reach wetlands leading to degradation of such habitats and subsequent invasion by native and alien aquatic species. The central African governments are aware that these laws and regulations should be strictly implemented.
- Central African governments should encourage the use of native species in the wetlands reforestation process to prevent soils drying out.
- Governments in each central African country should develop centres for aquatic and invasive plants, in order to centralise information sources, and monitor key populations.
- Out of the 21 threatened freshwater plant families, the Podostemaceae alone constitutes 29% of the total species. As the most important in terms of threaten species number, this freshwater plant family urgently needs special attention for conservation and projects should be encouraged in that direction.

7.8 References

Abell, R., Thieme, M.L., Revenga, C., Bryer, M., Kottelat, M., Bogutskaya, N., Coad, B., Mandrak, N., Balderas, S.C.,



Eichhornia crassipes (Water Hyacinth) is a superinvasive causing major degradation of water quality. Frequently covering the whole surface of the water, it prevents boat movement and threatens fisheries. Photo: © J.P. Ghogue.

Bussing, W., Stiassny, M.L.J., Skelton, P., Allen, G.R., Unmack, P., Naseka, A., Rebecca, N.G., Sindorf, N., Robertson, J., Armijo, E., Higgins, J.V., Heibel, T.J., Wikramanayake, E., Olson, D., Lopez, H.L., Reis, R.E., Lundberg, J.G., Sabaj Perez, M.H. and Petry, P. 2008. Freshwater Ecoregions of the World: A New Map of Biogeographic Units for Freshwater Biodiversity Conservation. *BioScience*. **58**(5): 403–414.

Adams, W.M., Aveling, R., Brockington, D., Dickson, B., Elliot, J., Hutton, J., Roe, D., Vira, B. and Wolmer, W. 2004. Biodiversity Conservation and the Eradication of Poverty. *Science*. **306**:1146–1149.

Beentje, H.J., Adams, B., Davis, S.D. and Hamilton, A.C. 1994. Regional overview: Africa. In: Davis, S.D., Heywood, V.H. and Hamilton, A.C. (eds.) *Centres of plant diversity*, pp. 101–148. IUCN Publication Unit, Cambridge.

Cheek, M., Pollard, B.J., Derbyshire, I., Onana, J.-M. and C. Wild, C. 2004. *The Plants of Kupe, Mwanenguba and the Bakossi Mountains, Cameroon. A conservation Checklist*. The Royal Botanic Gardens, Kew, UK.

Chevalier, A. 1913. *Etudes sur la Flore de l'Afrique Centrale Française (bassins de l'Oubangui et du Chari)*. Paris, France.

Cook, C.D.K. 1996. *Aquatic Plant Book*. SPB Academic Publishing, 2nd, revised Edition. The Hague, The Netherlands.

Cook, C.D.K. 2004. *Aquatic and wetland plants of southern Africa*. Backhuys Publishers, Leiden, The Netherlands.

Macropodiella pellucida (EN). Taken at the Metchum waterfalls on the Bamenda–Wum road. This curious stemless flowering plant is endemic to Cameroon, but its occurrence might extent to East Nigeria. Photo: © J.P. Ghogue.



- Dinerstein, E., Olson, D.M., Graham, D.J., Webster, A.L., Primm, S.A., Bookbinder, M.P. and Ledec, G. 1995. *A conservation assessment of the terrestrial ecoregions of Latin America and the Caribbean*. The World Bank, Washington, DC, USA.
- Exell, A.W. 1944. *Catalogue of the vascular plants of São Tomé (with Príncipe and Annobón)*. The Trustees of the British Museum, London.
- Fisher, B. and Christopher, T. 2007. Poverty and biodiversity: Measuring the overlap of human poverty and the biodiversity hotspots. *Ecological Economics* **62**: 93–101.
- Ghogue, J.P., Imaichi, R., Kita, Y. and Porembski, S. 2010. River ecology and distribution of *Podostemaceae* in Cameroon. In: Xander van der Burgt, L.J.G. Van der Maesen and Jean Michel Onana. *Systematics and Conservation of African Plants: Proceedings of the 18th AETFAT Congress*, pp. 597–604. Kew Publishing, UK.
- Grandvaux Barbosa, L.A. 1970. *Carta phytogeográfica de Angola*. Instituto de Investigação científica de Angola. Luanda.
- Hejda, M., Pyšek, P. and Jarošík, V. 2009. Impact of invasive plants on the species richness, diversity and composition of invaded communities. *Journal of Ecology* **97**: 393–403.
- Küper, W., Sommer, J.H., Lovett, J.C., Mutke, J., Linder, H.P., Beentje, H.J., Van Rompaey, R.S.A.R., Chatelain, C., Sosef, M. and Barthlott, W. 2004. Africa's hotspots of Biodiversity redefined. *Ann. Missouri Bot. Gard.* **91**: 525–535.
- Letouzey, R. 1985. *Etude phytogéographique du Cameroun*. Paul Chevalier, Paris, France.
- Linder, H.P. 2001. Plant diversity and endemism in sub-saharan tropical Africa. *Journal of Biogeography* **28**: 169–182.
- Linder, H.P., Lovett, J., Mutke, J.M., Barthlott, W., Jürgens, N., Rebelo, A.G. and Küper, W. 2005. A numerical re-evaluation of the sub-Saharan phytochoria of mainland Africa. *Biologist Skrifter* **55**: 229–252.
- Onana, J.M., Fenton, E. and Harvey, Y. 2010. *The Plants of Mefou proposed National Park, Central Province, Cameroon, A Conservation Checklist*. The Royal Botanic Gardens, Kew, UK.
- Pellegrin, F. 1924. *La Flore du Mayombe, d'après les récoltes de M. Georges Letestu*. Deuxième partie.
- PRB 2009. Fiche de données sur la population mondiale 2009. Available at: <http://www.prb.org/publications/datasheets/2009/2009wpds.aspx>
- Silans, R. 1958. *Les savanes de l'Afrique Centrale. Essai sur la physionomie, la structure et le dynamisme des formations végétales ligneuses des régions sèches de la république Centrafricaine*. Paul Chevalier, Paris, France.
- Smith, G.F. 2004. The African Plants Initiative: a big step for continental taxonomy. *Taxon* **53**(4): 1023–1025.
- Sosef, M.S.M., Wieringa, J.J., Jongkind, C.C.H., Achoundong, G., Azizet Issembé, Y., Bedigian, D., van den Berg, R.G., Breteler, F.J., Cheek, M., Degreef, J., Faden, R.B., Goldblatt, P., van der Maesen, L.J.G., Ngok Banak, L., Niangadouma, R., Nzabi, T., Nziengui, B., Rogers, Z.S., Stévart, T., van Valkenburg, J.L.C.H., Walters, G. and de Wilde, J.J.F.E. 2006. *Check-list des plantes vasculaires du Gabon / Checklist of Gabonese vascular plants*. Scripta Botanica Belgica, National Botanic Garden of Belgium.
- Thieme, M.L., Abell, R., Stiassny, M.L.J., Skelton, P., Lehner, B., Teugels, G.G., Dinerstein, E., Toham, A.K., Burgess, N. and Olson, D. 2005. *Freshwater Ecoregions of Africa and Madagascar: A Conservation Assessment*. Island Press, Washington DC, USA.
- White, F. 1983. *The vegetation of Africa. A descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa*. UNESCO, Paris, France.

Chapter 8. Regional synthesis for all taxa

Brooks, E.G.E.¹

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The combined data sets for freshwater fishes, molluscs, plants (selected taxa), crabs and odonates are analysed here to present a synthesis of the status and distribution of some key components of freshwater biodiversity throughout central Africa. The objective is to provide outputs of use in conservation planning for wetland ecosystems and wetland species at the regional, national and site scales. The combined data sets also provide a regional-scale knowledge base to enable the integration of freshwater biodiversity considerations within environmental and development planning throughout the region.

8.1 Patterns of species richness

The central Africa region supports a significant proportion of the world's species dependent upon freshwater wetland habitats

(Table 8.1). For these analyses we have included additional information on freshwater dependent mammals (as defined by the IUCN Red List), freshwater turtles, amphibians, and water birds, for which regional data sets also exist. Given that the region represents approximately 4% of total global land mass (excluding Antarctica), it is apparent that the majority of groups, mammals, water birds and plants in particular, are well represented within the region.

Of the 2,261 species assessed here at the regional scale, almost 15% are regionally threatened (Table 8.2). When compared with the global level of threat to some of those taxonomic groups that have been comprehensively assessed (e.g. mammals, 21% threatened; amphibians, 30% threatened (IUCN 2010), this figure appears to be relatively low. The history of conflict in the region, and limited infrastructure, has restricted the level of

Table 8.1 Estimated numbers of extant inland water-dependent species by major taxonomic group.

Taxon	Number of described species	Number of species in central Africa	% of global total found in central Africa
Fishes	~15,000	1,440	9.6%
Molluscs	~5,000	241	4.8%
Odonata	5,680	504	8.9%
Crabs	1,446	44	3.0%
Amphibians	4,231	303	7.2%
Mammals	145	22	15.2%
Water birds	1,989	198	10.0%
Turtles	260	4	1.5%
Aquatic plants	~2,614	435	16.6%

Data sources: Balian *et al.* (2008); IUCN Red List (2010)

¹ IUCN Species Programme, 219c Huntingdon Road, Cambridge CB3 0DL, UK.

scientific research. However the exact level of threat for all species is unknown as there is insufficient information to assess the status of 472 DD species, and it could be as high as 36% assuming all Data Deficient species are threatened (Figure 8.1). It is expected that development activities will increase extensively in the next few years, including the usage of central Africa's water resources, and the situation could change dramatically unless impacts to freshwater species are considered during the planning phases for future projects.

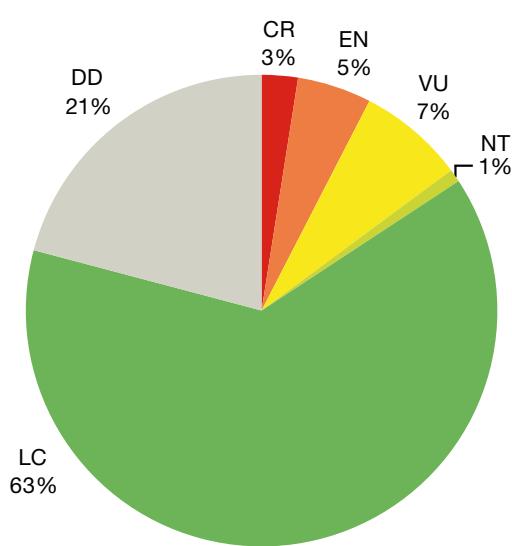


Figure 8.1 The proportion (%) of freshwater species in each regional IUCN Red List Category in central Africa. IUCN Red List Categories: EN – Endangered, VU – Vulnerable, LC – Least Concern, DD – Data Deficient.

A comparison can be made with other comprehensive regional freshwater biodiversity assessments. The central Africa region exhibits a much higher species richness than other regions of Africa (see Table 8.3). The relative levels of human development largely explain differences in the proportion of threatened species between southern, western and northern Africa (Darwall *et al.* 2009, Smith *et al.* 2009 and García *et al.* 2010), with the higher level of threat in eastern Africa blamed to some degree on the introduction of invasive species (Darwall *et al.* 2005). Central Africa however has a low level of development throughout the region, and therefore would be expected to reflect a smaller proportion of threatened species. Central Africa, like eastern Africa, shows very high levels of endemism (see Table 8.3). With many freshwater species restricted to water catchments with little option for dispersal, they face a higher risk of extinction compared to more widespread species.

Central Africa also shows a much higher proportion of Data Deficient species than is seen in other regions of Africa (Table 8.3). The history of conflict in the region has limited the level of scientific research and survey work as compared with that carried out in other parts of the continent, leaving information gaps for species' ranges, habitats, and potential threats. Data Deficient species are potentially threatened, and given the proportionally high level of threat seen for those species which could be assessed within central Africa, it is a priority to assess the status of these other potentially at risk species.

All the central Africa assessments of species that are endemic to the region are equivalent to global assessments and so also represent the risk of global extinction for the species. Of the 1,179 regionally endemic species assessed here, 263 species (22% of those assessed) are globally threatened (Table 8.4).

Table 8.2 Summary of Red List Category classifications at the regional scale by taxonomic groupings.

Taxon	Total*	EX	RE	EW	CR	EN	VU	NT	LC	DD	NA
Fishes	1,207	0	0	0	26	64	90	4	749	274	116
Molluscs	166	0	0	0	15	23	14	3	79	32	35
Odonates	458	0	0	0	0	3	9	7	374	65	46
Crabs	38	0	0	0	0	3	1	0	22	12	0
Aquatic plants	392	0	0	0	15	22	51	6	209	89	42
Total	2,261	0	0	0	56	115	165	20	1,433	472	239

IUCN Red List Categories: EX – Extinct, RE – Regionally Extinct, EW – Extinct in the Wild, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient, NA – Not Applicable (e.g. vagrant species, introduced species). * Excludes those species classified as Not Applicable (NA).

Table 8.3 Comparison of African regional freshwater biodiversity assessments.

	Central Africa	Eastern Africa*	Northern Africa	Southern Africa	Western Africa
Number of taxa assessed	2,261	1,594	877	1,279	1,395
% threatened	15%	23%	28%	7%	14%
% endemic	52%	73%	23%	42%	33%
% Data Deficient	21%	16%	14%	15%	16%

Regional data from Darwall *et al.* 2005; García *et al.* 2010; Darwall *et al.* 2009 and Smith *et al.* 2009. *Aquatic plants were not included in the eastern Africa regional assessments.

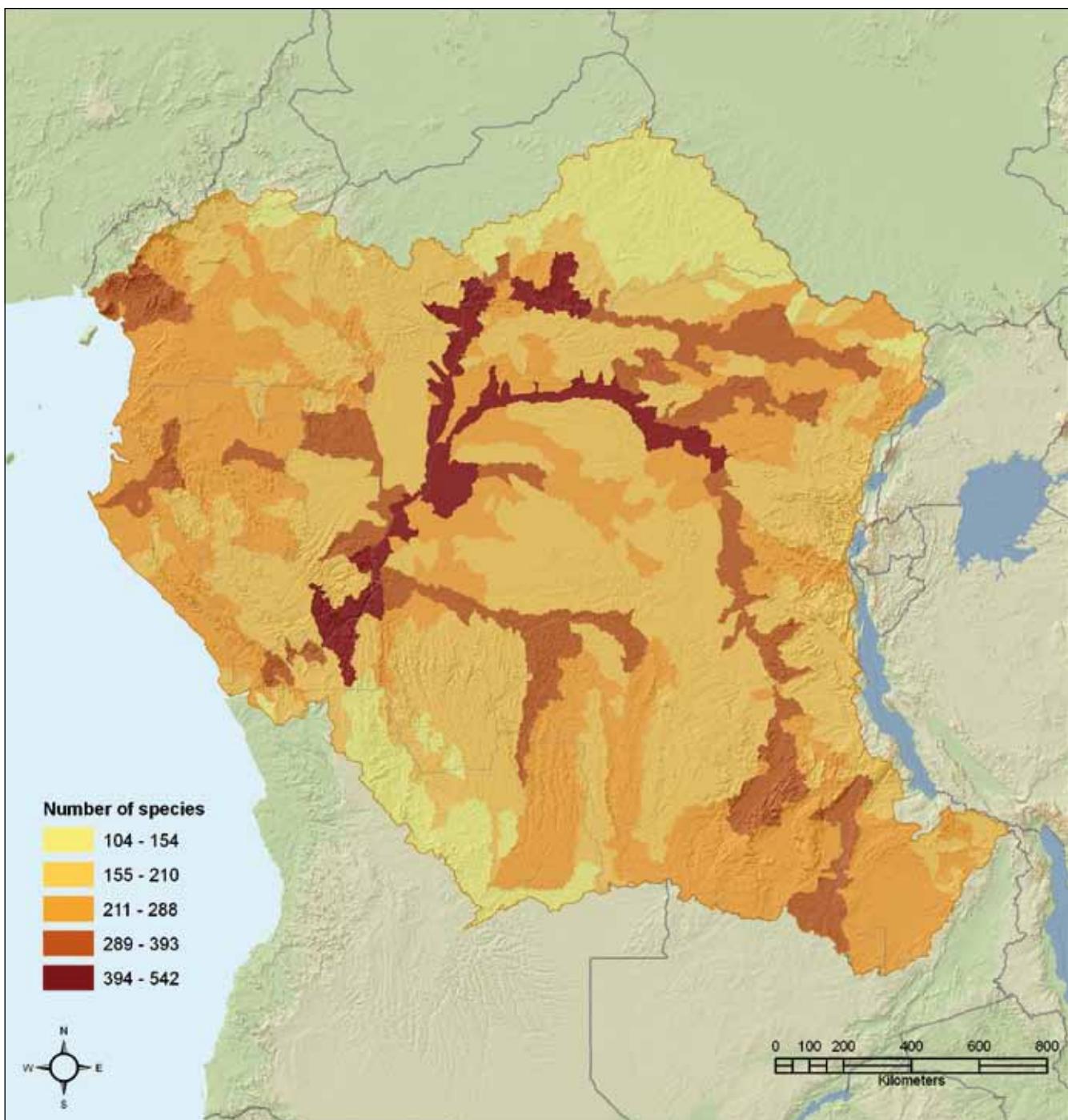


Figure 8.2 Central Africa species richness for fishes, molluscs, odonates and crabs, mapped to river sub-catchments.

Table 8.4 Summary of Red List Category classifications at the global scale by taxonomic groupings.

Taxon	Total	EX	EW	CR	EN	VU	NT	LC	DD
Fishes	890	0	0	24	58	81	4	474	249
Molluscs	97	0	0	15	22	14	3	24	19
Odonates	94	0	0	0	0	3	3	46	42
Crabs	38	0	0	0	3	1	0	22	12
Aquatic plants	60	0	0	10	10	22	0	5	13
Total	1,179	0	0	49	93	121	10	571	335

IUCN Red List Categories: EX – Extinct, RE – Regionally Extinct, EW – Extinct in the Wild, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient.

The Red List status for each species assessed for this project is listed on the accompanying DVD for both the global and regional scales.

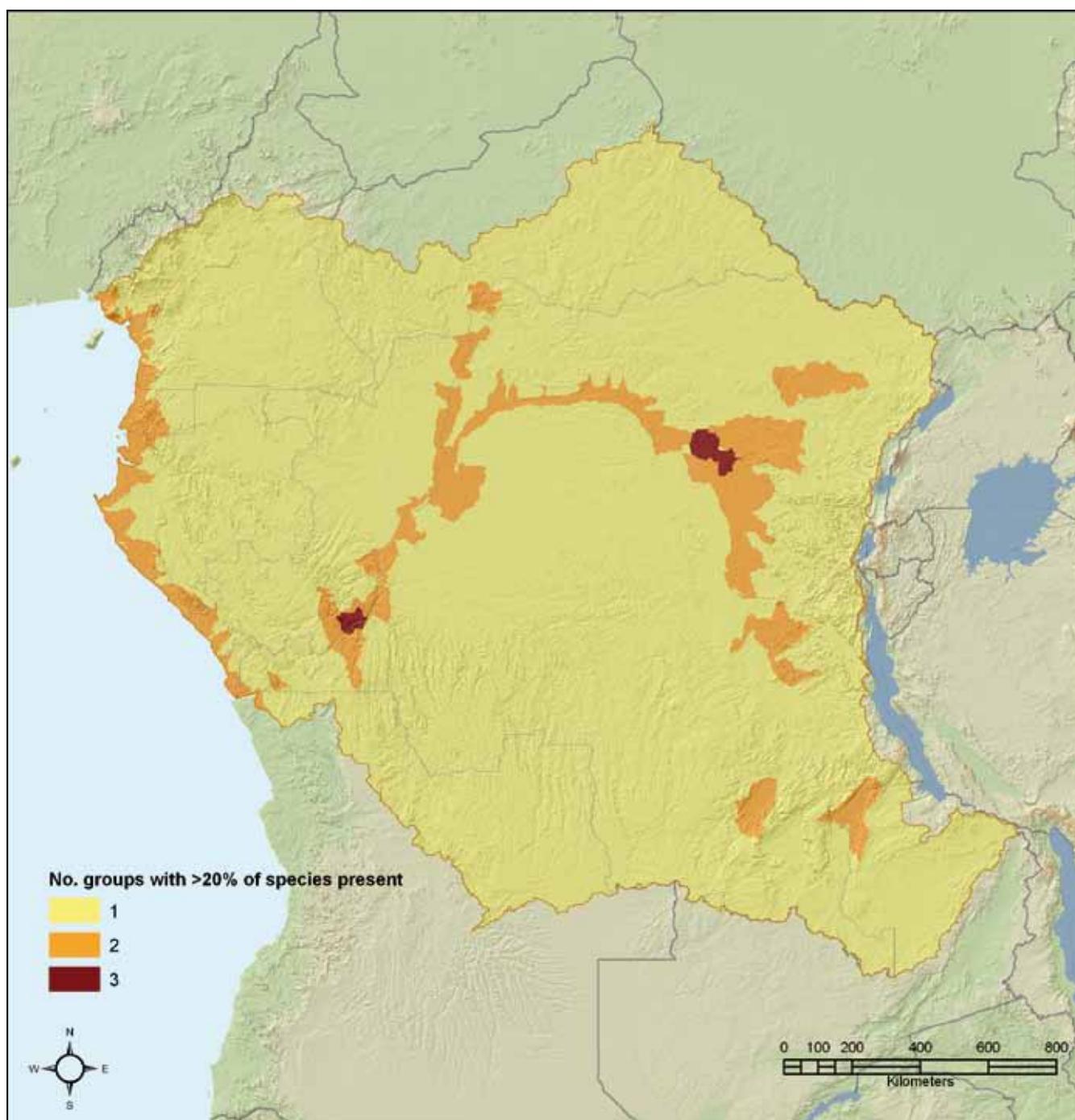
8.1.1 Centres of species richness

Species distribution maps for the priority taxonomic groups of fishes, molluscs, odonates and crabs were overlaid to identify those river basins holding the highest combined species richness. Aquatic plants were excluded from the analyses as a lack of specific range information meant many species could only be mapped to a country level. The area of greatest species richness is clearly defined by the channel of the Congo River, and its tributaries the Ubangi

River and the Kasai River (Figure 8.2). The Congo River has the highest species diversity of any freshwater system in Africa, and is second in species richness globally, after the Amazon Basin (Teugels and Thieme 2005). The river passes through a number of different habitats, and the Ubangi River in particular is thought to be one of the most undisturbed areas within central Africa.

Overall species richness is heavily weighted by the high fish diversity in the region. By overlaying the distribution maps for each taxonomic group, those river basins holding the greatest richness across all groups could be identified. Centres of overall species richness were identified as those sub-basins holding at

Figure 8.3 Distribution of river basins containing exceptionally high numbers of species from all taxonomic groups, mapped to river sub-catchments. The map represents those Hydro1k level 6 sub-basins holding at least 20% of the total regional species compliment for each of the fishes, molluscs, odonates, crabs and plants.



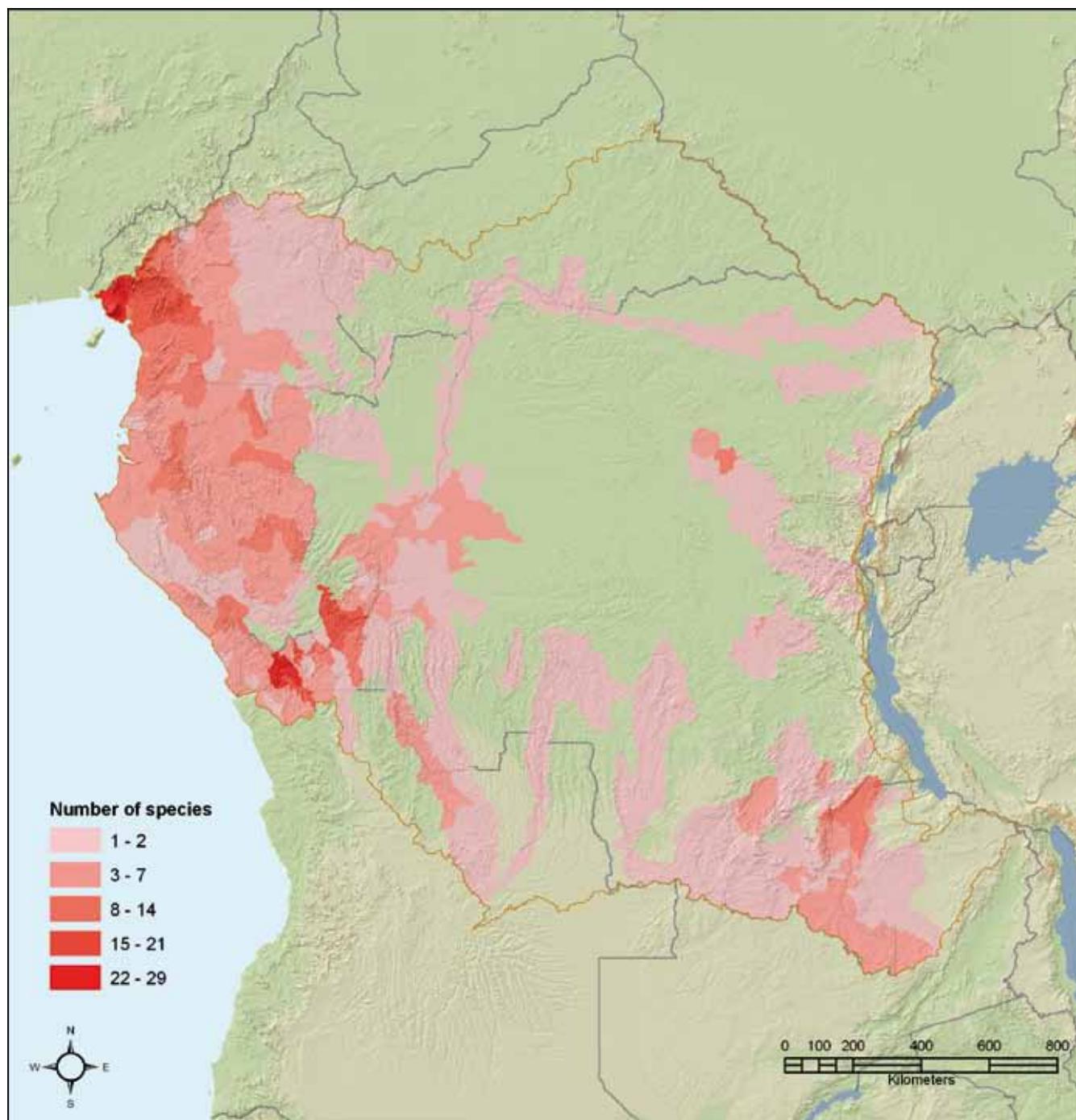
least 20% of the total numbers of mapped species within each of the four taxonomic groups (Figure 8.3). This approach now also identifies the coastal river basins as areas of high species richness across all taxonomic groups. The two basins of particular high species diversity are that of **Malebo Pool** and the **Upper Congo Rapids**.

Malebo Pool is a large shallow pool within the lower reaches of the Congo River. It has a surface area of approximately 500 km², and the depth fluctuates considerably within a range of 3–10 m. It supports an estimated 341 species of fish (28% of the regional total), 47 species of mollusc (28% of the regional total), 149 species of odonates (33% of the regional total), 107 species of the

selected aquatic plants (27% of the regional total), and six species of crab (16% of the regional total). Malebo Pool lies between the two capitals of Brazzaville and Kinshasha. This is an area of high urbanisation, along with a large and over-exploited fishery supplying both sides of the river. The central island of Ile Mbamou is of increasing agricultural importance, resulting in an escalation of erosion and runoff of sediments and pollutants into Malebo Pool.

The Boyoma Falls (formerly known as Stanley Falls) are an area of rapids where the river falls by 60 m along a stretch of 100 km. This area delineates the point where the Lualaba River ends, and the Congo River begins. Although the Boyoma Falls can be sited

Figure 8.4 The distribution of regionally threatened species of fishes, molluscs, odonates and crabs within central Africa, mapped to river sub-catchments.



as the largest waterfalls globally by volume, each of the seven cataracts that make up the rapids drops by no more than 15 m. It supports an estimated 281 species of fish (23% of the regional total), 44 species of mollusc (27% of the regional total), 154 species of odonates (34% of the regional total), 75 species of the selected aquatic plants (19% of the regional total), and four species of crab (11% of the regional total). The area is heavily impacted by artisanal mining, and 95% of industrial discharge and sewage in the region is dumped directly into the river (UNEP 1999). The continued civil unrest within the region includes struggle for control over the natural resources in the surrounding area, and also prevents the instigation of environmental protection within the region (Teugels and Thieme 2005).

8.1.2 Distribution of threatened species

The areas supporting the highest number of regionally threatened species are the coastal zones of **Northern**, **Central** and **Southern West Coastal Equatorial** ecoregions, the **Lower Congo Rapids**, and to a lesser extent, the **Bangweulu-Mweru** system in the south-east (Figure 8.4).

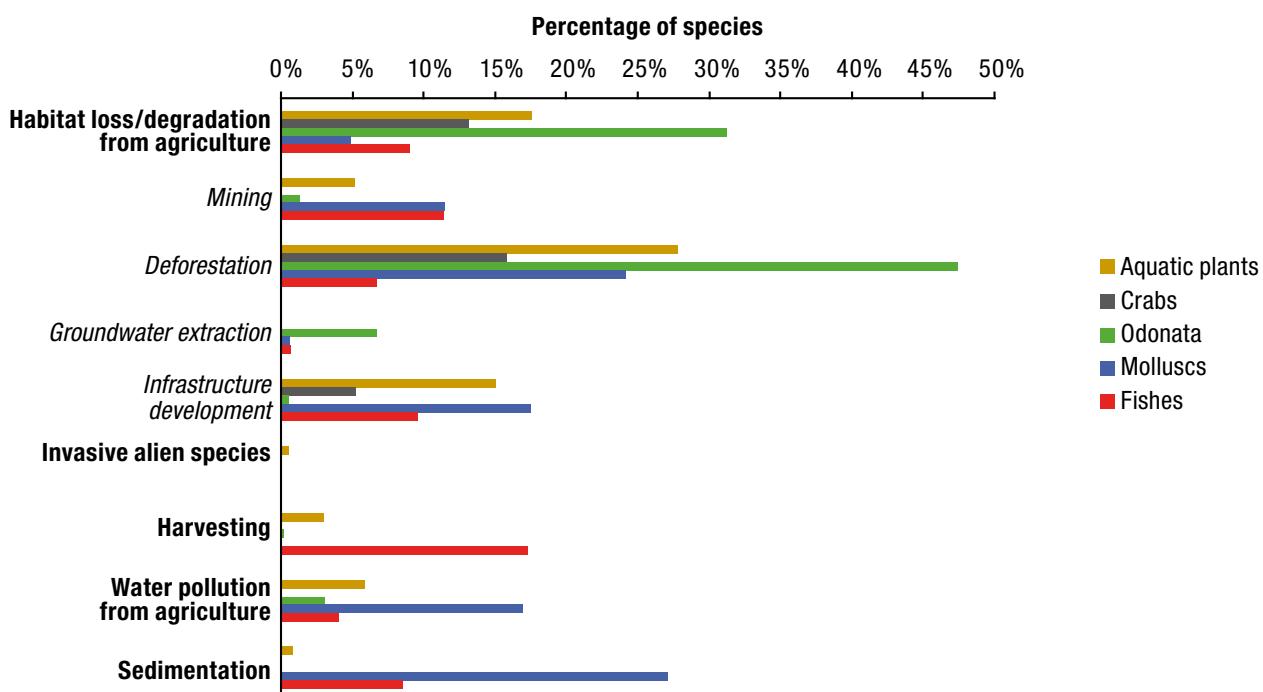
The coastal areas of Cameroon are forested plains and swamps, which support a high number of endemic species. The region's habitats are threatened by widespread logging, and offshore oil exploration and pollution is impacting the estuaries.

One of the areas sustaining the greatest number of threatened species is the **Western Equatorial Crater Lakes** region of southwestern Cameroon. Here a collection of 36 crater lakes lies along a volcanic ridge, the largest of which is Lake Barombi Mbo with a surface area of just 5 km². Most of these lakes are completely isolated from nearby water systems, and support an extremely high

level of endemism, particularly of fishes. All life within the lakes is under constant threat of lake 'burping'; seismic activity causing the release of carbon dioxide into the lake, turning it anoxic. In addition to this constant underlying threat, anthropogenic activities are, however, a cause for more immediate impacts to species. Increased agriculture results in deforestation and severe run-off carrying sediments, pesticides and fertilisers. In some lakes water levels have been lowered by water extraction, but those lakes most heavily affected by overfishing may now benefit from recent bans on commercial fishing.

The second highest centre of threatened species is the **Lower Congo Rapids** ecoregion. Located near to the mouth of the River Congo, this stretch of water receives all the pollutants collected from the length of the river, in particular from the areas around Brazzaville and Kinshasha situated just north of this area, at **Malebo Pool**. Water pollutants include sewage and domestic waste, agricultural run-off, and extensive industrial and mining seepage. Water samples taken in the area have shown lead levels to be four times higher than the US Environmental Protection Agency's recommended levels for children (Shumway *et al.* 2003, Thieme *et al.* 2005). This ecoregion also contains the Inga dams. There are currently two dams, Inga I and II, which generate 351 and 1,424 MW in capacity respectively. Although no environmental impact studies have been conducted, it is thought that some species, particularly endemic waterfall molluscs, are already threatened by the hydropower station. Plans are in place for Inga III (1,344 MW), however long term plans for Grand Inga Dam (39,000 MW), which if completed would have been double the size of the Three Gorges Dam, currently the largest energy-generating body ever built, have recently been repealed due to the catastrophic impacts both at a local and global scale (Showers 2009). This has instead been replaced with designs for Grand Inga Cascades, which are

Figure 8.5 Major current threats to freshwater species in central Africa.



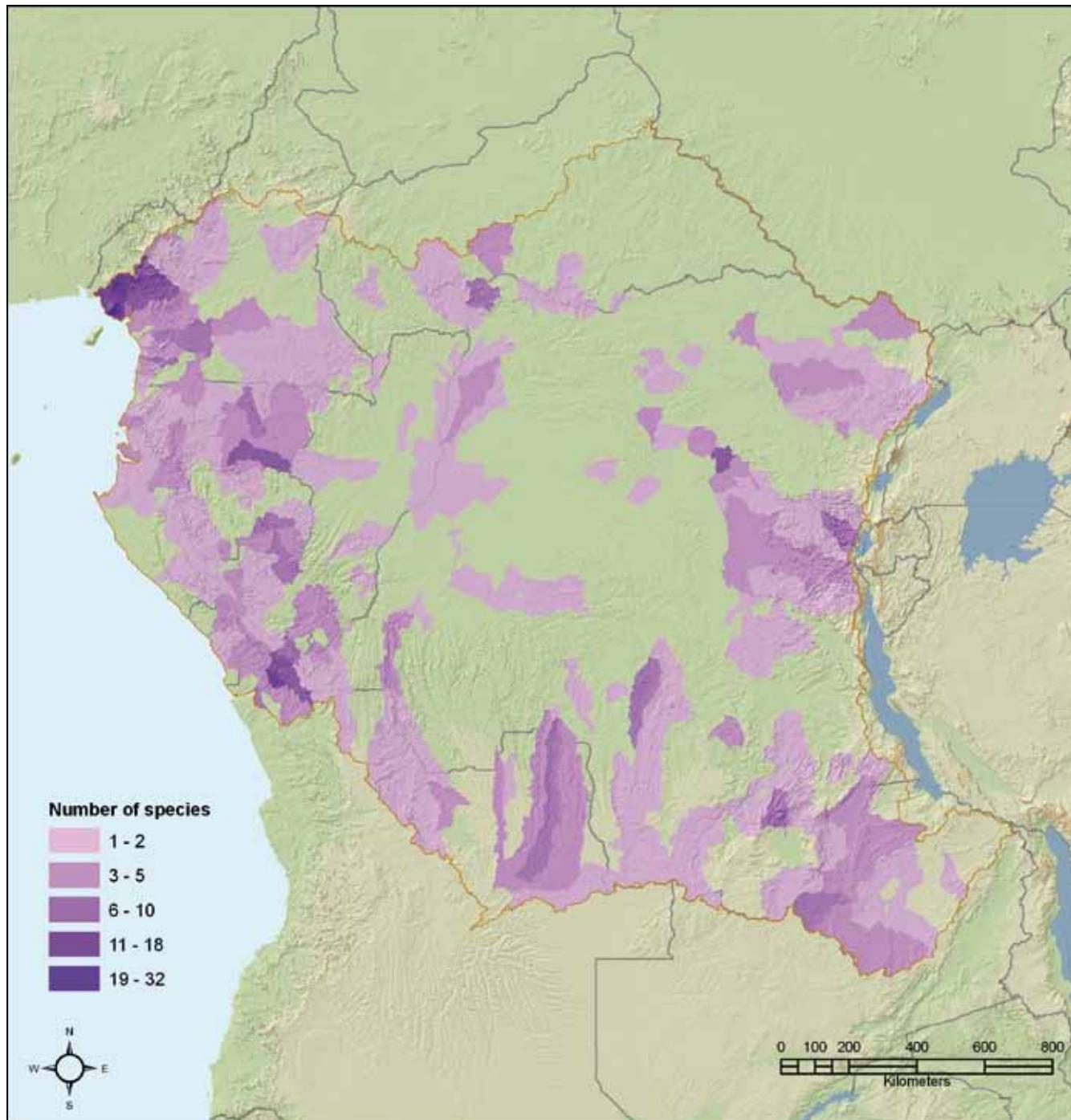
'run of the river' structures intended not to disrupt the river flow.

Figure 8.5 shows the major current threats to freshwater biodiversity in central Africa (for more detail on the threats to freshwater ecosystems in central Africa, see Chapter 1). Habitat loss is the largest threat, with deforestation, agriculture and mining, affecting 64% of assessed species. Sedimentation is a particular threat to molluscs, but still affects 12% of all freshwater species in the region. Water pollution from agriculture impacts 9% of all assessed species. Invasive species are a major threat to some areas of Africa, particularly eastern and southern

Africa; however, within central Africa this is only thought to be impacting around 1% of species. Although 52% of species have no known threats at present, only 2% of these are within threatened categories, illustrating that the vast majority of threatened species are facing threats now, and are not categorised as threatened on account of plausible future threats. Action must therefore be taken immediately to reduce the decreasing population trends these species are likely to be experiencing. For a further 39% of the species, threats are potentially present but there is insufficient information available to be sure (classified as "unknown").

8.1.3 Distribution of restricted range species

Figure 8.6 Number of species of fishes, molluscs, odonates and crabs restricted to single Hydro 1 K level 3 sub-basins. The distributions are mapped to the level 6 basin level.



Species with restricted ranges were defined as those regionally endemic species restricted to any level 3 river basin as defined in the HYDRO1k data layer. It is worth noting that basin sizes in the region do vary quite largely, from 98 km² to a maximum of 306,952 km², with an average of 32,726 km². The greatest density of restricted range species is found in the north-western area of the central Africa region, in the vicinity of the Lower Cross River and the **Western Equatorial Crater Lakes** (Figure 8.6). Other areas supporting a large number of range restricted species are the **Upper and Lower Congo Rapids**.

8.2 Conservation priorities for the region

Central Africa supports the highest diversity of freshwater species within Africa, of which a significant proportion are threatened. As development across the region increases the status of central Africa's freshwater biodiversity will worsen unless successful conservation measures can be undertaken.

An immediate priority is to implement conservation actions in the basins that have been identified to contain exceptional levels of species diversity (see section 8.1.1) and those containing high levels of threatened species (section 8.1.2). These actions need to address the total impacts of key threats, such as the downstream impacts of deforestation leading to sedimentation, and agricultural and mining pollution, and the upstream impacts of dams through the loss of riverine habitat and impacts to migration routes and natural dispersal. If this situation continues along current trends some species will become extirpated from catchments, and given the high levels of endemism in the area, are at risk of becoming globally Extinct. Ecosystem level consequences from the loss of freshwater species are poorly understood, as are the knock on effects to the services they provide to human populations so a precautionary approach is required. It is often the poorest communities that rely most heavily upon freshwater resources, such as for protein source, for building materials, and for income when subsistence harvest surpluses are sold. For instance, in the Salonga river system, revenue's from fishing account for 61% of cash income, and unlike agriculture, provide a year-round revenue. In these cases fishing acts as a 'bank in the water', allowing the local population access to an income source quickly to pay for basic necessities as and when costs arise (Béné *et al.* 2009). Consequently, this poorest section of the community, which has few alternative livelihood options, suffers heavily when species are lost and ecosystems are degraded.

8.2.1 Filling the information gaps

As stated above, central Africa contains the highest proportion of Data Deficient species of any region in Africa (Table 8.3), with a range from 19% of mollusc species to 32% of crab species falling into this Category, and up to 45% of odonates if only endemics are considered. Areas of particular need for research can be highlighted through mapping the extent of Data Deficient species ranges where available (Figure 8.7). Plants were not included in this analysis as

a high proportion are currently mapped at country level; a strong indication of the need for more specific locality data for flora in particular. In addition to those areas also identified as centres of species richness (Figure 8.2), it is also clear that there is a deficit of information in the headwater regions of the River Congo.

Further research and survey work are needed to gather more information on these species' distributions, taxonomy, ecology and their utilisation and threats. Due to their cultural history, central Africa and DRC in particular are greatly understudied areas, and more data are required to fill this information gap in order to complete a more comprehensive assessment of the entirety of Africa's freshwater systems. Findings from future field surveys will undoubtedly uncover more threatened species, and will likely add to the growing body of evidence that freshwater biodiversity has great value to local livelihoods.

8.2.2 Protected Areas

Protected areas need to be specifically designed for the protection of freshwater species, particularly those that have restricted ranges or limited numbers of congregation, migration or breeding sites. Design must take good account of the high connectivity within freshwater systems if the protected areas are to be effective. For example, the success of a protected area established for freshwater species conservation may be greatly reduced if upstream activities, often some distance outside the protected area boundaries, such as excessive water withdrawal or regulation, alter the downstream

Fisherman collecting net, Sanaga River, Cameroon. Photo: © Kevin Smith.



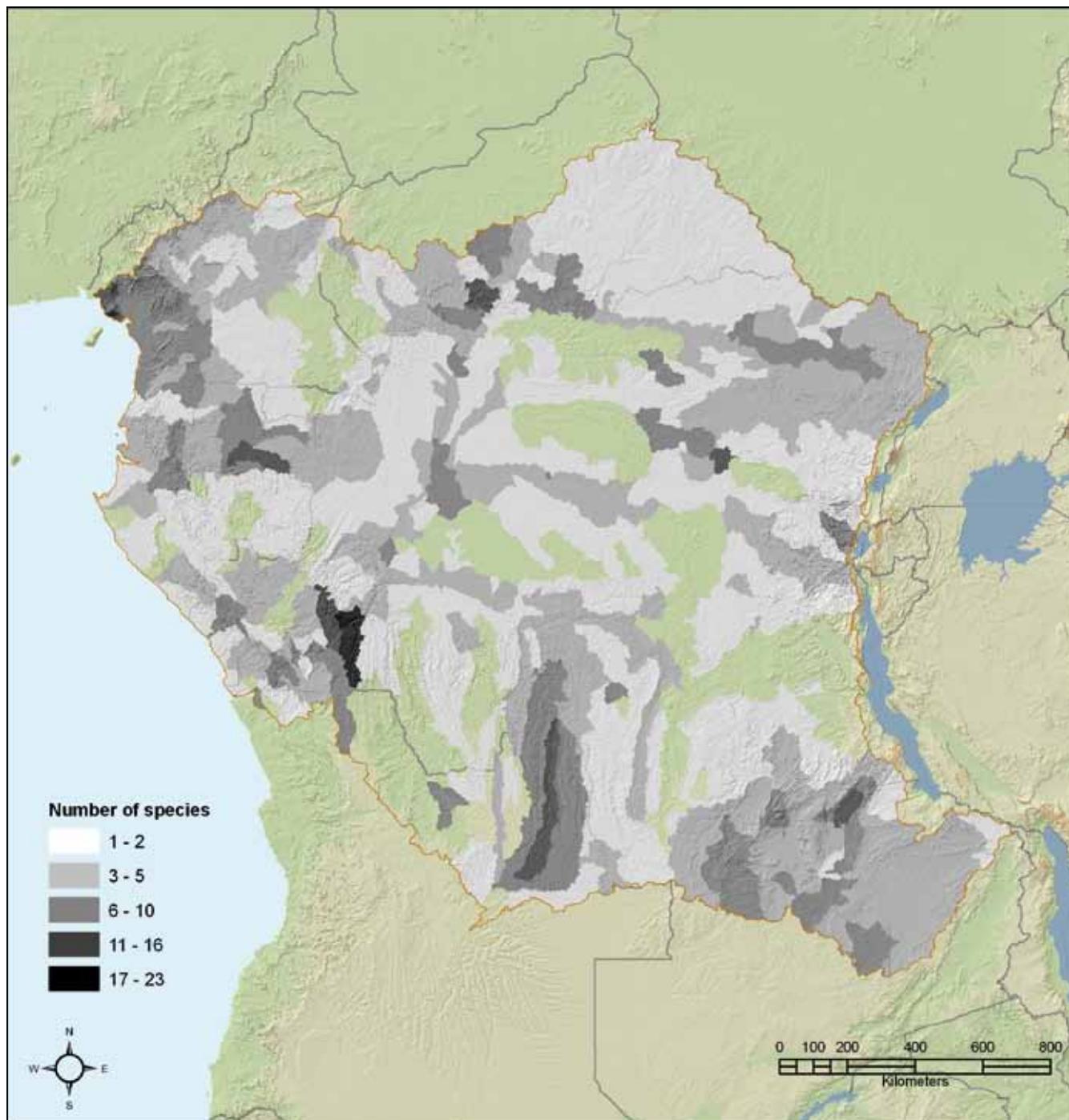
flow regime within the protected area to the detriment of those species being protected. A good understanding of the threats and ecology of the target species, as provided here, is often essential for optimising the design of the protected area. As central Africa is relatively un-developed, there is still an opportunity to identify and protect relatively pristine areas, and the development of protected areas and parks is an essential component of conservation recommendations. It is, however, critical that there are sufficient funds and the means to implement and manage conservation areas, particularly in the more isolated areas, most at risk from human encroachment. Without an increased

capacity to manage these areas protected areas may be of little conservation value.

8.2.3 Key Biodiversity Areas (KBAs)

Key Biodiversity Areas are sites of global significance for biodiversity conservation. Standard criteria can be applied to identify areas pivotal for the maintenance of species populations important for conservation, based on a framework of **vulnerability** and **irreplaceability** (Langhammer *et al.* 2007). Irreplaceability refers to the spatial options for conservation

Figure 8.7 Distribution of fishes, molluscs, odonates and crabs classified as Data Deficient, mapped to river sub-catchments. Only those species with locality information could be mapped.



of a species, in other words, how unique is a site critical for a species existence, and what other options for its conservation exist. Vulnerability is a measure of the probability that a site's biodiversity will be lost in the future. In freshwater terms these are defined within a practicable management unit, such as a river or lake basin. As part of the Pan-Africa assessment the IUCN Species Programme has developed a series of criteria to identify sub-catchments as Key Biodiversity Areas based on vulnerability and irreplaceability (Darwall and Vié 2005). These are:

Criteria 1: A site is known or thought to hold a significant number of one or more globally threatened species or other species of conservation concern. This is the vulnerability based criteria as it identifies sub-catchments containing species with the highest risk of being lost in the future. To apply this criterion each species must be assessed using the IUCN Red List, with those classified as Vulnerable, Endangered or Critically Endangered triggering KBA qualification.

Criteria 2: A site is known or thought to hold non-trivial numbers of one or more species (or infraspecific taxa as appropriate) of restricted range. This is the first of the irreplaceability criteria. Threshold values for restricted range differ between taxonomic groups. For fish, crabs and molluscs the threshold value was set as less than 20,000 km² and for odonates the threshold value was set at less than 50,000 km².

Criteria 3: A site is known or thought to hold a significant component of the group of species that are confined to an appropriate biogeographic unit or units. This is the second of the irreplaceability criteria. Freshwater Ecoregions of the World (Abell *et al.* 2008) were utilised as the biogeographic units and for each sub-catchment the proportion of species that occur in just one ecoregion was calculated. A sub-catchment qualifies under criterion 3 if 25% or more of the species within it are restricted to the ecoregion.

A KBA can be identified under the vulnerability and the irreplaceability criteria simultaneously; indeed many species trigger more than one criterion. A KBA network defined according to the presence of species meeting the criteria would be expected to include all sites that play a crucial role in maintaining the global population of these species.

KBA analysis for the irreplaceability criterion includes mapped species that are currently listed as Data Deficient. Additional field surveys may prove a species to be more widespread, however, until known otherwise, we should assume these species have restricted ranges and are of conservation concern.

Based on these criteria we identified 471 level 6 sub-catchments in central Africa that would qualify as potential freshwater Key Biodiversity Areas (Figure 8.8). These sub-basins may qualify as KBAs independently or as a combination of connected sub-catchments, depending on local management options, and can be applied to define a graduation of freshwater protected areas, from a freshwater focal point, to a critical management zone or

a catchment management zone (Abell *et al.* 2007). For instance, a single level 6 sub-catchment, such as that associated with the Western Equatorial Crater Lakes, might be defined as the appropriate management unit for *Stomatelia mongo* and would therefore qualify as a KBA in its own right. More often, the most practical management unit will consist of connected level 6 sub-catchments, such as those making up the Ubangi River.

8.2.4 Environmental Impact Assessments (EIAs)

EIAs, when correctly undertaken, are a valuable tool for informing the development planning process, particularly where threatened or restricted range species are expected to be found. This report (and the IUCN Red List website) provides data useful to the initial planning stages of EIAs, as the expected species composition of every sub-catchment in the region can be identified, along with information on species ecology, and their conservation status in the wider global or regional context. This information is of great value in that it enables the person conducting the EIA to better understand the conservation value of a species through knowing whether it is endemic to a particular river basin or is threatened. It should be noted, however, that the spatial data presented are of too low resolution to replace the need for additional field surveys as required for a fully comprehensive EIA.

8.2.5 Integrated Water Resource Management (IWRM) and Environmental Flows

The interaction between anthropogenic requirements from a freshwater ecosystem and its requirements for maintaining basic ecological function is complex, and many human activities if badly managed can have direct and devastating impacts on freshwater ecosystems. With this in mind, water resources must be managed in a way that the ecological requirements of freshwater species are considered when planning and managing use of hydrological resources, in order to ensure the maintenance of goods and services that those ecosystems provide. Integrated Water Resource Management (IWRM) is a concept of integrating the work of conservation in maintaining ecosystem functions whilst maximising economic and social benefits from a given river basin (see the Global Water Partnership Toolbox for more information on IWRM and case studies, at www.gwptoolbox.org). A component of IWRM is the management of Environmental Flows, defined as "the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated. Environmental flows provide critical contributions to river health, economic development and poverty alleviation. They ensure the continued availability of the many benefits that healthy river and groundwater systems bring to society" (Dyson *et al.* 2003). Management of Environmental Flows aims to maintain the health of freshwater ecosystems through defining and providing the specific water requirements of those freshwater species within the system. These species not only require a specific quantity and quality of water to flow, but the timing of the flow cycle may be critical for such events as spawning

and migration in some fish species. The biodiversity assessments conducted here provide a baseline dataset of the species found within each catchment, and information on their basic ecological requirements and life history. More detailed studies can then be focused on those species for which specific flow requirements are thought to be most critical.

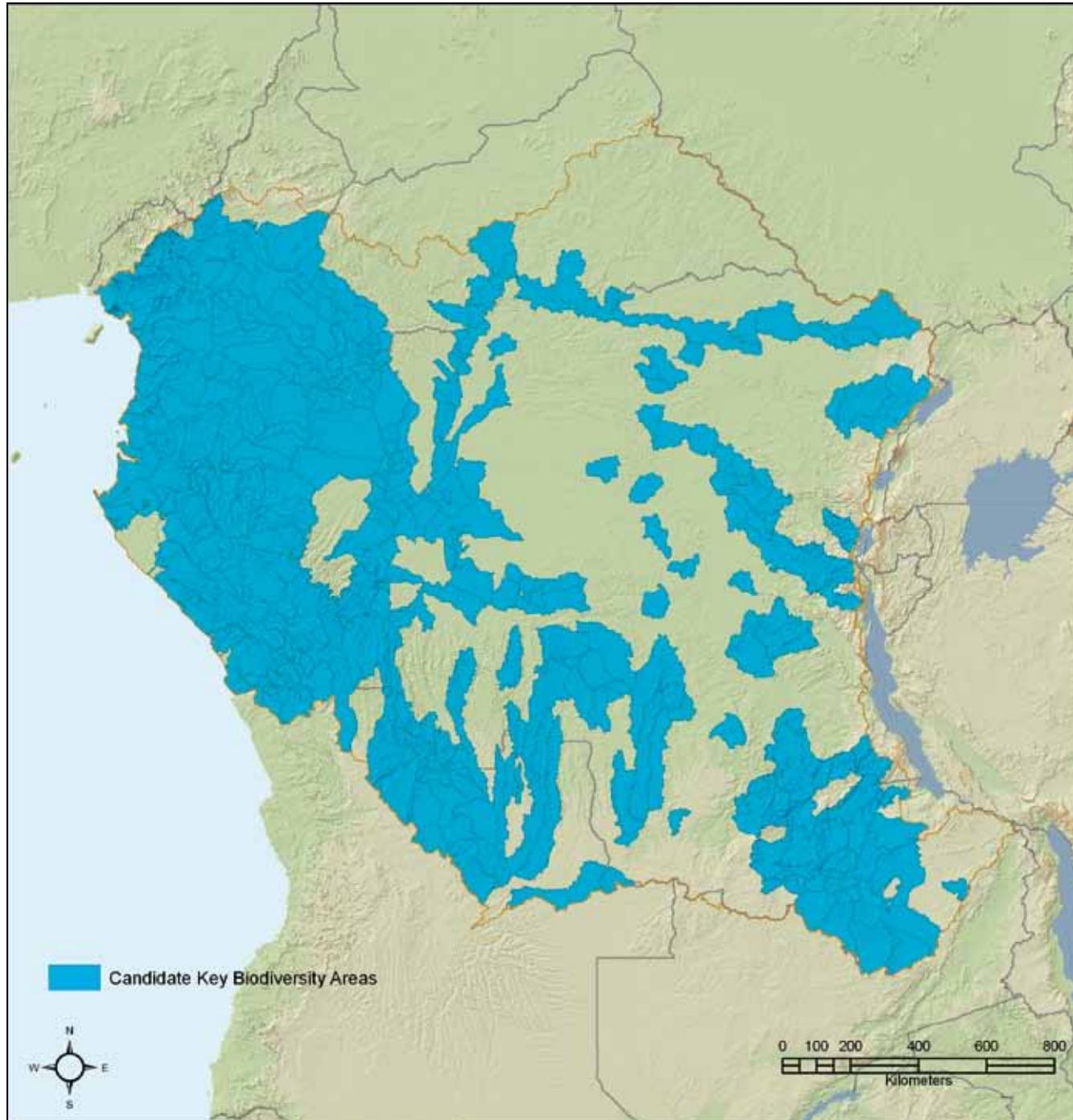
8.2.6 Outputs for decision makers

One of the most challenging parts of the process is presentation of the biodiversity assessment outputs in a format which is suitable and accessible to the widest range of stakeholders. In particular, outputs need to be accessible to natural resource

managers, developers and policy makers. This requires production of a range of products, including brief summaries of the issues and recommendations (policy briefs), more detailed technical reports, and comprehensive data sets. This report will serve as the detailed technical report of the assessment findings, and the full database including electronic maps for all species distributions is provided in the attached DVD. All species global assessments and distribution maps (jpeg) will be directly accessible online through the IUCN website (www.iucnredlist.org). Regional assessments are also available at <http://www.iucnredlist.org/initiatives/freshwater/centralafrica>. Ultimately, all species distribution maps will be accessible online.

Identification of the primary end-users of this information is also

Figure 8.8 Potential Key Biodiversity Areas (KBAs) for the central Africa region, mapped to river sub-catchments.



a challenge given the multitude of different organizations with overlapping and sometime contradictory jurisdiction for the management of wetland ecosystems. Preliminary efforts have been taken to identify these stakeholders through an online survey of end-user data needs but more work needs to be done in this area. The preliminary results can be found at: www.unep-wcmc.org/freshwater_biodiversity/Africa/survey/.

In conclusion, we hope that the information provided through this assessment will be taken up by the key stakeholders in freshwater ecosystems throughout central Africa and will be integrated in the decision making processes for environmental and development planning in wetland ecosystems. In this way, we hope that the future impacts of development actions affecting inland water ecosystems can be minimized and mitigated to the benefit of freshwater species and those people who rely on freshwater species for their livelihoods and pleasure.

8.3 References

- Abell, R., Allan, J.D. and Lehner, B. 2007. Unlocking the potential of Protected Areas for freshwaters. *Biological Conservation* **134**:48–63.
- Abell, R., Thieme, M.L., Revenga, C., Bryer, M., Kottelat, M., Bogutskaya, N., Coad, B., Mandrak, N., Balderas, S.C., Bussing, W., Stiassny, M.L.J., Skelton, P., Allen, G.R., Unmack, P., Naseka, A., Ng, R., Sindorf, N., Robertson, J., Armijo, E., Higgins, J.V., Heibel, T.J., Wikramanayake, E., Olson, D., López, H.L., Reis, R.E., Lundberg, J.G., Sabaj Pérez, M.H. and Petry, P. 2008. Freshwater Ecoregions of the World: A New Map of Biogeographic Units for Freshwater Biodiversity Conservation. *BioScience* **58**:403.
- Balian, E.V., Segers, H., Lévéque, C. and Martens, K. 2008. The Freshwater Animal Diversity Assessment. *Hydrobiologia* **595**:1–637.
- Béné, C., Steel, E., Luadia, B. K. and Gordon, A. 2009. Fish as the “bank in the water” – Evidence from chronic-poor communities in Congo. *Food Policy* **34**(1):108–118.
- Birdlife International 2010. IUCN Red List for Birds. Birdlife International, Cambridge, UK.
- Darwall, W. and Vié, J.C. 2005. *Identifying important sites for conservation of freshwater biodiversity: extending the species-based approach*. Gland, Switzerland and Cambridge, UK: IUCN.
- Darwall, W. R. T., Smith, K.G., Tweddle, D. and Skelton, P. (eds.) 2009. *The Status and Distribution of Freshwater Biodiversity in Southern Africa*. Gland, Switzerland and Grahamstown, South Africa: IUCN and SAIAB.
- Dyson, M., Bergkamp, G. and Scanlon, J. (eds.) 2003. *Flow. The Essentials of Environmental Flows*. IUCN, Gland, Switzerland and Cambridge, UK.
- García, N., Cuttelod, A. and Abdul Malak, D. (eds.) 2010. *The Status and Distribution of Freshwater Biodiversity in Northern Africa*. IUCN, Gland, Switzerland, Cambridge, UK, and Malaga.
- IUCN 2010. 2010 IUCN Red List of Threatened Species. www.iucnredlist.org.
- Langhammer, P.F., Bakarr, M.I., Bennun, L.A., Brooks, T.M., Clay, R.P., Darwall, W., De Silva, N., Edgar, G., Eken, G., Fishpool, L., Fonseca, G.A.B. da, Foster, M., Knox, D.H., Matiku, P., Radford, E.A., Rodrigues, A.S.L., Salaman, P., Sechrest, W. and Tordoff, A. 2007. *Identification and Gap Analysis of Key Biodiversity Areas as Targets for Comprehensive Protected Area Systems*. IUCN, Gland, Switzerland.
- Showers, K.B. 2009. Congo River’s Grand Inga hydroelectricity scheme: linking environmental history, policy and impact. *Water Hist.* **1**:31–58.
- Shumway, C.A., Musibono, D., Ifuta, S., Sullivan, J., Schelly, R., Punga, J., Palata, J.-C. and Puema, V. 2003. *Congo River Environment and Development Project (CREDP) biodiversity survey: systematics, ecology and conservation along the Congo River, September–October 2002*. New England Aquarium Press, Boston, MA, USA.
- Smith, K.G., Diop, M.D., Niane, M. and Darwall, W.R.T. (eds.) (2009). *The Status and Distribution of Freshwater Biodiversity in Western Africa*. Gland, Switzerland and Cambridge, UK: IUCN.
- Teugels, G.G. and Thieme, M.L. 2005. Freshwater Fish Biodiversity in the Congo Basin. In: Thieme, M.L., Abell, R., Stiassny, M.L.J., Skelton, P., Lehner, B., Teugels, G.G., Dinerstein, E., Kamdem Toham, A., Burgess, N. and Olson, D. (eds.) 2005. *Freshwater ecoregions of Africa and Madagascar: a conservation assessment*. Island Press, Washington DC, USA.
- Thieme, M.L., Abell, R., Stiassny, M.L.J., Skelton, P., Lehner, B., Teugels, G.G., Dinerstein, E., Kamdem Toham, A., Burgess, N. and Olson, D. 2005. *Freshwater Ecoregions of Africa and Madagascar: a conservation assessment*. Island Press, Washington DC, USA.
- UNEP 1999. *Regional overview of land-based sources and activities affecting the coastal and associated freshwater environment in the West and Central Africa region*. Regional Seas Reports and Studies No. 171. UNEP/GPA Co-ordination Office and West and Central Africa Action Plan, Regional Co-ordinating Unit, The Hague, The Netherlands, and Abidjan, Côte d’Ivoire.

Appendix 1. Example species summary and distribution map

<u><i>Stenocnemis pachystigma</i></u>		LC	
Taxonomic Authority: (Selys, 1886)		<input type="checkbox"/> Global Assessment <input checked="" type="checkbox"/> Regional Assessment	
		Region: Central Africa	
		<input type="checkbox"/> Endemic to region	
Upper Level Taxonomy			
Kingdom:	ANIMALIA	Phylum:	ARTHROPODA
Class:	INSECTA	Order:	ODONATA
Family:	PLATYCNEMIDIDAE		
Lower Level Taxonomy			
Rank:	Infra- rank name:	<input type="checkbox"/> Plant Hybrid	
Subpopulation:	Authority:		
General Information			
Distribution			
Global distribution: Southwestern Cameroon and adjacent southeast Nigeria. Historic record from Sierra Leone is assumed to be erroneous (mislabelling of locality, Dijkstra pers. comm.).			
Central Africa regional assessment: Southwestern Cameroon and Congo.			
Range Size	Elevation	Biogeographic Realm	
Area of Occupancy:	Upper limit:	<input checked="" type="checkbox"/> Afrotropical	
Extent of Occurrence:	Lower limit:	<input type="checkbox"/> Antarctic	
Map Status:	Depth	<input type="checkbox"/> Australasian	
	Upper limit:	<input type="checkbox"/> Neotropical	
	Lower limit:	<input type="checkbox"/> Oceanian	
	Depth Zones	<input type="checkbox"/> Palearctic	
	<input type="checkbox"/> Shallow photic	<input type="checkbox"/> Indomalayan	
	<input type="checkbox"/> Photic	<input type="checkbox"/> Nearctic	
	<input type="checkbox"/> Bathyl		
	<input type="checkbox"/> Hadal		
	<input type="checkbox"/> Abyssal		
Population			
No information available.			
Total Population Size			
Minimum Population Size:	Maximum Population Size:		
Habitat and Ecology			
The species appears to have a very specialised habitat. Larvae probably pertaining to this species were found among roots on dripping rockfaces beside a waterfall in submontane (i.e. above 700 m) rainforest (Vick 1998).			
System	Movement pattern	Crop Wild Relative	
<input type="checkbox"/> Terrestrial	<input checked="" type="checkbox"/> Freshwater	<input type="checkbox"/> Is the species a wild relative of a crop?	
	<input type="checkbox"/> Nomadic	<input type="checkbox"/> Congregatory/Dispersive	
	<input type="checkbox"/> Migratory	<input type="checkbox"/> Altitudinally migrant	

Threats

The specific threats to the species in Cameroon and southeast Nigeria are unknown but forest destruction is believed to be potential threat.

	Past	Present	Future
1 Habitat Loss/Degradation (human induced)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1.1 Agriculture	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1.1.1 Crops	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1.3 Extraction	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1.3.3 Wood	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1.3.3.2 Selective logging	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Conservation Measures

No information available. Further research into the species habitat, ecology, population, range and threats is required, as well as monitoring of population trends.

	In Place	Needed
3 Research actions	<input type="checkbox"/>	<input checked="" type="checkbox"/>
3.2 Population numbers and range	<input type="checkbox"/>	<input checked="" type="checkbox"/>
3.3 Biology and Ecology	<input type="checkbox"/>	<input checked="" type="checkbox"/>
3.4 Habitat status	<input type="checkbox"/>	<input checked="" type="checkbox"/>
3.5 Threats	<input type="checkbox"/>	<input checked="" type="checkbox"/>
3.9 Trends/Monitoring	<input type="checkbox"/>	<input checked="" type="checkbox"/>

Countries of Occurrence

	PRESENCE							ORIGIN				
	Year Round	Breeding Season only	Non-breeding season only	Passage migrant	Possibly extinct	Extinct	Presence uncertain	Native	Introduced	Re-introduced	Vagrant	Origin uncertain
Cameroon	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>						
Congo	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>						

General Habitats

	Score	Description	Major Importance
1 Forest	1	Suitable	Unset
1.6 Forest - Subtropical/Tropical Moist Lowland	1	Suitable	Unset
5 Wetlands (inland)	1	Suitable	Unset
5.1 Wetlands (inland) - Permanent Rivers/Streams/Creeks (includes waterfalls)	1	Suitable	Unset

Land Cover

	Score	Description
Water Bodies (natural & artificial)	1	Suitable

Ecosystem Services

Insufficient Information available Species provides no ecosystem services

Species Utilisation

Species is not utilised at all

IUCN Red Listing

Red List Assessment: (using 2001 IUCN system) Least Concern (LC)

Threat category adjusted from Global to Regional status: No Change in Category

Red List Criteria:

Date Last Seen (only for EX, EW or Possibly EX species):

Is the species Possibly Extinct? Possibly Extinct Candidate?

Rationale for the Red List Assessment

The species is present over a wide range within the region and is assessed as Least Concern.

Reason(s) for Change in Red List Category from the Previous Assessment:

- | | | |
|--|---|--|
| <input type="checkbox"/> Genuine Change | <input type="checkbox"/> Nongenuine Change | <input type="checkbox"/> No Change |
| <ul style="list-style-type: none"> <input type="checkbox"/> Genuine (recent) <input type="checkbox"/> Genuine (since first assessment) | <ul style="list-style-type: none"> <input type="checkbox"/> New information <input type="checkbox"/> Knowledge of Criteria <input type="checkbox"/> Incorrect data used previously | <ul style="list-style-type: none"> <input type="checkbox"/> Taxonomy <input type="checkbox"/> Criteria Revisio <input type="checkbox"/> Other |
| | | <ul style="list-style-type: none"> <input type="checkbox"/> Same category and criteria <input type="checkbox"/> Same category but change in criteria |

Current Population Trend: Unknown

Date of Assessment: 19/03/2008

Name(s) of the Assessor(s): Dijkstra, K.D, Kipping, J., and Schutte, K., Odonata Specialist Group, Central Africa Evaluation wor

Evaluator(s): Clausnitzer, V.

Notes:

B1ab(ii,iii) VU

Short-listed by Dijkstra & Vick (2004) as western African odonate requiring special attention. Estimated to occur in 10 or less locations within a 20,000 km² area of forest habitat, which is expected to deteriorate in the future due to illegal logging and agricultural expansion and is therefore listed as Vulnerable.

% population decline in the past:

Time period over which the past decline has been measured for applying Criterion A or C1 (in years or generations):

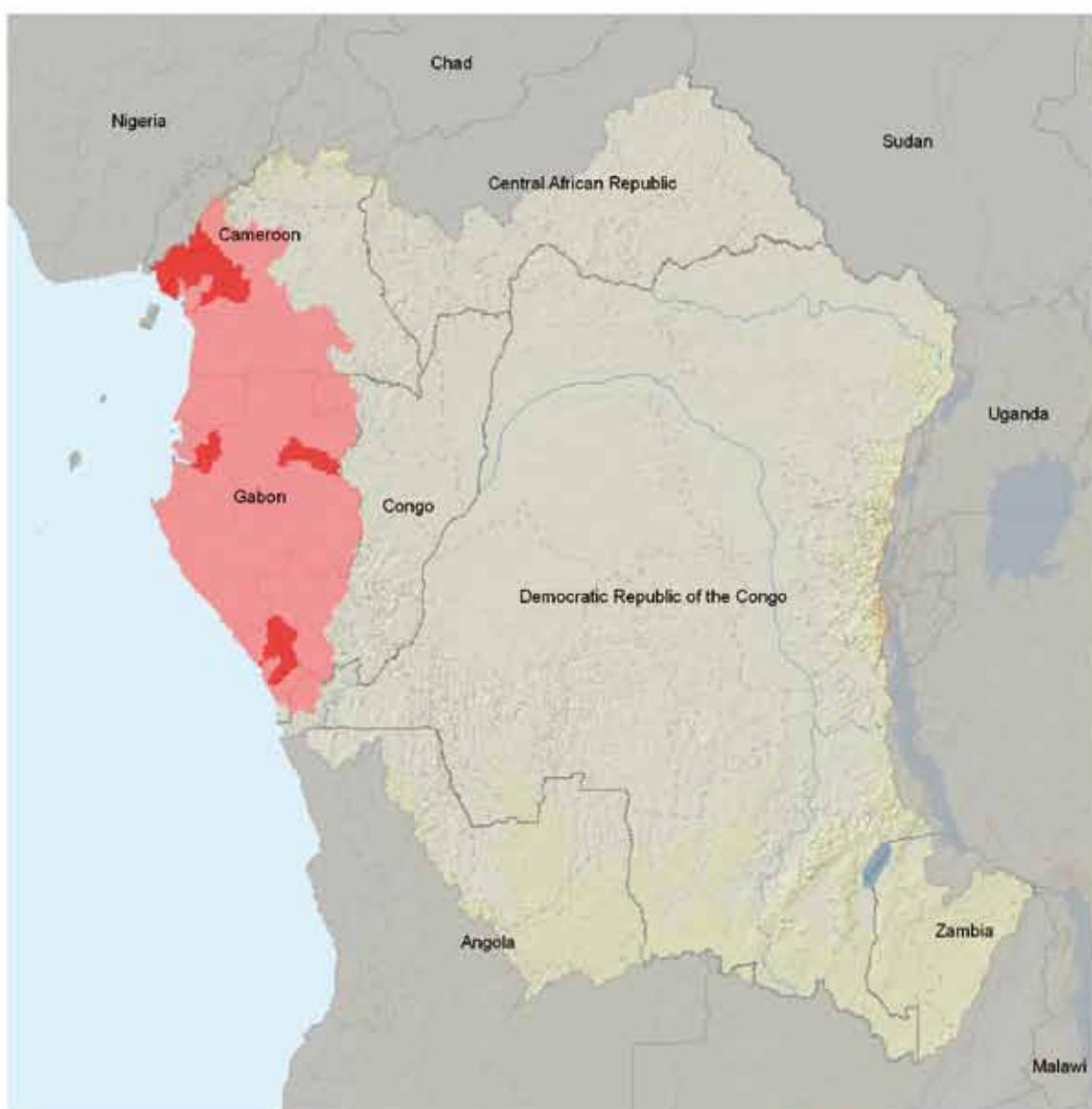
% population decline in the future:

Time period over which the future decline has been measured for applying Criterion A or C1 (in years or generations):

Number of Locations:

Severely Fragmented:

Number of Mature Individuals:



Stenocnemis pachystigma

NE DD LC NT VU EN CR EW EX
gall stereographic central point: 0°, 0°
map created 11/26/2010

range type (native)

- █ Extant
- █ Probably extant

- national boundaries
- - - subnational boundaries
- lakes, rivers, canals
- salt pans, intermittent rivers



data source: (See spatial data for detailed source information)
Odonata Database Africa

Mapped to river catchments and lake boundaries

0 680 kilometer

The boundaries and names shown and the designations used on this map do not imply any official endorsement, acceptance or opinion by IUCN.
The data used for the regional maps is the most up-to-date possible, which may be more recent than that used for the creation of the regional assessment itself.



THE IUCN RED LIST
OF THREATENED SPECIES™

Central Africa Regional Assessment

Appendix 2. Data DVD

- (i) Executive Summary
- (ii) Central Africa Assessment Report PDF
- (iii) Species Summaries
- (iv) Species Maps
- (v) Species Shapefiles
- (vi) Species Lists

IUCN Red List of Threatened Species™ – Regional Assessment

Africa

The Status and Distribution of Freshwater Biodiversity in Eastern Africa. Compiled by William R.T. Darwall, Kevin G. Smith, Thomas Lowe and Jean-Christophe Vié, 2005.

The Status and Distribution of Freshwater Biodiversity in Southern Africa. Compiled by William R.T. Darwall, Kevin G. Smith, Denis Tweddle and Paul Skelton, 2009.

The Status and Distribution of Freshwater Biodiversity in Western Africa. Compiled by Smith, K.G., Diop, M.D., Niane, M. and Darwall, W.R.T. 2009.

The Status and Distribution of Freshwater Biodiversity in Northern Africa. Compiled by N. Garcia, A Cuttelod, and D. Abdul Malak. 2010.

Other regions

The Status and Distribution of Freshwater Fish Endemic to the Mediterranean Basin. Compiled by Kevin G. Smith and William R.T. Darwall, 2006.

The Status and Distribution of Reptiles and Amphibians of the Mediterranean Basin. Compiled by Neil Cox, Janice Chanson and Simon Stuart, 2006.

The Status and Distribution of European Mammals. Compiled by Helen J. Temple and Andrew Terry, 2007.

Overview of Cartilaginous Fishes (Chondrichthyans) in the Mediterranean Sea. Compiled by Rachel D. Cavanagh and Claudine Gibson, 2007.

European Red List of Amphibians. Compiled by Helen J. Temple and Neil Cox, 2009.

European Red List of Reptiles. Compiled by Neil Cox and Helen J. Temple, 2009.

The Status and Distribution of Dragonflies of the Mediterranean Basin. Compiled by Elisa Riservato, Jean-Pierre Boudot, Sonia Ferreira, Milos Jović, Vincent J. Kalkman, Wolfgang Schneider and Boudjéma Samraoui, 2009.

The Status and Distribution of Mediterranean Mammals. Compiled by Helen J. Temple and Annabelle Cuttelod, 2009.

The Status and Distribution of Freshwater Biodiversity in the Eastern Himalaya. Compiled by Allen, D.J., Molur, S., and Daniel, B.A. 2010.



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