



IDENTIFICATION AND VALIDATION OF WESTERN AFRICAN FRESHWATER KEY BIODIVERSITY AREAS

Edited by Thomas Starnes and William R.T. Darwall



The IUCN Red List of Threatened Species™ – Regional Assessment



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Cover photo: The Purple Marsh Crab *Afrithelphusa monodosa* inhabits burrows dug into moist soil in savannah wetlands. The species, known only from two locations in the north-west Guinea, was re-assessed on the IUCN Red List of Threatened Species™ as Endangered (EN) as part of this work. Its natural swamp habitat is threatened by agricultural expansion. © Piotr Naskrecki

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Executive summary

Western Africa is rich in freshwater biodiversity and regional endemism, supporting the entire global populations of many threatened freshwater species including fishes, molluscs, dragonflies, crabs, shrimps and aquatic plants. This report builds on a regional baseline assessment completed in 2009 as well as an assessment of freshwater Key Biodiversity Areas in 2015. The conservation status of freshwater species is found to be declining, but strikingly there is a lack of sufficient monitoring data to reveal conservation trends of freshwater species, with many species not having been observed for decades.

This report identifies key threats to specific species and locations, making recommendations for the conservation of these sites as Key Biodiversity Areas, as well as highlighting specific sites in urgent need of surveys and identifying critical research actions. It is hoped that the information presented here will be used by governments, conservation practitioners and researchers to help protect and conserve the unique freshwater biodiversity of western Africa through sustainable regional development.

Key messages

- **Western Africa supports a rich diversity of freshwater species, many of which are endemic.** Here we provide a regional re-assessment, building on the previous assessment and bringing in new data to support the analysis. We report on the global conservation status of some 1,502 freshwater species, including 555 species of freshwater fishes, 100 species of freshwater molluscs, 307 species of odonates (dragonflies and damselflies), 54 species of freshwater decapods (crabs and shrimps) and 486 species of aquatic plants, drawing on data from the IUCN Red List of Threatened Species™.
- **Freshwater species are threatened with extinction.** We find that 213 species, or 14% of all native freshwater species, are globally threatened with extinction. The level of threat varies substantially between taxonomic groups. Of the aquatic plants and odonates, 4% and 5% are threatened, respectively. However, other taxonomic groups face higher levels of threat; 25% of freshwater fishes and freshwater molluscs are globally threatened, and for the smallest taxonomic group assessed, the decapods, 37% are threatened.
- **Freshwater biodiversity is in decline.** The Red List Index shows an increased extinction risk for 1% of freshwater fishes and 6% of freshwater molluscs, but no change was detected for other groups. This is despite clear evidence pointing to increased environmental degradation and human pressure in the region during the previous 10 years. The Red List Index is a relatively coarse measure of changes in conservation status over time, and there is a lag between genuine change and change detected by the RLI. The Living Planet Index shows a 65% decline in species population abundance in Africa, and an 84% decline in freshwater populations globally.
- **Monitoring is urgently needed.** Standardised regional surveys have not been conducted for many years, if at all, and there are no significant long-term programmes for monitoring the state of freshwater biodiversity throughout the region. Many of the Red List assessments are therefore necessarily based on inferred declines in species populations or distributions based on habitat degradation, rather than robust scientific monitoring data. Novel survey techniques such as eDNA monitoring has huge potential to address the monitoring shortfall for freshwater biodiversity in western Africa.
- **Major threats to freshwater biodiversity stem from pollution, habitat loss, harvesting, mining and water management.** Certain threats have disproportionate impact on specific taxonomic groups, such as mining on fishes or drought on plants. The most frequently identified threat to freshwater species is pollution from agricultural and industrial effluents and wastewater.

- **Actions must be taken to halt and reverse declines to freshwater diversity in western Africa.** It is vital that conservation actions are implemented to halt and reverse the declines to freshwater biodiversity where possible. Conservation actions are recommended here in this report, for each taxonomic group and for freshwater biodiversity overall.
- **Key Biodiversity Areas are sites of global importance for the conservation of biodiversity.** Here we revise the CEPF freshwater KBAs of the Guinean Forests of West Africa, re-assessing them against the Global KBA Standard and identifying next steps for their recognition and conservation. We also describe a large KBA capacity-building process that has been undertaken regionally.
- **A few critical sites contain irreplaceable populations of threatened species.** Some twenty-two sub-catchments are identified as irreplaceable sites, representing the only localities of thirty-nine threatened freshwater species. These sites can be used as a basis to a) ensure greater management focus on the unique freshwater biodiversity elements at these sites; b) target identification of Key Biodiversity Areas and designation of protected and conserved areas, and c) safeguard these critical sites for freshwater biodiversity in the face of wide-scale and rapid development across the region.
- **Freshwater biodiversity supports livelihoods and food security.** Income from fisheries combined with that from agriculture contributes to poverty alleviation for a rapidly growing population. The role of small-scale inland fisheries is often marginalised in political, economic and conservation policies, and their contribution to food security, livelihoods local and national economies must be recognised and taken into account by decision makers, to ensure that these benefits continue to be realised.
- **The data collated and presented in this report should be used by decision makers to inform sustainable development in western Africa whilst safeguarding its globally significant freshwater biodiversity.** Recommendations are made for the conservation of species and their habitats, for further research opportunities and for the integration of freshwater biodiversity into the mainstream conservation agenda, such as through spatial conservation prioritisation exercises and the designation of Key Biodiversity Areas. This report was disseminated with a policy brief to relevant stakeholders throughout the region by the IUCN Central and West Africa Regional Office (PACO).

Chapter 1

Introduction

Darwall, W.R.T.¹

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1.1 Background

From 2020 to 2050 most of the world’s population growth is predicted to take place in Africa. This will lead to increased pressure on natural resources, such as those provided by wetland ecosystems. For example, energy demands are growing in Africa at twice the global average such that expansion of hydropower is predicted to increase significantly providing more than 23% of Africa’s power by 2040. More than 50 hydropower projects are currently under construction in Africa (International Hydropower Association, 2020). With the majority of people forecast to be food insecure in 2020 living in Africa, conversion of land to agriculture is also set to continue increasing. This would put further pressure on wetlands for conversion to agriculture. These and many other building pressures on wetland ecosystems have already led to a major loss and degradation of freshwater biodiversity in the western Africa region according to the baseline assessment completed in 2009 (Smith et al., 2009). The massive urbanisation and growth of cities such as Lagos, Accra, and Freetown are also creating significant pressure on freshwater ecosystems, such as through pollution and the increasing demand for natural resources, such as sand for construction. Eleven years later we now report how the status of freshwater ecosystems in the western Africa region has changed over this time period

and initiate a process for identifying those sites important for the conservation of freshwater species, known as Key Biodiversity Areas (KBAs). Having identified species of concern and critical sites for their protection we can now help inform and stimulate on-the-ground conservation action following the IUCN Species Survival Commissions adopted “ASSESS-PLAN-ACT” cycle.

1.2 Global status of freshwater biodiversity

Despite the estimated \$4 trillion annual value of ecosystem services provided to support human life there is a global freshwater biodiversity crisis (Béné et al., 2016; Costanza et al., 2014; Lynch et al., 2016; Youn et al., 2014). The declining status of freshwater ecosystems and their constituent species is now well known and widely reported (e.g. Darwall et al., 2018). An estimated three-quarters of the world’s inland natural wetlands were lost during the 20th century (Davidson, 2014) and this has led to a significant decline in freshwater species diversity. According to the International Union for Conservation of Nature (IUCN, 2021) approximately one in three of the approximately 34,000 species dependent upon freshwater habitats thus far assessed is threatened with extinction. A subset of freshwater 3,741 vertebrate populations monitored over time has declined

¹ Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

on average by more than 84% between 1970 and 2016, a rate of decline roughly twice that recorded for either marine or terrestrial systems (WWF, 2020).

This loss and degradation of freshwater biodiversity has far reaching implications with respect to our chances for achieving many of the globally agreed goals and targets, such as the Sustainable Development Goals (SDGs). For example, the SDGs include targets to protect and restore water-related ecosystems (Target 6.1); to ensure the conservation, restoration, and sustainable use of terrestrial and inland freshwater ecosystems, and their services (Target 15.1); and to reduce the degradation of natural habitats, halt the loss of biodiversity, and protect and prevent the extinction of threatened species (Target 15.5). Despite these laudable objectives it is clear that without a change in direction these and other targets for freshwater ecosystems will not be met and these failures will in many cases undermine other goals, such as for reduction in poverty and hunger, both of which rely heavily on resources from freshwaters, such as inland fisheries.

The good news is that we know what is needed to reverse this decline but it will take a major change in direction if we are to succeed. An Emergency Recovery Plan for freshwater biodiversity (Tickner et al., 2020) has been developed which needs to be implemented. Developed by scientists and freshwater experts from across the world, this practical, science-based plan incorporates six pillars –each of which has been demonstrated to be effective through case studies across the world.

1. Let rivers flow more naturally
2. Improve water quality in freshwater ecosystems
3. Protect and restore critical habitats
4. End overfishing and unsustainable sand mining in rivers and lakes
5. Prevent and control invasions by non-native species
6. Protect free-flowing rivers and remove obsolete dams

Only by implementing this plan, which is echoed in the Convention on Biological Diversity 5th Global Biodiversity Outlook (Secretariat of the Convention on Biological Diversity, 2020), can we hope to restore the world's freshwater ecosystems and reverse decades of decline in freshwater species populations.

1.2.1 Species diversity

Freshwater animals are generally defined as those species which depend upon freshwater habitats for any critical part of their life cycle. The definition of freshwater plants or hydrophytes is generally accepted to be “all plants that tolerate or require flooding for a minimum duration of saturation/inundation” (Anon, 2000). The only global

assessment of freshwater species diversity was published in 2008 at which time the overall magnitude of described freshwater animal species was estimated as 126,000, half of which are represented by the very speciose class of Insecta (Balian et al., 2008). The true number will be much higher than this as, for example, the estimated number of formally described freshwater fishes has increased from a reported 6,851 species in 1976 (Nelson, 1976) to the 2021 estimate of 18,075 species (Fricke, Eschmeyer & van der Laan, 2021) now representing approximately 50% of known fish species, and almost 25% of the world's known vertebrates. When amphibians, aquatic reptiles and mammals are added to this total, it becomes clear that as much as one third of all vertebrate species are confined to fresh water. There are an estimated 2,614 aquatic vascular macrophyte plant species within the two better-known plant divisions Pteridophyta and Spermatophyta (Chambers et al., 2008). 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 (Chambers et al., 2008). The relative richness of species in freshwater ecosystems is extremely high given that these species are restricted to living in a habitat which only covers an estimated 0.8% of the world's surface area (Gleick, 1996).

1.2.2 Causes for biodiversity decline

The causes of this freshwater biodiversity crisis have been summarised in Darwall et al., (2018) and have been recognised for many years (Abell, 2002; Anon, 1999; Collen et al., 2014; Dudgeon et al., 2006; McAllister, Hamilton & Harvey, 1997; Strayer & Dudgeon, 2010; Thieme et al., 2010; Vörösmarty et al., 2010), yet little action has been taken to address them. A fundamental driver of the decline in freshwater biodiversity is the dramatic increase in global consumption of natural resources over the last century (Garcia-Moreno et al., 2014). This has led to unsustainable water abstraction, widespread habitat loss and degradation, increased levels of pollution, and a proliferation of invasive species (Garrick et al., 2017). Many wetlands have been converted to agricultural production (Ramsar Convention Secretariat, 2017), and other fresh waters are actively used as sinks for pollutants or dumps for effluent and industrial waste, without consideration of the harm caused or the resultant loss of biodiversity and ecosystem functioning in these systems (Craig et al., 2017). Engineering-based solutions for water provisioning emphasize water infrastructure (Green et al., 2015; Tickner et al., 2016; Vörösmarty et al., 2010). These may help meet human demands for water in the short term, but often have significant impacts on freshwater ecosystems (Harrison et al., 2016). Changes in precipitation and temperature regimes linked to climate change greatly compound these impacts (Tedesco et al., 2013).

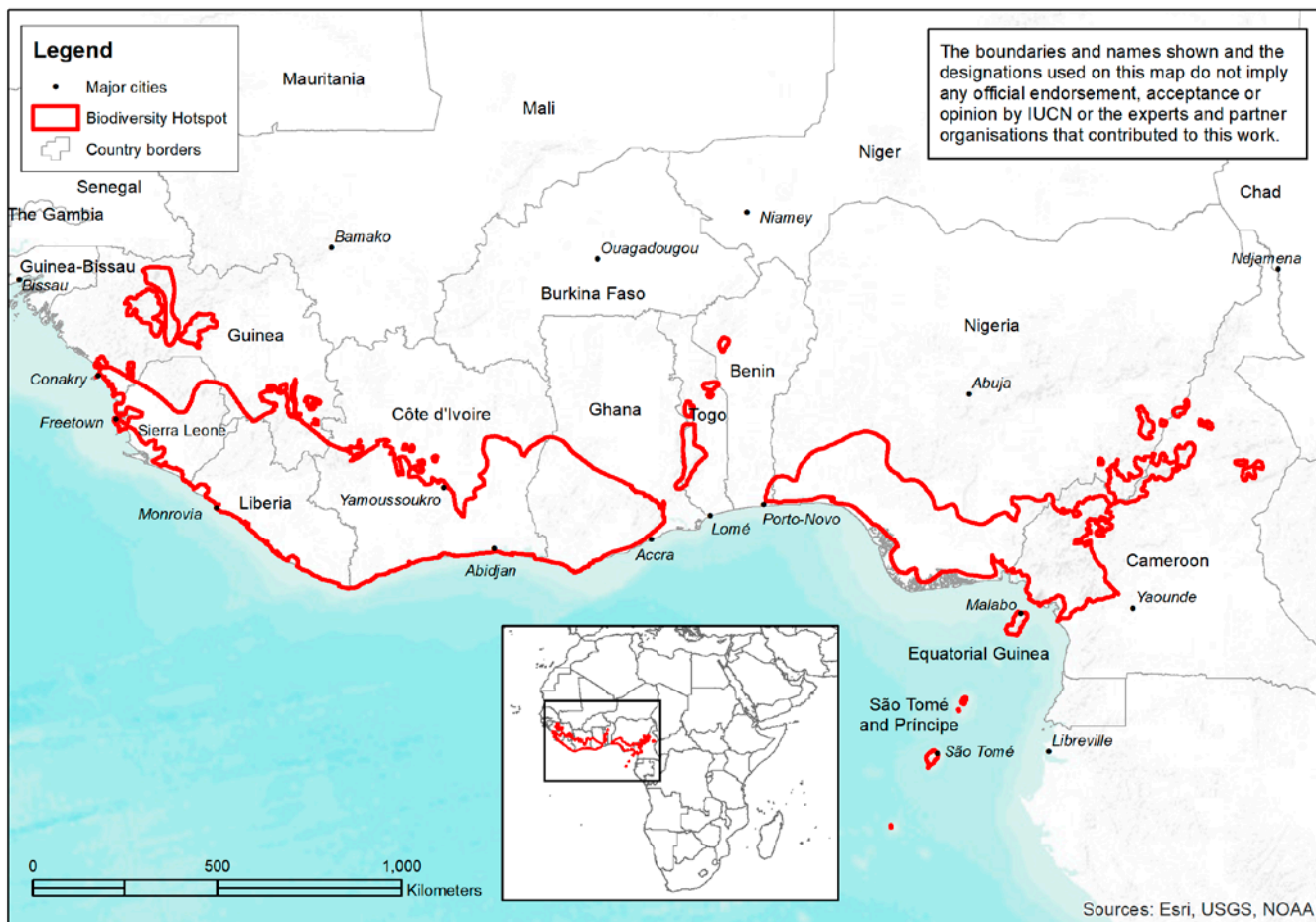


Figure 1.1 Map of the Guinean Forests of West Africa Biodiversity Hotspot. Source: Compiled by the report authors using data from GADM (2020) and Myers et al. (2000).

1.3 Situation analysis for the western Africa region

The Guinean Forests of West Africa Biodiversity Hotspot (hereafter, for brevity, the hotspot), as defined by (Mittermeier et al., 2004), extends across the southern part of western Africa and into Central Africa north of the Congo Wilderness Area (Figure 1.1). A detailed description of the hotspot is given in the CEPF ecosystem profile (CEPF, 2015). In summary, the hotspot covers 621,705 km², and can be divided into two subregions. The first subregion, referred to as the ‘Upper Guinean Forests’, stretches from Guinea in the west, through Sierra Leone, Liberia, Côte d’Ivoire, Ghana, Togo and, marginally, into Benin. The second subregion, the ‘Lower Guinean Forests’, covers much of southern Nigeria, extends into southwestern Cameroon, and also includes São Tomé and Príncipe and the offshore islands of Equatorial Guinea. The Guinean Forests are one of eight biodiversity hotspots in Africa and Madagascar.

The hotspot supports impressive levels of biodiversity, including numerous endemic species in addition to many other ecological features that render it globally unique. The

Niger Delta swamp forests, for instance, are the second largest swamp forests on the continent. One of the largest rivers in western Africa, the Volta, and the delta of the longest and largest river in western Africa, the Niger, occur within the hotspot boundary.

Freshwater ecosystems in the hotspot provide immense benefits to local and national economies and provide the basis for the livelihoods of many of the poorest people within the hotspot (Smith et al., 2009). Benefits include flood regulation, where functioning wetlands buffer the rise and fall of floodwaters, provision and purification of water for drinking, transport routes following waterways, and many direct benefits such as provision of building materials, nutrient rich floodplain pastures, medicines, and food such as from the inland fisheries. It is difficult to quantify, in economic terms, the value of, or reliance upon, wetland goods and services by local communities but the following examples demonstrate their importance. The value of fisheries production for the major river systems in western Africa has been estimated as just over USD 200 million per year (The WorldFish Center, 2008).

1.3.1 Climate

The prevailing climate of the hotspot is tropical and humid, with annual maximum temperatures ranging from around 30 to 36°C. The climate has a significant effect on the biodiversity of the hotspot, permitting a high diversity of species to persist. The cooler end of this temperature range is found near to the coast, and temperatures increase as one moves northwards (Hijmans et al., 2005).

During wetter climatic periods, such as those of the past few thousand years, the region would have been covered in large part by tropical rainforest formations, perhaps over as much as 624,000 km². However, the forest cover has been reduced to a series of fragments of high forest separated by large areas of agricultural land (often termed farm-bush), and numerous villages and towns. In 2004 the hotspot was reported to retain approximately 93,047 km² of natural vegetation, or roughly 15 percent of its original cover (Mittermeier et al., 2004) but this figure will have further declined since then.

1.3.2 Major river systems

The hotspot region is drained by three of the 13 major river basins in Africa: the Niger, the Senegal and the Volta. The Senegal River basin spans four countries: Guinea, Mali, Mauritania and Senegal, with its three main tributaries being the Bafing, Bakoye and Faleme Rivers. All three of these tributaries originate from Fouta Djallon mountains in Guinea. The Niger River is the longest and largest river in western Africa, and spreads over 10 countries, including Algeria, Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Guinea, Mali, Niger, and Nigeria. The Niger River originates in the Loma Mountains of Sierra Leone, and has numerous tributaries joining. One of the major tributaries of Niger River is Benue, which merges with the river at Lokoya in Nigeria. The Volta River basin spans six countries: Benin, Burkina Faso, Cote d'Ivoire, Ghana, Togo, and Mali. The three major tributaries of the Volta River are: the White Volta, the Black Volta and the Oti.

Additional large rivers draining the countries of the hotspot include the Gambia River, which stems from the Fouta Djallon of Guinea, the Sewa River of Sierra Leone, which has many of its tributaries arising from the Loma Mountains and Tingi Hills, the many coastal rivers, such as the Moa and Manu, draining Guinea, the Cross River which is the main river of south-eastern Nigeria, and the Sanaga River in Cameroon.

1.3.3 Freshwater ecoregions

The general distribution and status of freshwater biodiversity across the hotspot has been described in some detail within the context of the set of freshwater ecoregions delineated for Africa by (Thieme et al., 2005). The 15 freshwater ecoregions

overlapping the hotspot are shown in Figure 1.2. These ecoregions typically fall within the major river basins of the hotspot (shown in Figure 1.3). A general description of each ecoregion is given in Table 1.1.

1.3.4 Freshwater species

The following overview of the freshwater species of the hotspot is largely based on the IUCN baseline assessment completed in 2009 (Smith et al., 2009), which aimed to include information on all known, described species of freshwater fishes, odonates (dragonflies and damselflies), molluscs, crabs and selected families of aquatic plants in the region. Information on freshwater shrimps was obtained from the assessments of all 25 species of the hotspot as part of a wider global assessment of all freshwater shrimp species (De Grave et al., 2015).

The hotspot supports high levels of species diversity and endemism, particularly in the southern coastal area of Guinea, within the lower River Jong in Sierra Leone, the Ebrié Lagoon in Côte d'Ivoire, the lower Ogun and Oueme rivers and their coastal lagoons in Benin, and in western Nigeria and the Niger Delta. In these areas, as well as in others, diversity of freshwater taxa such as crabs and shrimps, amphibians, odonates (dragonflies and damselflies), plants and molluscs, is particularly high.

In the freshwater fish community 542 species were reported as being native to the region (Lalèyè & Entsua-Mensah, 2009) with the highest species richness found within the Niger Delta and the Atlantic river catchments of Sierra Leone and Liberia. The Niger Delta itself had 180 recorded freshwater fish species and an additional 19 species thought likely to be present. More than half of the freshwater fishes recorded were endemic to the western Africa region, but only a few were thought to be endemic to the hotspot itself, primarily as the hotspot boundaries are largely based upon forest habitats and not river catchments, and most river systems in the hotspot originate outside its boundaries. Many species are, however, endemic to catchments crossing the hotspot.

Freshwater gastropod molluscs are reasonably well known in the region largely because certain species of the genera *Lymnaea* (*Lymnaeidae*), *Biomphalaria* and *Bulinus* (*Planorbidae*) act as intermediate hosts for medically important parasitic flatworms (trematodes) of humans and domestic animals (Kristensen et al., 2009). National surveys carried out in several countries over the past century were designed to target these genera but they also recorded other mollusc species. The results of these surveys and of other collections were collated by Brown (1994, 1980). Around 70 species were recorded in the hotspot, of which 13 were threatened. The bivalves, with 35 species recorded from the hotspot, are not as well-known as the gastropods.

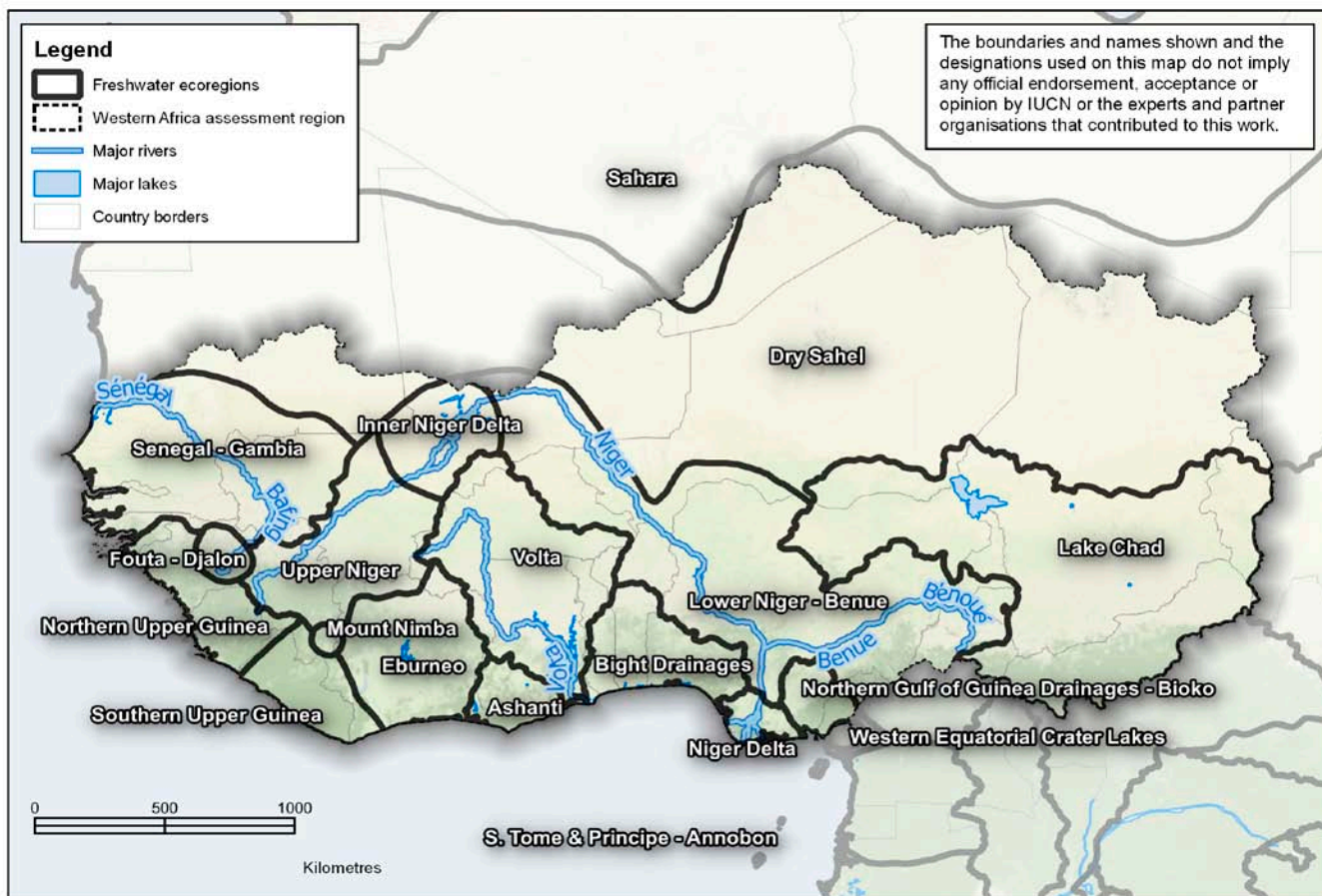


Figure 1.2 Freshwater ecoregions within Guinean Forests of West Africa Hotspot. Source: Compiled by the report authors using data from Abell et al. (2008).

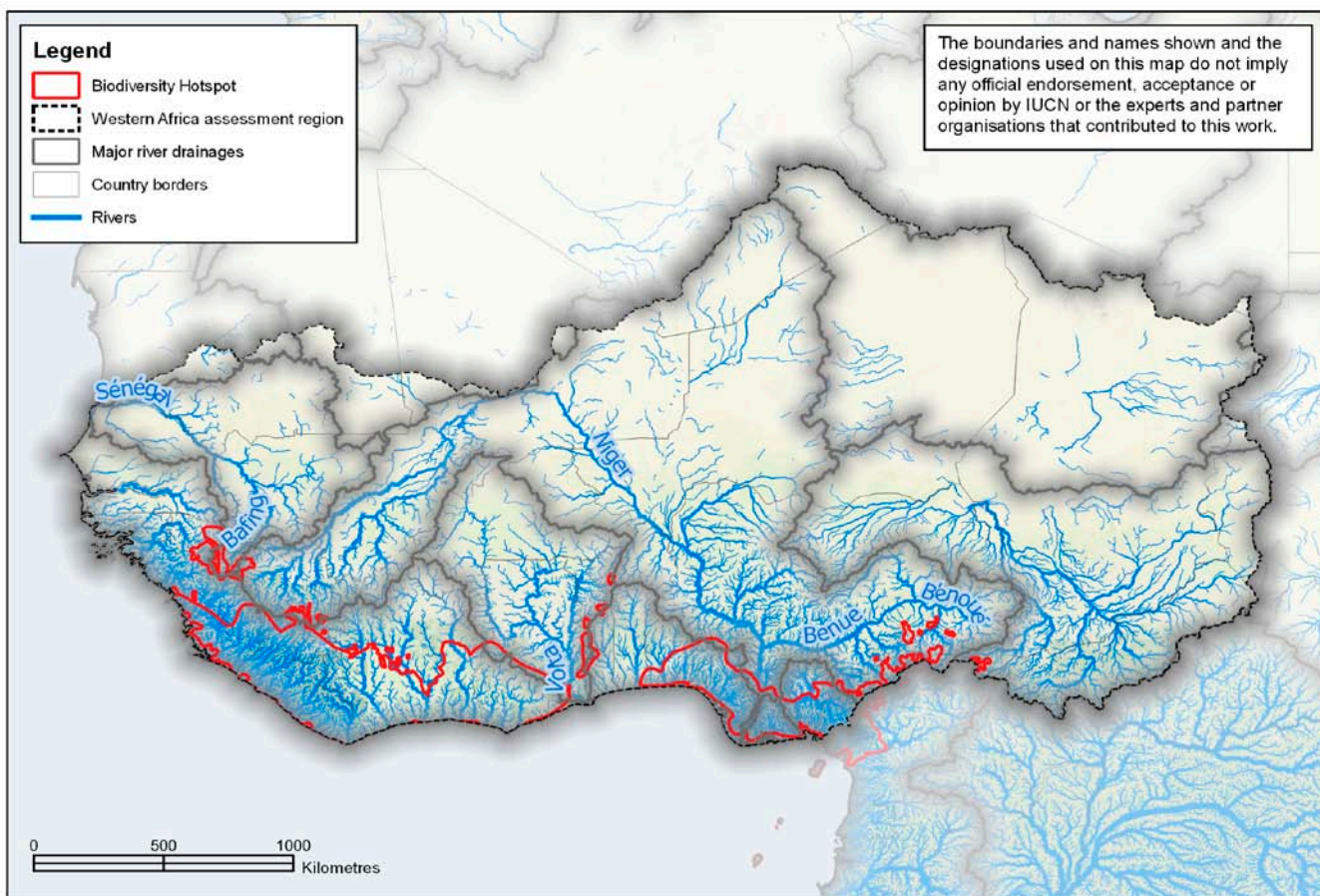


Figure 1.3 Map of the major river basins of western Africa and the West Africa Biodiversity Hotspot. Source: Compiled by the report authors using data from Myers et al. (2000); GADM (2020); Lehner & Grill (2013).

Table 1.1 The freshwater ecoregions as defined in Thieme et al. (2005). Major habitat types: Xeric systems –XS; Savannah dry forest SDF; Highland and mountain systems – HMS; Island rivers – IR; Moist forest rivers – MFR; Floodplains, swamps and lakes – FSL; Large. Source: Compiled by the report authors using data from Thieme et al. (2005)

Ecoregion	Major Habitat Type	Biological Distinctiveness	Conservation Status	Ecoregion delimitation
Senegal-Gambia catchments	SDF	NI	V	Includes coastal basins from the Senegal river to the Gêbe. Nilo-Sudanian fauna, the fish species probably colonised from the Niger.
Volta	SDF	BO	C	Delimited by the Volta basin and includes similar fish species to the Niger.
Bight Coastal	SDF	CO	C	Coastal basins that lie in the Dahomey Gap (an area of savannah breaking the coastal forest strip) and flows into the Gulf of Guinea, from the Mono to the Ogun-Oshun. Nilo-Sudanian fauna, the fish species probably colonised from the Niger.
Lower Niger-Benue	SDF	CO	C	Niger basin from the end of the Inner Niger Delta at Tombouctou to the start of the coastal Niger Delta, including the whole Benue catchment. Typical Nilo-Sudanian fauna assemblage.
Fouta-Djalon	HMS	BO	V	Rivers of the Fouta-Djalon plateau and includes headwaters of the Senegal and Niger rivers. Upper Guinean fish fauna with endemic species adapted to headwater streams.
Mount Nimba	HMS	BO	E	Streams of Mount Nimba in the southern area of the Guinean highlands. High levels of species richness among invertebrates.
Bijagos	IR	BO	V	The Bijagos Archipelago contains depauperate freshwater fauna but is important for wading birds.
Northern Upper Guinea	MFR	CO	E	Coastal forest drainages from the Coliba and Kogon to the Moa. High levels of endemism amongst fish species.
Southern Upper Guinea	MFR	BO	E	Coastal forest drainages from the Mano to the Cavally. High levels of endemism amongst fish species.
Upper Niger	MFR	NI	V	Upper Niger basin above the Inner Niger Delta. Nilo-Sudanian fauna, similar to the Senegal River.
Northern West Coastal Equatorial	MFR	GO	E	Coastal rivers from the Cross River to the Bay of Cameroon and the Island of Bioko. This area acted as refuge during last ice age and has many endemic species. Fish fauna is in common with Nilo-Sudan and the Congo.
Ashanti	MFR	BO	E	Coastal rivers in western Ghana from the Bia to the Pra. Primarily Nilo-Sudanian fish fauna.
Inner Niger Delta	FSL	CO	E	Defined by the floodplains of the Inner Niger Delta. A species rich area with some endemic fishes and an important area for wetland birds.
Lake Chad Catchment	FSL	NI	E	The Lake Chad basin including the Logone and Chari rivers. Has typical Nilo-Sudanian fish fauna but is important for wetland birds.
Niger Delta	LRD	GO	C	The affluents, swamps and mangrove forest of the Niger Delta from the Imo to the Benin River. The delta possesses high levels of aquatic species richness and has an endemic family of fish species (Denticipidae).

Odonates (dragonflies and damselflies) species are numerous across the hotspot with an estimated 316 species recorded. Just before the publication of this report, the IUCN SSC Dragonfly Specialist Group updated the Odonata Database of Africa (ODA) with a considerable batch of new records from recent field trips in the region. These new data could not be included in this analysis, but the new records data bring the species total for the region up to 360 species (V. Clausnitzer, K.-D. Dijkstra and J. Kipping, pers. comm). Of the 316 species assessed here, sixteen species were assessed as globally threatened, of which four species were Critically Endangered.

Among the freshwater invertebrates the crabs and shrimps were the most highly threatened, with 16 of the 72 species recorded in the hotspot assessed as threatened. Western Africa is noted as a centre of diversity for Africa's freshwater crabs (Cumberlidge et al., 2009).

Finally, a high diversity of aquatic plants was recorded, particularly in the lower Niger River. Of these, 472 species were assessed for the Red List as part of the baseline assessment. More recently a number of additional species have also been assessed (Niang-Diop & Ouedraogo, 2009).

Table 1.2 Summary of Red List Category classifications at the regional scale by taxonomic group as recorded in 2009. Source: Compiled by the report authors using data from the IUCN Red List (2009) in Smith et al. (2009).

Taxon	Total*	EX	RE	EW	CR	EN	VU	NT	LC	DD	NA
Fishes	521	0	0	0	16	44	77	56	273	55	16
Odonates	287	0	0	0	7	6	14	3	217	40	24
Molluscs	90	0	0	0	5	5	5	2	59	14	4
Crabs	25	0	0	0	2	4	4	0	10	5	0
Aquatic Plants	472	0	0	0	2	0	5	5	356	104	23
Total	1395	0	0	0	32	59	105	66	915	218	67

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), **NE** – Not Evaluated.

* Excludes those species classified as Not Applicable (NA).

In summary, with the inclusion of Red List assessments for a number of additional taxonomic groups assessed through other initiatives, the number of freshwater dependent species assessed for their global risk of extinction in western Africa by 2009 was 1,009 of which 197 species (19.5% of those assessed) were assessed as globally threatened (Table 1.2).

1.3.5 Key Biodiversity Areas (KBAs) – sites of importance for freshwater species

Many species are best conserved by protecting their habitats and the biological communities they are part of, through conservation actions across a network of sites. The sites that make up these networks are often Key Biodiversity Areas (KBAs), defined as the most important places in the world for species and their habitats. By mapping these most important sites, and providing information about the wildlife living there, private industry, governments and other stakeholders can make the best decisions about how to manage that land (or waters), where to avoid development, and how best to conserve and protect the animals and plants for which the sites are so important.

In 2015, as a component in development of the CEPF Ecosystem Profile for the hotspot, a preliminary set of freshwater KBAs was identified with potential site boundaries delineated according to river/lake sub catchments units, as the widely accepted management unit most applicable to the freshwater realm. A subset of those sub catchments containing KBA “trigger species” (species potentially meeting at least one of the KBA qualifying criteria) were subsequently proposed as potential KBAs and circulated for stakeholder review. Thirteen of these sites were then identified as being most likely to benefit from the financial resources available through CEPF investments (Figure 1.4). During this CEPF profiling exercise a large number of additional sub-catchments were identified as

holding potential KBA trigger species. Consequently, the full complement of potential freshwater KBAs is incomplete and those few that have been identified need to be validated against the KBA Global Standard (International Union for Conservation of Nature (IUCN), 2016) which incorporates qualifying thresholds and data requirements not in place at the time of their proposal.

1.3.6 Drivers of biodiversity decline

Threats to the rivers, lakes and wetlands of the hotspot, and their associated biodiversity and ecosystem services, are linked to a growing population, industrial and agricultural development and a changing climate. Major current threats have been identified as habitat loss and water pollution, in particular from sedimentation due to deforestation, agriculture, human settlements, mining, and oil exploration (Smith et al., 2009), with 11 of the 15 freshwater ecoregions overlapping the hotspot listed as Critical or Endangered (see Table 1.1) (Thieme et al., 2005).

As an example for the scale of this building pressure on freshwater ecosystems, the US Agency for International Development (USAID), starting a water monitoring and sanitation project in northern Nigeria, bluntly stated in 2017: ‘Nigeria’s water, sanitation, and hygiene (WASH) sector has reached an alarming state of decline, with nearly one-third of the population (about 70 million) lacking access to improved drinking water sources and approximately two-thirds living without adequate sanitation facilities. With one of the fastest-growing urban populations in the world, Nigeria’s municipal centres in particular are likely to face increasing difficulty in meeting the water and sanitation service needs of their citizens (DAI, 2017)’.

The main driver behind these increasing pressures on freshwater ecosystems is the region’s rapidly increasing

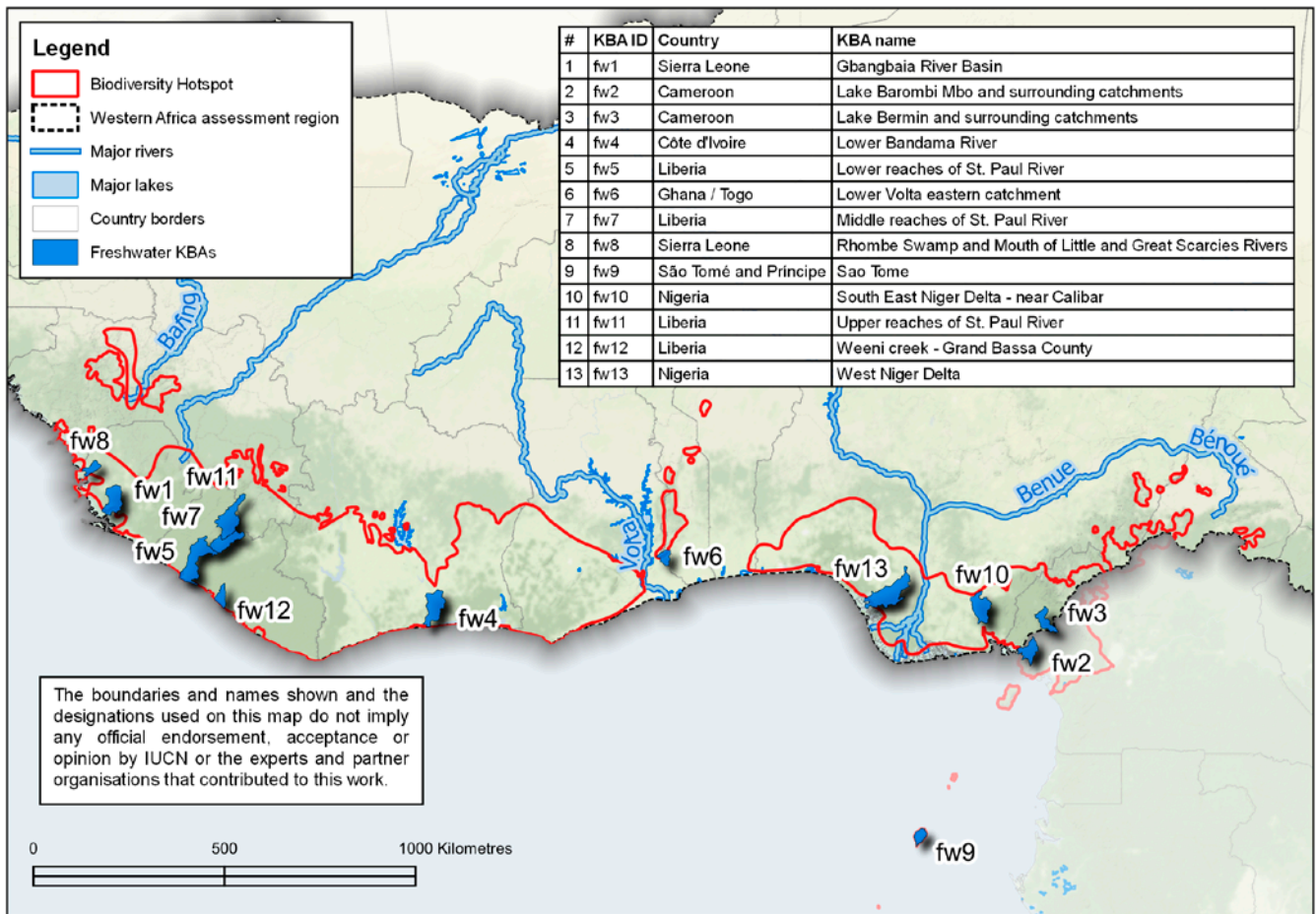


Figure 1.4 Map of CEPF FW KBAs in the Guinean Forests of West Africa Hotspot. Source: Compiled by the report authors using data from CEPF (2015). GADM (2020); Lehner & Grill (2013).

population. Western Africa still has one of the highest annual population growth rates of any region on the continent, estimated at about 2.6% in 2012 (African Development Bank Group, 2012). Economic development (and particularly the growth of commercial agriculture and extractive industries) has accelerated in forest-zone countries as several civil conflicts have subsided. Western Africa has had the fastest rate of GDP growth on the continent, predicted at 6.8% in 2013 and 7.4% in 2014 (African Development Bank Group, 2013), although due to the COVID-19 pandemic this has slowed to a projected 2.8 percent in 2021 and 3.9 percent in 2022, as COVID-19 lockdowns are eased (African Development Bank, 2021). These drivers are reinforced by the tendency of all human beings to give priority to their short-term self-interests, and to consume resources beyond their immediate survival needs.

The rapid population increase is being further fuelled by immigration from the Sahel region where tens of millions of people depend upon the services provided by its shrinking wetlands. However, these wetlands are degrading across the Sahel region, often due to ill-advised economic development projects such as water diversions to support irrigated agriculture, leading to water scarcity (Wetlands International, 2017). Consequently, some wetlands have ceased to provide

refuge in hard times and people are migrating in search of alternative livelihoods. Many of these migrants are coming into the hotspot, further increasing pressure on the region's already heavily impacted wetland resources. For example, water offtake upstream of the Inner Niger Delta has reduced the annual flooding needed to support herders, fishers and farmers to the point where more than a million people could be permanently displaced. The loss and degradation of wetland services within the hotspot itself is forcing many people to migrate even further afield to Europe. An example is the Senegal River which can no longer rely on seasonal floods due to a major dam upstream in Mali and is now unable to sustain the livelihoods of farmers, herders and fishers. Although this issue is widely recognised by the authorities the expansion of irrigated agriculture continues, further increasing the pressure on these wetlands. The scale and extent of these pressures on wetland ecosystems are now presented in more detail.

Agriculture. Agricultural expansion often leads to the loss and/or degradation of freshwater ecosystems which are commonly viewed as wastelands most suitable for conversion to other uses, such as agriculture. In western Africa agricultural expansion stands as the primary cause of deforestation, with around 80% of the original forested

landscape now forest-agriculture mosaics (Norris et al., 2010) and an estimated overall decline in forest cover since 1900 of approximately 83% (Aleman, Jarzyna & Staver, 2018). Deforestation in turn impacts freshwater ecosystems, such as through increased levels of sedimentation and disruption to hydrological cycles. Within the region Nigeria is top of the list of those countries experiencing the greatest change in area of annual crops (absolute increase in arable cropland) over the period 1999–2008, while Sierra Leone, Guinea and the Gambia are in the top five countries in which annual crops expanded at the greatest rate (relative to the area of cropland) (Phalan et al., 2013).

Seventy percent of world cocoa production is by smallholders in western Africa and the level of production has increased by 50 percent in the first decade of the 21st century (Wessel & Quist-Wessel, 2015). With more than six million ha of land now planted with cocoa, the environmental impacts are significant. Cocoa farmers usually clear tropical forests to plant new cocoa trees rather than reusing the same land. That practice has spurred massive deforestation in western Africa, particularly in Ivory Coast where experts estimate that 70% of the country's illegal deforestation is related to cocoa farming (World Wildlife Fund (WWF), 2017). The combination of forest loss, leading to increased sediment run-off, loss of riparian forest cover, and the resulting leaching of pesticides and fertilisers into freshwater ecosystems represents a potentially major impact on freshwater species.

Cotton production has increased markedly since the 1960s (Perret, 2006). Although no single country dominates international exports, the region as a whole is the world's third largest exporter after the US and Central Asia. Cotton production in the region is mostly rain fed and cultivated in regions receiving annual rainfall of between 500–700 mm and 1,200–1,500 mm covering the northern zones of coastal countries and the southern zones of land-locked countries. Cotton production and exports from western African countries have, however, been undercut by controversial (and significant) government subsidies to cotton sectors in the United States.

Oil palm plantations are widely considered as one of the greatest current and potential causes of deforestation in Africa, even though there are questions whether yields comparable with Southeast Asia are even achievable given climatic and infrastructural limitations (Mallon et al., 2015). Nigeria is the world's third largest producer after Indonesia and Malaysia, and the last decades have seen a huge increase in production throughout western Africa, with an estimated 2.8 million tons produced in 2018 (European Palm Oil Alliance (EPOA), 2019) to supply export markets. While in many western African countries the damage to Guinean forest streams and their biota has already been

done, palm oil-plantations are presently expanding in the last unspoiled regions of Liberia and Sierra Leone, where levels of deforestation were 6 to 12 times greater in 2015 than in 2001, respectively (UNEP-WCMC, IUCN and NGS, 2018).

Conflict. Wars have multiple impacts on biodiversity and protected areas, and the livelihoods of local people dependent on natural resources. Civil war, internal conflicts, insurrection, the presence of illegal armed groups and spillover from conflicts in neighbouring countries have affected many countries of western Africa over the last 50–60 years. Overharvesting of wildlife and vegetation in conflict zones exacerbates existing constraints on the access to natural resources, threatening both the resources base and the livelihoods of local communities dependent on these resources (Dudley et al., 2002).

Pollution. The primary impacts of pollution are on freshwater-dependent species. Widely reported sources of pollution in the region include mining and oil exploration; pesticides, which are commonly used to control disease vectors like malaria, trypanosomiasis and schistosomiasis, and fertilizers; and domestic and industrial pollutants. These effects are compounded by the increased sedimentation due to soil erosion resulting from deforestation, in turn causing extensive eutrophication of lakes and rivers.

Energy Production and Mining. An unprecedented mineral boom is now underway in Africa (Weng et al., 2013) with a mining exploration budget of 1.12 billion US dollars in 2019 (Garside, 2021) and Burkina Faso, Ghana and Cote d'Ivoire investing heavily. Indeed, much of the recent increase in foreign direct investment in Africa is linked to extractive industries. For example, in 2011 close to 150 Australian mineral companies were investing \$20 billion in more than 40 African countries (Sachs, Negin & Denning, 2011). China is rapidly increasing investments in minerals in Africa, especially for high-volume resources such as coal, iron, copper and cobalt and other metals (Zhang & Wilkes, 2010). In 2013, China's Ministry of Commerce and Ministry of Environmental Protection issued joint Environmental Guidelines on Foreign Investment and Cooperation to direct Chinese companies to further regulate their environmental behaviours in foreign investment and cooperation.

Gold is the largest mineral resource in western Africa. Since the 1980s, gold has attracted considerable investment, and artisanal gold mining also is still prevalent today, providing livelihoods for several hundred thousand people in countries like Mali, Burkina Faso, Côte d'Ivoire and Guinea. Artisanal gold (and diamond) mining requires little capital or equipment, can affect large areas, tends to be unregulated, and since it often occurs in riparian zones, contributes to pollution of water courses through the use of chemicals

(even in protected areas). The other main substances mined (apart from construction and road-building materials) are diamonds, iron ore, bauxite, phosphate and uranium.

Open-cast (or open-pit) operations for heavy metals can have a substantial footprint and may pose problems for rehabilitation. Well-known examples in the region (a number of which have attracted considerable attention of conservation organisations) include Mount Nimba and Mount Putu in Liberia, Simandou in Guinea, Tonkololi in Sierra Leone, and the 14-million tons per year Sangaredi Mine in Guinea (for bauxite). As another example, small-scale alluvial mining and commercial extraction of sand adjacent to the Ankobra and Birim Rivers in Ghana has severely impacted fish life below the discharge site.

Sand for construction is considered to be the second most heavily consumed of the world's natural resources, behind freshwater (Villioth, 2014). The mining of sand from river beds and floodplains in western Africa to supply the rapidly increasing appetite of the construction industry as cities and towns develop at pace is putting tremendous pressure on freshwater ecosystems. The impacts of sand mining for freshwater species and habitats are significant, including for example, loss of habitat, changes to sedimentation patterns and species losses and changes, but more research is required to understand the full impacts (Koehnken et al., 2020).

Finally, oil is an important part of the extractive economies of Gabon and Nigeria (especially in and around the Niger Delta) and exploration is increasing, including off-shore Liberia. Niger, for example, has undergone a rapid increase in its oil extraction and refinery activity in recent years. Besides the obvious environmental footprint impacts, other direct and indirect effects of mining and oil exploration on wildlife are probably comparable to those observed for logging concessions, especially road construction, increased human population densities, and hunting.

Dams and other system modifications. (Dudgeon, Paugy & Lévêque, 2011) provide a recent synopsis of the impacts of dams and water abstraction on African freshwater fauna. More than 1,200 dams have been constructed on small and large rivers in Africa; many more are either under construction or have been proposed with a particular focus on western Africa. Dams have been built for a range of purposes, including for domestic, industrial and mining water supply, crop irrigation and hydroelectricity. Most of the largest dams were built after the mid-1950s, on large rivers and for electricity supply. However, more recently, many smaller reservoirs have been established to meet other water demands including, irrigation, water supply (domestic use) or

fish production. The wider environmental impacts of dams are well established and will not be discussed here.

Alien invasive species. The main impact of alien invasive species is probably among the region's freshwater fish species. Sixteen species of fishes have been introduced to the central Africa region, including *Oreochromis niloticus* and *Heterotis niloticus*, which has become a dominant component in many rivers of the Cuvette Centrale. The most important alien invasive species, however, is probably the Water Hyacinth *Eichhornia crassipes*, a super-invasive species that has caused major degradation of water quality across the region, impacting freshwater species and also disrupting fisheries access and boat transportation.

Fisheries. Almost thirty years ago, (Brainerd, 1997) warned that most fishery resources were close to their maximum level of exploitation, fully exploited or overexploited. For western Africa, fishing was documented as a key threat to ~5% of threatened fish species in the 2009 assessment (Lalèyè & Entsa-Mensah, 2009). In many areas in the region, especially the Volta system, increased harvest levels have changed fish community structure and distribution and lowered recruitment. For example, in the Oueme system of Benin, larger predatory species have been replaced by smaller catfish, cichlids and cyprinids.

Although the international ornamental pet trade in tropical freshwater fish is huge, amounting to many millions of US dollars a year, and 82% of African freshwater fish in trade are threatened species, the trade appears based mainly on captive-bred specimens (Raghavan et al., 2013) and it has not yet been reported as a specific threat to fish in West Africa.

Climate change. In western Africa, the last century or so has seen tremendous climate variability, as evidenced by the 1930–1960 wet period, the 1970–1980 droughts and the return of rainfall in the 1990s and 2000s. The PARCC (Protected Areas Resilient to Climate Change in West Africa) project assessed the sensitivity and adaptive capacity of the terrestrial and freshwater vertebrates of this region (as defined in this situation analysis, plus Chad) to the impacts of climate change (Carr, Hughes & Foden, 2014). Western Africa's freshwater fishes show a high sensitivity to climate change and its impacts, especially due to specific habitat and microhabitat associations, which may be affected by climate changes; a low intrinsic capacity for dispersal also emerges as the most common trait within this group. The presence of physical barriers such as unsuitable habitats which potentially prevent dispersal poses a particular problem.

1.4 Objectives of the study

It is clear from the situation analysis presented above that freshwater ecosystems and the services they provide are seriously impacted by human activities across the region. In the study presented here we aim to provide an up-to-date baseline on the distribution and status of freshwater biodiversity across the region as a foundation for conservation and environmental decision making of relevance to freshwater species. Specifically, we will:

- i) re-assess all freshwater species for the IUCN Red List, providing an index of change in the status of freshwater biodiversity (a Red List Index) since the baseline assessment was completed in 2009;
- ii) evaluate the thirteen proposed freshwater KBAs against the KBA Global Standard and with the benefit of updated information on the relevant KBA trigger species;
- iii) raise awareness and capacity for KBA designation in 6 countries of the hotspot and;
- iv) demonstrate how the information can be used to identify a network of sites to best represent freshwater biodiversity throughout the hotspot.

Working through IUCN's regional offices we will then ensure the findings are communicated to those NGOs involved in: i) conservation actions on the ground, ii) conservation planning at the National level, and iii) private sector companies interested in minimising their impacts on freshwater biodiversity. The project findings will also help donors, such as the Critical Ecosystem Partnership Fund (CEPF), direct their support to those species and sites in most need of conservation or restoration actions.

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Chapter 2

Assessment methodology

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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, wetland birds, amphibians and fishes have received most attention. However, it is important that we take a more holistic approach by collating information to conserve other components of the food web that are essential to the maintenance of healthy functioning wetland ecosystems, even if they are neither publicly charismatic nor often noticed, as is generally the case for submerged species. As it is not practical to assess all species, a number of taxonomic groups have been prioritised for comprehensive assessment at the global scale (i.e. assessment of all described species within the taxonomic group on the global IUCN Red List of Threatened Species TM, www.iucnredlist.org) as part of IUCN's global freshwater biodiversity assessment.

2.1.1 Fishes

Fishes are arguably the most important products (in terms of human use) of freshwater ecosystems at a global scale. In 2016 the total capture of fishes from inland waters globally was 11.6 million tonnes and this represents an 11% increase in comparison to the 2005–2014 average (FAO, 2018). Within

Africa, which accounts for 25% of global inland catches (FAO, 2018), fishes provide an important food source for over 400 million people and contribute essential proteins, fats, minerals and vitamins to their diets (Heck & Béné, 2005). As well as essential nutrition, this capture provides income for and supports the livelihoods of the poorest of communities, through both consumption and non-food uses (Dugan et al., 2010).

For the purposes of this assessment, freshwater fishes are defined as those species that spend all or a critical part of their life cycle in freshwaters. There are approximately 17,800 freshwater fish species globally (R. van der Laan pers. comm. 2019) and at present, global extinction risk has been assessed for approximately 51% (9,138 species) of freshwater fishes using the IUCN Red List Categories and Criteria (IUCN, 2019). A global freshwater fish assessment is currently under way with the aim of assessing all species for the Red List by 2021.

Lévêque et al., (1990) identified 558 fish species belonging to 180 genera and 61 families in the western Africa region. This assessment was later updated by (Paugy, Lévêque & Teugels, 2003), increasing the number of known species in the region to 584, within 192 genera and 64 families. Since 2010 an estimated 13 new species have been described, increasing the number of western African fishes to 597. This includes a number of predominantly marine species which

¹ Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

are also found in brackish water. In this current report we focus only on the freshwater fish species of which there are 555 species, from 164 genera and 49 families now recorded from western Africa. Of these, 10 species and one subspecies are not native to the region and one species is a misidentification. The current assessment reported here focuses on described native species only.

2.1.2 Molluscs

Freshwater molluscs are one of the most diverse and threatened groups of freshwater taxa, and were found to be the group most at risk of extinction and most poorly known in the continental African assessment by Darwall et al. (2011), with 29% of species assessed as threatened and 30% assessed as Data Deficient (DD). Freshwater molluscs are mostly unobtrusive and are not normally considered to be charismatic, rarely attracting the attention of the popular media, unless in a negative light as some species are vectors in the transmission of human and livestock parasites and diseases. This is unfortunate as freshwater molluscs play a vital role in the provision of ecosystem services and are essential to the maintenance of wetlands, primarily due to their contribution to water quality and nutrient cycling through filter-feeding, algal-grazing and as a food source to other animals (Howard & Cuffey, 2006; Vaughn, Nichols & Spooner, 2008; Vaughn, Gido & Spooner, 2004).

There are some 6,000–7,000 freshwater mollusc species described globally (MolluscaBase Eds., 2021). At present, the global risk of extinction has been assessed for approximately 57% (3,688 species) of described freshwater mollusc species on the IUCN Red List (International Union for Conservation of Nature (IUCN), 2021). The extinction risk of 83 species of freshwater mollusc native to the western Africa region was assessed according to the IUCN Red List Categories and Criteria (IUCN, 2012). A further 17 species had recently been assessed and were included in this report.

2.1.3 Odonates

Larvae of almost all species of dragonflies and damselflies (order Odonata) 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. The larvae are voracious predators, often regarded as important in the control of insect pest species. A wide array of ecological niches is represented within the group and, as they are susceptible to changes in water flow, turbidity or loss of aquatic vegetation (Trueman & Rowe, 2009), they have been widely used as an indicator of wetland quality. There are approximately 6,300 extant described species of odonate

but, even though the group is well studied and relatively easily surveyed, it is believed that the actual number is closer to 7,000 species (Kalkman et al., 2007). At present, the global risk of extinction has been assessed for 85% (5,342 species) of described odonates (IUCN, 2021).

Odonate species selected for inclusion in this report encompassed all 307 species assessed on the Red List with all or part of their mapped range within the western Africa assessment region. This included 249 species with mapped ranges and a further 58 species with distributions represented only by point locality data. The species richness maps presented in the odonates chapter (Chapter 6) are produced for the 249 species with mapped ranges. The conservation status summaries and Red List Index were calculated using the full suite of 307 species.

Just before the publication of this report, the IUCN SSC Dragonfly Specialist Group updated the Odonata Database of Africa (ODA) with a considerable batch of new records from recent field trips in the region. These new data could not be included in this analysis, but the new records data bring the species total for the region up to 360 species (V. Clausnitzer, K.-D. Dijkstra and J. Kipping, pers. comm).

2.1.4 Decapods

Freshwater decapod crustaceans include crabs, crayfishes and shrimps. In western Africa, the native freshwater decapod groups are the crabs and shrimps – there are no crayfishes native to western Africa.

Freshwater crabs are one of the most ecologically important freshwater macro-invertebrate groups globally. They play a key role in nutrient cycling due to the high importance of detritus in the diet of many species, coupled with their abundance and high biomass (Cumberlidge et al., 2009). As freshwater crabs are found in a wide variety of aquatic habitats, and as they are normally associated with relatively good quality water, they are excellent indicators of water quality (Yeo et al., 2008). Additionally, they are a key component of tropical aquatic food webs, acting as prey items for a large number of predators, as well as being widely consumed by humans (Cumberlidge et al., 2009).

There are 2,755 freshwater decapods assessed on the IUCN Red List, including 2,642 strictly freshwater species as well as 147 freshwater & terrestrial and 4 freshwater & marine species (IUCN, 2021).

2.1.4.1 Crabs

There are an estimated 1,400 species of freshwater crab globally, as well as several hundred species which inhabit both freshwater and marine systems (Cumberlidge, 2016).

These are divided into eight families of which just one, Potamonautidae, is recognised from Sub-Saharan Africa, being endemic to the continent (including Madagascar, the Seychelles and other surrounding islands) (Cumberlidge, 2008). Currently 145 species of Potamonautidae are assessed on the Red List (IUCN, 2021).

All 26 native species of freshwater crabs from six genera within the Potamonautidae were reassessed in the present work, including the monospecific genus *Globonautes macropus* (EN), allowing a complete Red List Index to be calculated for the western African freshwater crabs against the 2008 baseline (Smith et al., 2009).

2.1.4.2 Shrimps

There are around 770–800 species of freshwater shrimp globally, accounting for approximately 20% of total shrimp diversity (De Grave et al., 2015). Some 29 species of freshwater shrimp were included in the present work, representing eight genera from five families, including two monospecific genera; *Caridinopsis chevalieri* (LC) and *Euryrhynchoides holthuisi* (DD). A global assessment of freshwater shrimps was completed in 2015 (De Grave et al., 2015) and only one recently discovered species – *Euryrhynchina puteola* (DD) was assessed as part of this project.

2.1.5 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 nutritious, medicinal, cultural, structural or biological properties. Some species also provide important wetland ecosystem services such as water filtration and nutrient recycling.

Following Cook (1996), aquatic plants are defined here as “vascular plants whose photosynthetically active parts are permanently or, at least, for several months of the year, submerged in water or float on the surface of the water”, and following this definition, it is estimated that aquatic plants represent between 1–2% of all plant species, equivalent to approximately 2,900–5,800 of the approximate 300,000 species of vascular plants (Vié, Hilton-Taylor & Stuart, 2009). However, if considering non-vascular plants, such as bryophytes, the number of freshwater-dependent plants is higher by at least an order of magnitude (R. Lansdown pers. comm. 2019).

For this work, 382 species from 59 families were assessed on the IUCN Red List. A further 104 species were identified as being native to western Africa but were not reassessed since they had all been assessed recently. In total, then,

486 species of aquatic plants are considered in this study. A further 43 species, 13 species of Lentibulariaceae and 30 species of Podostemaceae, were identified to be within scope but ultimately were not assessed here.

2.2 Nomenclature

Taxonomic schemes are constantly changing due to results from ongoing studies, in particular with the introduction of molecular techniques. As it is in many cases difficult to find a universally agreed taxonomic hierarchy, the taxonomy followed here is that adopted by the IUCN Red List, which, where possible, employs existing published world checklists. For this study, fish classification generally follows Eschmeyer’s Catalog of Fishes (Fricke, Eschmeyer & van der Laan, 2019) and odonate classification generally follows the World Odonata List maintained at the University of Puget Sound (Schorr & Paulson, 2019). For plants, where appropriate, we follow the World Checklist of Selected Plant Families hosted by the Royal Botanic Gardens, Kew (WCSP, 2019), but other more specialist lists are also followed. There is currently no widely accepted single taxonomy for molluscs and decapods, and we therefore follow the standards recommended by the IUCN SSC Mollusc Specialist Group and the IUCN SSC Freshwater Crustacean Specialist Group, respectively.

2.3 Species mapping

Species distributions were mapped to river sub-catchments as delineated by HydroBASINS (Lehner & Grill, 2013) levels 8 and 12 using the Freshwater Mapping Application (IUCN, 2020). 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 (Collares-Pereira & Cowx, 2004).

The majority of species had published distribution maps from previous IUCN Red List assessments, for example as conducted by Darwall et al. (2011). These distribution maps were used as a starting point and updated based on current knowledge. The global native distribution of each species was mapped, including ranges extending outside of Africa. This had the benefit not only of being able to assess each species’ global extinction risk, but also to determine through spatial analysis which species were endemic to the region and to calculate the proportions of species’ global range contained within potential Key Biodiversity Areas.

For ecoregion analysis, species with 95% or more of their range within an ecoregion were considered endemic to the

ecoregion. This is the same threshold adopted in the Global KBA Standard (IUCN, 2016). Species with less than 0.5% of their range within an ecoregion were not considered present within the ecoregion.

The standard IUCN Red List attributes were used to indicate the presence and origin of species at different localities within their distribution ranges (IUCN Red List Technical Working Group, 2018). Where data were available, point localities (the latitude and longitude for a species collection record) were used to identify sites containing known occurrences of the species (coded as Presence 1: Extant). These point data were supplemented by expert knowledge of presence in sub-basins where no specific collection records were available. The preliminary species distribution maps were digitised and then further edited at the Red List review workshop (see 2.5 Data collection and quality control) where errors were deleted from the maps and dubious records were recoded as Presence Uncertain (Presence 6). Inferred distributions (coded as Presence 3: Possibly Extant), where a species is expected to occur but has not yet been confirmed, were determined through a combination of expert knowledge, coarse scale distribution records and unpublished information. Distributions where the species were Possibly Extinct (Presence 4), Extinct (Presence 5) and Introduced (Origin 3) were also captured where known.

For calculating the species richness maps, species' mapped ranges from the Red List assessments were filtered so as to include portions of the range where the species was extant, native (or reintroduced) and excluding portions of the range that represent possibly extant, possibly extinct, extinct, introduced, vagrant and migratory passage only.

Species richness maps presented in this work represent the western Africa region only. Species' global ranges may extend outside of this region, are included in analysis e.g. calculating range restriction, but these portions of species ranges are not displayed in the maps herein.

All mapping was done using ArcGIS software (ESRI, 2018). HydroBASIN distribution maps, with point data overlays and/or detailed in-lake polygon overlays for selected species, are published online on the IUCN Red List website (www.iucnredlist.org) and are freely available to download for non-commercial use.

2.3.1 Range restricted species

The previous work on freshwater biodiversity in western Africa (Smith, 2009) defined species with severely restricted ranges as those with ranges less than 20,000 km². Here we have taken the threshold of 10,000 km² in line with the lower limit for range restricted species as defined by the KBA Global Standard (IUCN, 2016). The KBA

Standard defined range restricted species as those with ranges at or below the 25th percentile of range size within a comprehensively assessed taxonomic group, or 10,000 km², whichever is higher. As none of the freshwater groups are comprehensively assessed globally, we have used the default 10,000 km² threshold. This makes the results more directly applicable to KBA identification for these species.

2.4 Assessment of species threat status

The Red List Categories and Criteria are widely accepted as the most objective and authoritative system available for assessing the risk of a species becoming extinct (Mace et al., 2008; Rodrigues et al., 2006). The IUCN Red List of Threatened Species™ is the world's most comprehensive information source on the global conservation status of plant, animal and fungi species, and is widely used to help inform conservation priority setting. The risk of extinction was assessed according to the IUCN Red List Categories and Criteria: Version 3.1 (IUCN, 2012) for all species in the priority taxonomic groups native to the LMNNC.

The nine Red List Categories at the global level are shown in Figure 2.8. A species is assessed as **Extinct (EX)** when there is no reasonable doubt that the last individual has died. A species is assessed as **Extinct in the Wild (EW)** when it is known only to survive in cultivation, captivity or as a naturalised population well outside its native range. A species assessed as **Critically Endangered (CR)** is considered to be facing an extremely high risk of extinction in the wild. A species assessed as **Endangered (EN)** is considered to be facing a very high risk of extinction in the wild. A species assessed as **Vulnerable (VU)** is considered to be facing a high risk of extinction in the wild. All species listed as Critically Endangered, Endangered or Vulnerable are termed threatened. A species is assessed as **Near Threatened (NT)** when it is close to qualifying for a threatened category, or if it is the focus of a specific and targeted conservation programme, the cessation of which would result in the species soon qualifying as threatened. A species is assessed as **Least Concern (LC)** if it does not qualify (and is not close to qualifying) as threatened or Near Threatened. Least Concern species are generally common and widespread. A species is assessed as **Data Deficient (DD)** if there is insufficient information to make a direct or indirect assessment of its risk of extinction. DD is therefore not a category of threat and instead indicates that further information on the species is required. Species assessed as DD are priorities for additional research and should be acknowledged as potentially threatened. To determine whether a species should be assigned to one of the three threatened categories, there are five criteria with quantitative

thresholds, reflecting biological indicators of populations threatened with extinction. For a detailed explanation of the categories and of the criteria that must be met for a species to qualify under each category please refer to *The IUCN Red List Categories and Criteria: Version 3.1* (IUCN, 2012). Red List assessments are published online on the IUCN Red List website (www.iucnredlist.org).

Recommended research and conservation actions are documented as part of Red List assessments, representing a good starting point for guiding relevant conservation strategies. These are classified according to the Research Needed Classification Scheme and the Conservation Actions Classification Scheme, respectively (Salafsky et al., 2008). Sometimes Red List assessors supply additional specific recommendations in text form. The recommendations are summarised for all species within each taxonomic group, in the respective chapters (Chapters 3–7).

2.4.1 Data collation and quality control

The assessments of species extinction risk required sourcing and collating the best information on all known, described species within the priority taxonomic groups. As the primary source for this information, the best regional and international experts for these taxa were first identified through consultation with the relevant IUCN SSC Specialist Groups and with previous contributors to Smith et al. (2009).

Regional and international experts for these taxa were identified by IUCN and through consultation with the relevant IUCN SSC Specialist Groups. Most of these experts had already received prior training in use of the Species Information Service Data Entry Module (SIS DEM), the application of the IUCN Red List Categories and Criteria (IUCN, 2012), assessing species extinction risk, and in mapping freshwater species distributions as per the *Freshwater Species Mapping Standards for IUCN Red List Assessments* (IUCN Red List Technical Working Group, 2018). Additional training was provided by IUCN.

2.5 Red List Index

The IUCN Red List Index (RLI) is used to measure trends in the overall extinction risk of groups of species, as an indicator of trends in the status of biodiversity (Bubb et al., 2009). Extinction is a key measure of biodiversity loss and, as a result, the RLI has been adopted as a biodiversity indicator by a number of international conservation policies and agreements. For example, the global RLI has been used to track progress towards the Convention on Biological Diversity's (CBD) 2010 Aichi Biodiversity Targets, while subsets of the RLI have been used to track progress under

various multilateral environmental agreements, such as the Ramsar Convention and the Convention on Migratory Species (CMS) (Bubb et al., 2009; Butchart et al., 2005, 2005; Tittensor et al., 2014). The RLI is also the official indicator for the Sustainable Development Goals (SDGs) Target 15.5.

The RLI is based upon the categories of species extinction risk as published on the IUCN Red List. All species within the group being investigated must have been assessed for the IUCN Red List at least twice in order to calculate the RLI. The RLI is calculated from the number of species in each Red List category and the number of species changing categories between assessments as a result of genuine improvement or deterioration in status (i.e. genuine changes). Changes in category resulting from improved knowledge or revised taxonomy (i.e. non-genuine changes) are excluded (Bubb et al., 2009).

The RLI can be calculated using Equation 9.1 (Butchart et al., 2007):

$$RLI_t = 1 - \frac{\sum_s W_{c(t,s)}}{W_{EX} N}$$

Equation 2.1 Equation to calculate the IUCN Red List Index

Where $W_{c(t,s)}$ is the weight of category c for species s at time t , W_{EX} is the weight for the category Extinct (EX), and N is the number of assessed species excluding those considered Data Deficient (DD) in the current time period and those considered to be EX in the year the set of species was first assessed. The category weights (c) used are: Least Concern (LC) = 0, Near Threatened (NT) = 1, Vulnerable (VU) = 2, Endangered (EN) = 3, Critically Endangered (CR) = 4, and CR (Possibly Extinct) (CR(PE)), CR (Possibly Extinct in the Wild) (CR(PEW)), Extinct in the Wild (EW) and Extinct (EX) = 5.

To calculate the RLI, the number of species in each Red List category is first multiplied by the category weight. These products are then summed and divided by the maximum possible product (the number of species multiplied by the maximum weight) and then subtracted from 1. The index produced can range from 0 to 1, where 1 indicates that all species are Least Concern and 0 indicates that all species are Extinct. Declines in RLI values over time indicate that the expected risk of extinction is increasing, increases in RLI values over time indicate that the expected risk of extinction is decreasing, and unchanging RLI values indicate that the expected risk of extinction is remaining the same.

It is possible to disaggregate global RLIs to show trends at finer scales, for example at national or regional scales. RLIs at sub-global scales can either be based on global

or regional Red List assessments. If considering global assessments then it is necessary to assess for each species within that region that underwent a genuine change in its status (as indicated by movement between Red List categories) whether the processes driving this change also occurred within the region (Bubb et al., 2009).

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Chapter 3

The status and distribution of freshwater fishes in western Africa

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3.1 Overview of western African fishes in relation to the freshwater ecoregions

During the last 40 years, many research programs have contributed to improve our knowledge of freshwater fishes in western Africa, as reviewed by Smith et al., (2009). The most notable of these research programs includes compilation of the important Checklist of the Freshwater Fishes of Africa (CLOFFA) (Daget, Gosse & Thys Van Den Audenaerde, 1991, 1986a, 1986b, 1984). This was followed by an important book, published by *Institut de recherche pour le développement*, France (ORSTOM) and the *Royal Museum for Central Africa*, Belgium (MRAC) (Lévêque, Paugy & Teugels, 1992, 1990), that identifies 558 fish species belonging to 180 genera and 61 families in the western Africa

region. This assessment was later updated by Paugy et al., (2003), increasing the number of known species in the region to 584, within 192 genera and 64 families.

Since 2010, an estimated 13 new species have been described, including one species of *Pronothobranchius* (Valdesalici, 2013); two species of *Enteromius*, previously considered 'Barbus', (Bamba, Vreven & Snoeks, 2011; Lederoun & Vreven, 2016), one cichlid species (*Astatotilapia tchadensis*, (Trape, 2016) and nine species of *Chiloglanis* (Mochokidae) (Schmidt et al., 2017). This has increased the number of western African fishes to 597 (more than 10% of the total for continental Africa). These statistics include a number of predominantly marine species that are also found in brackish water. In this current report, we focus only on the freshwater fish species of which there are 555 species, from 164 genera and 49 families now recorded from western

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Africa. Of these, 10 species and one sub-species are not native to the region and one species is a misidentification. The current assessment reported here focuses on native described species only.

The western African region, as defined here, contains 15 of the freshwater ecoregions defined by Abell et al., (2008) (Chapter 1, Figure 1.2 and Table 1.1). Characteristics of the fish communities in each ecoregion are summarised in Smith et al., (2009). Here we provide an update on what has changed since the 2009 baseline.

3.1.1 Xeric systems

3.1.1.1 Dry Sahel

A few of the region's fish species are specially adapted to live in the temporary water systems that exist in the Dry Sahel. A new species of haplochromine cichlid fish, *Astatotilapia tchadensis* has been described recently in one of the water bodies of the Sahara desert, Lake Boukou (Chad) (Trape, 2016). As little is known about this species, it has not been included in the current assessment.

3.1.2 Savannah dry forest rivers

3.1.2.1 Senegal-Gambia catchments

To date, 211 species of fish are recorded from this ecoregion, with two only restricted range species. One of the restricted range species, *Malapterurus occidentalis* (LC) is recorded from the middle Gambia River (Gambia) and the Géba River (Guinea-Bissau) and the second, *Pronothobranchius gambiensis* (EN) is known from the majority of localities comprising the temporary pools and swamps of the Gambia River drainage in Gambia and Senegal.

3.1.2.2 Volta

An estimated 240 fish species have been recorded from the Volta ecoregion. The eight species restricted to the ecoregion are *Brycinus luteus* (EN), *Micropanchax bracheti* (EN), *Chiloglanis voltae* (LC), *Synodontis voltae* (DD), *Synodontis macrophthalmus* (CR), *E. vandewallei* (DD), *Prothobranchius seymouri* (EN) and, *Irvineia voltae* (EN).

3.1.2.3 Lower Niger-Benue

This part of western Africa contains a rich fish fauna, including an estimated 289 species. Of these, the following three species are confirmed to be endemic to the ecoregion, *Chiloglanis benuensis*, *Dagetichthys lakdoensis* and *Synodontis omias*, all of which are assessed as Least Concern.

3.1.2.4 Bight Drainages

Some 246 species have been recorded from this ecoregion. Fifty-two of these species are endemic to western Africa and

four, possibly five, of these are endemic to the ecoregion, namely, *Micropanchax keilhacki* (LC), *Synodontis ouemeensis* (LC) *Enteromius clauseni* (CR) and *Marcusenius brucii* (DD), with *Labeobarbus lagensis* (DD) a possible endemic which may also be recorded from Ghana and Cameroon.

3.1.3 Highland and mountain systems

3.1.3.1 Fouta Djallon

To date 195 fish species have been recorded from this ecoregion, with four species being strict endemics. The endemic species are *Enteromius anniae* (EN); *Enteromius cadenati* (VU); *Enteromius guineensis* (VU) and *Rhexipanchax lamberti* (LC).

3.1.4 Moist forest rivers

3.1.4.1 Northern Upper Guinea

The forested coastal streams and rivers of Upper Guinea support a diverse and largely endemic aquatic fauna (Lévêque, 1997; Lévêque et al., 1989). The rivers in this ecoregion originate on the well-watered slopes of the Guinean Range and have likely served as a refugium during past climatic fluctuations (Lévêque, 1997). The Konkouré River is one of the richest among the Atlantic basins, with 96 freshwater fish species recorded there. With the inclusion of the uppermost stretches of the Konkouré, Corubal and Little Scarcies rivers (strictly in the Fouta-Djallon ecoregion), there are 279 fish species recorded in the ecoregion. Many of these species have restricted distributions with 35 being ecoregion endemics. These endemic species are generally small-bodied fishes adapted to the swift currents and clear waters of the ecoregion and are usually restricted to individual river basins (Schmidt, Bart & Pezold, 2016; Schmidt & Pezold, 2011; Thieme et al., 2005).

3.1.4.2 Southern Upper Guinea

This ecoregion contains many aquatic species and high levels of endemism (Hugueny & Lévêque, 1994; Thieme et al., 2005). Some 246 fish species have been recorded here. Nineteen species are endemic to the ecoregion, mostly within the families Cyprinidae, Nothobranchiidae, Cichlidae, Amphiliidae, and include several recently described *Chiloglanis* spp. that are restricted to individual river basins (Schmidt et al., 2017).

3.1.4.3 Eburneo

This ecoregion contains some 228 fish species with four endemics; *Clarias lamottei* (VU), *Micralestes comoensis* (EN), *Synodontis comoensis* (LC) and *Epiplatys etzeli* (EN). *Citharinus eburneensis* (NT) is almost entirely restricted to the ecoregion but is also recorded from the Tano River in Ghana.

3.1.4.4 Ashanti

This ecoregion contains 195 fish species. Of these, the following six species are endemic to the ecoregion: *Coptodon discolor* (NT), *Limbochromis robertsi* (EN), *Chrysichthys walkeri* (VU), *Enteromius subinensis* (EN), *Enteromius walkeri* (LC) and *Nimbapanchax petersi* (EN).

3.1.4.5 Upper Niger

There are 267 recorded fish species from this ecoregion. Three species are endemic to the ecoregion: *Brycinus carolinae* (EN), *Micropanchax ehrichi* (LC), and *Enteromius kissiensis* (DD). An undescribed *Amphilius sp. nov.* 'Niger River drainage' (EN) is restricted to the headwater streams of the Niger River drainage.

3.1.5 Floodplains, swamps, and lakes

3.1.5.1 Lake Chad catchment

There are 160 species of fish recorded from the Lake Chad and its catchment. The following two species are endemic to the ecoregion: *Barilius shariensis* (DD) and *Pronothobranchius kiyawensis* (EN).

3.1.6 Large river deltas

3.1.6.1 Niger Delta

The Niger Delta contains 221 freshwater fish species. Six fish species are thought to be endemic to the ecoregion. These endemic species are *Ctenopoma nebulosum* (EN); *Neolebias powelli* (EN); *Fundulopanchax arnoldi* (EN); *Parauchenoglanis buettikoferi* (CR), *Epiplatys biafranus* (EN) and *Notoglanidium akiri* (EN).

3.2 Conservation status

There are 131 (24%) threatened freshwater fish species within the western African region, of which 21 (4%) are Critically Endangered, 66 (12%) are Endangered, and 44 (8%) are Vulnerable (Table 3.1 and Figure 3.1). Fifteen species (3%) are Near Threatened with the remaining species assessed as Least Concern (377 spp.) or Data Deficient (32 spp.), noting that Data Deficient species are potentially also threatened. There has been an increase in the number of species assessed as Critically Endangered from 16 in the earlier assessment (Lalèyè & Entsua-Mensah, 2009) to 21 in this study. Similarly, the number of species listed as Endangered has increased from 44 to 66 over the period 2009 to 2019. Correspondingly, over this time period there has been a decrease in the number of species listed as Vulnerable from 77 to 44, and as Near Threatened from 56 to 15. Many of the species previously listed as Vulnerable are now either assessed as Critically Endangered or Endangered, while some of the species previously listed as Near Threatened are now assessed as

Table 3.1 Number of native and endemic freshwater fish species per Red List category in western Africa. Numbers in parentheses refer to the previous assessment (Smith et al., 2009) and include regional assessments. Source: Compiled by the report authors using data from the IUCN Red List (2021) and Smith et al. (2009).

IUCN Red List Category	Number of native species	Number of regionally endemic species
Extinct (EX)	0 (0)	0 (0)
Extinct in the Wild (EW)	0 (0)	0 (0)
Critically Endangered (CR)	21 (16)	16 (15)
Endangered (EN)	66 (44)	61 (39)
Vulnerable (VU)	44 (77)	40 (59)
Near Threatened (NT)	15 (56)	11 (45)
Least Concern (LC)	377 (273)	131 (109)
Data Deficient (DD)	32 (55)	19 (33)
TOTAL	555 (521)	278 (300)

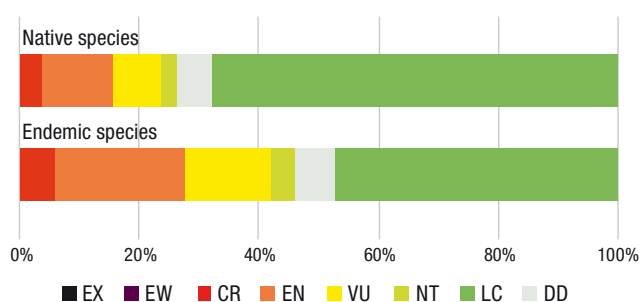


Figure 3.1 Percentage of native and endemic freshwater fish species per Red List category in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

either Vulnerable or Endangered. This pattern of decline is not unexpected given that, since 2009, the human population in the region has on average increased annually by 2.75% (United Nations, 2019) alongside a significant increase in industrialisation and urbanisation. Meanwhile, the main conservation focus has been on existing protected areas, which are rarely designated for freshwater species and sites identified for birds and mammals. The conservation needs of freshwater ecosystems appear to have gone largely unrecognised during this period of intense development. A closer examination of the reasons for the observed changes in species threatened status is given in Chapter 8, where the Red List Index of change (RLI) is presented for all the taxonomic groups assessed through this study.

3.3 Species richness patterns

The spatial distribution of species richness for western African freshwater fishes is presented in Figure 3.2. The highest species richness was recorded in the Lower Niger-Benue. Other species rich areas include Northern Upper Guinea, Upper Niger, Southern Upper Guinea and Bight

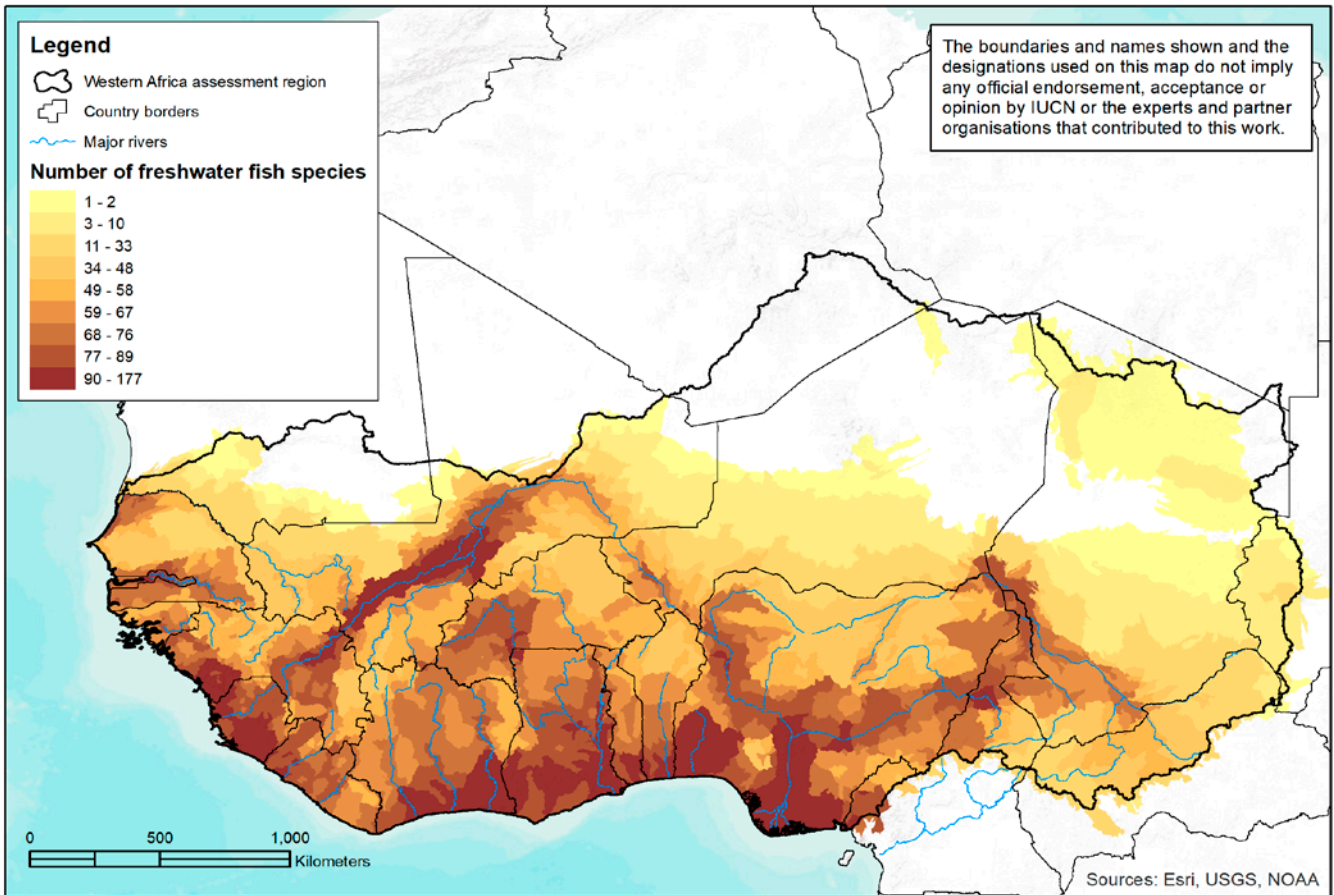


Figure 3.2 Species richness of freshwater fishes in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

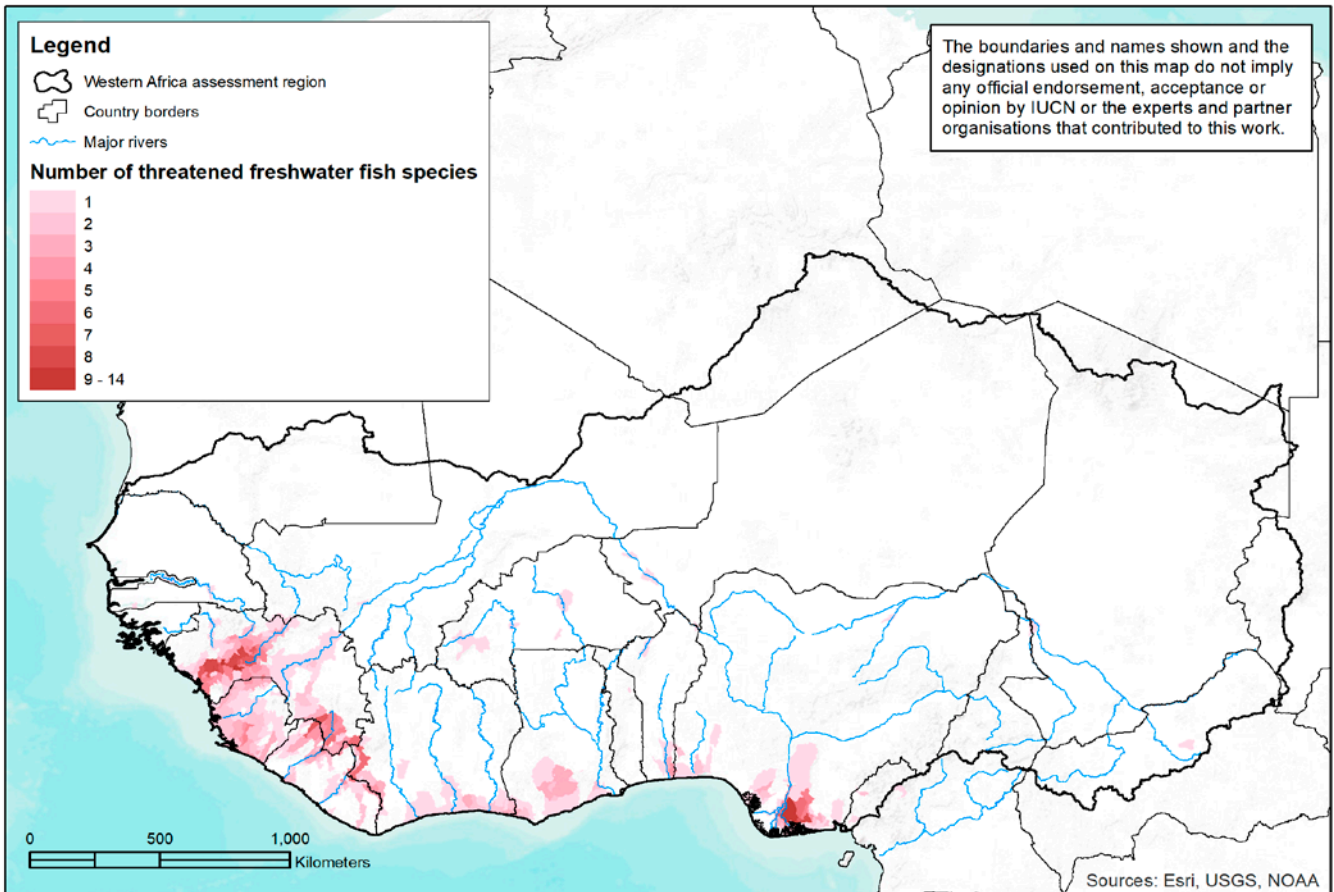


Figure 3.3 Species richness of threatened freshwater fishes in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

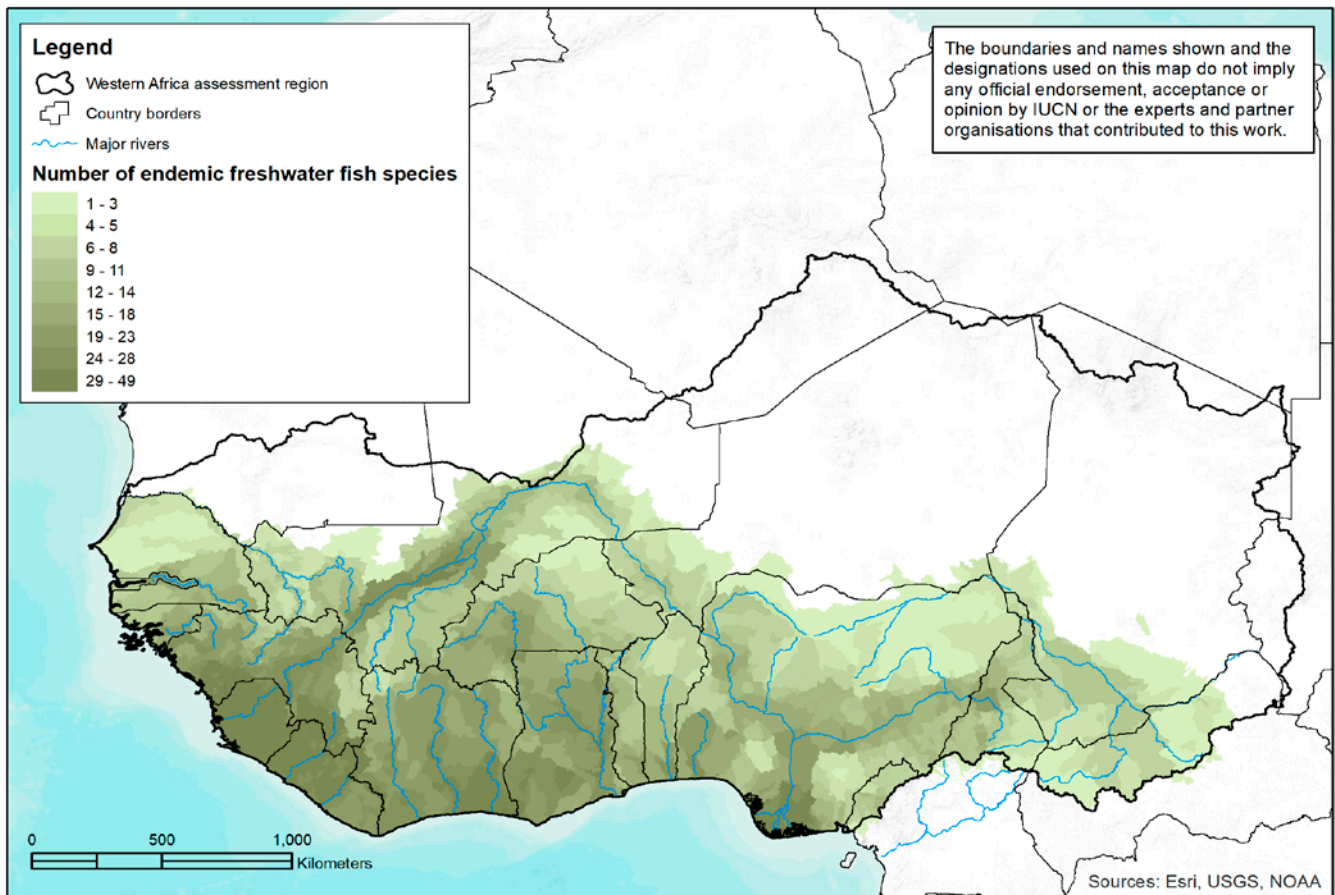


Figure 3.4 Species richness of regionally endemic freshwater fishes in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

Drainages, Volta, Northern Gulf of Guinea Drainages, Eburnea, Niger Delta, Senegal-Gambia ecoregion, Fouta-Djalou and Ashanti.

The Niger Delta remains the area with the highest concentration of threatened species with up to 10 species recorded in each Level 8 HydroBASIN (Figure 3.3). Relatively high numbers of threatened species are also found in the rivers of the western part of Guinea.

Two hundred and seventy eight species are restricted to the western Africa region with their distribution shown in Figure 3.4. There is one main center of endemism, the Upper Guinea region (coastal drainages of Guinea, Sierra Leone, and western Liberia) with up to 49 species mapped to a single Level 8 HydroBASIN (Figure 3.4). Upper Guinea, Niger Delta, Volta and Ashanti each contain six ecoregion-restricted species. The other ecoregions are each represented with between two and four endemic species.

3.4 Major threats to freshwater fishes

The most commonly coded threats to freshwater fish species of western Africa according to this latest IUCN assessment are: pollution, biological resource use, mining, natural system

modification, agriculture and aquaculture, climate change and severe weather, invasive and other problematic species, genes and diseases, human intrusions and disturbances, transport and service corridors (Figure 3.5).

Pollution continues to rank as the highest threat, being recorded as a threat to 317 species. This is mainly attributed to 'agriculture and forestry effluents' (responsible for 49.4% of coded threats from 'pollution'), 'industrial and military effluents' (31.2%), 'domestic and urban waste water' (19.0%), and 'garbage and solid waste' (0.3%). These threats often compound upon each other, for example, agriculture or mining activities are often associated with deforestation.

In comparison to the 2009 assessment the most notable difference is the perceived increase in threat from biological resource use, now recorded to impact 299 of the species assessed (Figure 3.5). This is thought likely to be a response to the region's rapid population growth with the population rising from 307,035,257 in 2010 to 401,855,177 in 2020 (United Nations, 2019), combined with a lack of employment which has led to overexploitation of biological resources to support basic livelihoods. Fish, in particular, have come under increasing pressure as fishing in most countries is accessed freely and therefore offers a potential source of livelihood.

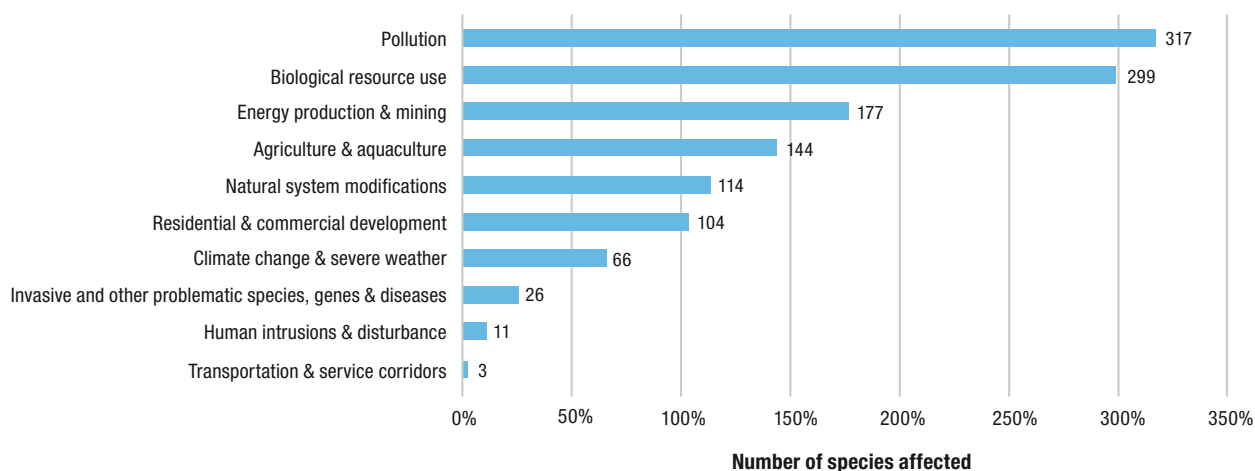


Figure 3.5 The number of fish species coded against each IUCN Red List threat category. Source: Compiled by the report authors using data from the IUCN Red List (2021).

The main threats to freshwater fishes across the region are discussed in more detail below.

3.4.1 Pollution

Aquatic ecosystems in western Africa are impacted by a wide range of pollutants originating from many sources, the most notable of which are urban development, commercial/ industrial effluent, domestic waste and the use of pesticides.

As a consequence of ongoing population and industrial growth in the region, aquatic environments have become subject to increasing inflows of organic matter in quantities that exceed capacity for natural purification, dilution and physical and chemical breakdown. In this situation, plant biomass increases at rates beyond the rate of consumption by herbivores. This excessive input and production of organic matter in turn leads to eutrophication and increased likelihood of oxygen deficit and subsequent fish kills leaving areas unsuitable for fish habitation.



Figure 3.6 Polluting organic landfills on the shores of Lake Nokoué in Benin. © Philippe Lalèyè

An example of pollution impacts following input of inadequately treated human waste and domestic discharges arising from increasing residential developments is seen on the Offin River (e.g. in the vicinity of Wiawso) where it is thought to be impacting species such as the electric catfish *Malapterurus tanoensis*.

Species such as *Notoglanidium walkeri* (NT) found in Appolonia close to Accra, Ghana and the Agnèbi River in Côte d'Ivoire and *Chiloglanis niger* (EN) known only from the Menchum River in the Benue basin (Bamenda Heights) in Cameroon are heavily impacted by pollution associated with increased urban development. *Lipidarchus adonis* (VU) is found in small coastal basins (Tano, Ankobra, Bia, Comoe and Bandama) in southern Ghana and Côte d'Ivoire where it is impacted by the increased input of agrochemicals, mining effluent, increased sedimentation following deforestation, and domestic pollution. *Chrysichthys walkeri* (VU) which is only known from the Pra basin including the Offin and Birim Rivers in south-western Ghana is also threatened due to the combined impacts of mining, deforestation and inadequately treated human waste and domestic discharges.

Another significant threat to the region's fishes is the increasing use of pesticides which are widely employed by the public and animal health sectors to curb, if not to eradicate, endemic diseases such as malaria, schistosomiasis and trypanosomiasis through the control of their insect or mollusc hosts. These chemicals eventually leach into the aquatic environment and, depending on their concentration, either kill fish species or render the environment unsuitable.

Pollution from oil extraction in Nigeria, Ghana and Cameroon represents a major threat to many fish species. Oil leaked into the rivers, lakes or wetlands either directly kills the fish or drives them away, and often taints their flesh thereby

reducing their economic value and making them potentially toxic for human consumption. A further impact of oil spills or leaks is seen where oil spreads across the water surface inhibiting exchange of gases between the water and atmosphere impacting all aquatic life. Oil is also toxic if ingested, and where it sinks it smothers fish feeding and nursery grounds (FAO, 1991).

3.4.2 Biological resource use

An estimated 299 fish species are recorded to be directly impacted through over-exploitation for human use such as through fishing, or are indirectly impacted by use of other resources such as timber, mangroves, and other riparian vegetation, which protect or provide habitat for fish (Figure 3.5). (Brainerd, 1997) reported that most fishery resources in Africa are either close to their maximum level of exploitation, fully exploited in some cases, or are overexploited. This latest assessment indicates that the pressures of overfishing are becoming more widespread.

With increasing population growth in the region and lack of employment, overfishing is becoming more widespread with many of the youth, especially in riparian and coastal communities, forced into fishing given that it is freely accessed in most countries of the region.

Both widely distributed species and those with limited distributions appear equally susceptible to overfishing. Examples of widely distributed species that are overexploited include; *Hydrocynus brevis*, *Hydrocynus forskalii*, *Bagrus bajad*, *Tylochromis intermedius*, some *Chrysichthys* spp., and *Citharinus eburneensis*. Species with more restricted distributions reported as being potentially susceptible to overfishing include; *Brycinus leuciscus* (endemic to the Volta basin, Niger-Benue, Gambia and Cassamance, and Togo); *Steatochranus irvinei* (endemic to the Volta basin in Ghana and Burkina Faso); *Chrysichthys teugelsi* (from the middle and upper courses of rivers Cess, Sarguin and Cavally in Cote d'Ivoire and Liberia) and *Synodontis arnoulti* (endemic to the Volta basin).

Compounding the situation, the larger human population has led to increased demand for other biological resources, such as timber for construction and fuel wood, creating an additional threat to fish habitats and consequently to fish communities in the region.

Mangroves, an important biological resource, are being harvested in many places along river estuaries (e.g., the lower Volta River at Ada, the Pra at Shama and Anwona village and the Ankobra River at Sanwoma, Ankobra Village) for both fuel wood and construction. This over extraction of mangrove habitat is indirectly affecting many reliant fish species, primarily through loss of important habitat. Mangrove



Figure 3.7 Pristine mangrove vegetation (*Rhizophora* spp.) in the Lower Volta River. © Hederick Dankwa



Figure 3.8 Harvested mangrove for use as fuel wood in the Lower Volta River. © Hederick Dankwa



Figure 3.9 Effects of overfishing in the Fosu Lagoon, Cape Coast, Ghana where fully matured *Sarotherodon melanotheron* are observed to be smaller than they used to be. © Hederick Dankwa

canopy cover increases the diversity and complexity of estuarine systems within which juvenile fishes take refuge and avoid predation. Mangrove root systems serve as areas or points of attachment for the growth of periphyton, zooplankton and other organisms, which serve as food for fish. The continuous removal of mangrove cover is also likely to reduce litter production, which is the basis for the detrital food chain upon which most fishes depend, affecting fish distributions, and eventually production (Dankwa & Gordon, 2002). In addition, mangrove vegetation helps prevent soil erosion, and their continuous harvesting therefore leads

to increased siltation in estuaries and lagoons potentially further affecting some fish species.

Recruitment overfishing is also evident where increased harvesting has led to changes in fish community structure and distribution, with an overall reduction in recruitment. Overfishing has also led to a decline in average fish size and often lowers trophic levels of fish communities following the disappearance of larger species. This 'fishing down the food web' is particularly evident in the Ouémé River in Benin, where small-sized catfish, cichlids and cyprinids have replaced large centropomids and catfishes (Helfman, 2007). Some other potentially overexploited species include; *Tylochromis intermedius* which occurs in coastal rivers from Gambia to Ghana; *Citharinus eburneensis* in Ghana and Cote d'Ivoire; *Chrysichthys teugelsi* in Cote d'Ivoire and Liberia and *Notoglanidium maculatum* (VU) in Sierra Leone.

3.4.3 Energy production and mining

Mining operations are quite extensive across the region. In Ghana for example, widespread mining activities are present in the Pra basin (comprising the Pra, Offin and Birim rivers) as well as the Ankobra, where species such as *Lepidarchus adonis* (VU) and *Limbochromis robertsi* (EN) are both threatened in part due to mining impacts. In the Farmington River (Gibi Mountains) and Via River in Saint Paul's River drainage in Liberia some restricted range species such as *Enteromius boboi* (CR), *Enteromius carchahinoides* (CR) and *Labeo curriei* (CR) are highly threatened due to mining operations. Mining of tin in the Bauchi plateau in Nigeria has also led to another species, *Garra trewavassae*, being assessed as Critically Endangered. As a final example, mining operations in southeastern Guinea and around Mount Nimba are threatening several species endemic to the Upper Niger and Southern Upper Guinea ecoregion including *Chiloglanis nzerekore* (EN) and *Chiloglanis tweddlei* (EN).

Development of new mining operations and ongoing extraction from established mines impacts the freshwater environment in many diverse ways. Increased sedimentation resulting from construction of new access roads, land clearance and deforestation, and the mining/extraction operations themselves all impact freshwater habitats, especially forested streams that are naturally relatively clear flowing and free from turbidity. These activities associated with mining lead to increased levels of suspended matter in the water, which may physically harm fish (e.g. through clogging of their gills) and reduce the photosynthetic efficiency of primary producers impacting the food web supporting fish species. In addition, reduction in water clarity may in some cases lead to actual loss of species such as tilapias that feed on surface algae, which is no longer able to grow in the turbid conditions.

In a study on the impact of mining operations on the ecology of the River Offin in Ghana, (Dankwa, Biney & DeGraft-Johnson, 2005) reported that turbidity, conductivity, and concentrations of lead and cadmium in the water column were higher in the dredging area. Fish in the dredging area also had higher mean concentrations of trace metals in their tissues compared to those from non-impacted sites, while the structure of the fish community in the dredging area showed lower species richness than adjacent areas. Planktivores, mainly cichlids, were completely absent from the impacted areas. Similarly, autotrophs (blue-green and green algae) were virtually absent from sites with high turbidity due to mining.

Localised mining operations are also usually associated with larger, sometimes trans-national, development schemes focused on delivering these raw materials to a global market. These associated activities include the construction of railways, roads, electrical transmission grids, and ports, all of which are likely to negatively affect the quality and extent of freshwater habitats. Sand mining in riverbeds and floodplains is also widespread and increasing in order to satisfy the growing demand as construction levels increase across the region (see Chapter 1). This activity has a significant negative impact on benthic fish species and the spawning sites of most species.

Mining operations also introduce harmful chemicals into rivers on a regular basis. Even at very low concentrations,



Figure 3.10 Evidence of extreme increases in sedimentation due to mining activities on the Pra River at Daboase. © Hederick Dankwa



Figure 3.11 Land degradation due to mining activities along sections of the Ankobra River. © Hederick Dankwa

these chemicals may, in the long term, effect changes in fish communities and populations. For example, in Sinoe County Liberia several streams with high levels of artisanal gold mining activity were found completely devoid of fishes (Pezold, Schmidt & Stiasny, 2016).

3.4.4 Natural system modifications

A most significant impact to the functioning of freshwater ecosystems is the increase in instream infrastructures such as dams, which disrupt river and wetland hydrology and in some cases block fish migrations. With increasing demand for hydroelectric power, for both domestic and industrial use, and potable water, many river systems in western Africa now have at least one dam and often many more. There are more than 150 large dams in the region (Zhang, Urpelainen & Schlenker, 2018). Some of the major dams in the region are on the Niger River – the Markala (Niger) and Kainji (Nigeria); on the Volta system (two dams) – Akosombo and Kpong (Ghana) and Bagre (Burkina Faso); on the Senegal River – Diama and Lac de Guireres (Senegal) and on the Bia River (Côte d'Ivoire). Many small dams also exist in the region.

Creation of dams on river courses results in a number of ecological changes, which potentially impact fish living above and below the dam. Fish migrations are physically impacted where they are unable to pass barriers, including for both upstream and downstream migrations. The natural timing and quantity of river flow, which provides environmental cues for initiating life cycle transitions in fish, such as spawning, egg hatching, rearing and lateral migrations onto flood plains for feeding or reproduction are also often disrupted (Welcomme, 1991). A typical case is the damming of the Volta River. Before construction of the dams at Akosombo and Kpong, the river flow rates varied considerably across the seasons with the mean discharge rates between 1936 and 1963, prior to the dams being closed, ranging between 36 m³/s and 5128 m³/s. Following completion of the dams, the downstream discharge below the dams is virtually constant, at approximately 1000 m³/s throughout the year excepting occasions when excess water is spilled from the dams (Dankwa et al., 2017). Thus, regular flooding of the lateral plains has been considerably impacted, resulting in reduced fish production and the local disappearance of certain species such as *Enteromius leonensis*, *Brycinus nurse*, *Clarias senegalensis*, *Heterotis niloticus*, *Hippopotamyrus pictus*, *Labeo senegalensis*, *Mormyrus hasselquisti*, *Raiamas senegalensis*. With the second dam (Bui Dam) on the same river inaugurated in 2013, the impacts could have been compounded but there is no data available to determine the impact.

Upstream impacts of dams are also significant as formerly riverine conditions are effectively converted into lacustrine

conditions with resultant changes in water chemistry and thermal stratification of the water column and oxygen regimes. In many cases, this renders conditions unsuitable for species specialised to riverine habitats. Spawning and feeding grounds, such as rocky areas and gravel beds may also be lost or degraded through flooding and siltation. In the Volta system, after the river was dammed in 1963, the prior dominance of insectivorous fishes in the river gave way to predominantly herbivorous and plankton feeding fishes in the newly formed lake (Petr, 1968). In another example, the Moonfish (*Citharinus eburneensis*) is reported to have disappeared from the Bia River system following construction of a hydroelectric dam in 1959 creating Lake Anyamé in Cote d'Ivoire. Dams on the Konkouré River basin in the Northern Upper Guinea ecoregion have also resulted in a reduction in available habitat for some threatened species, particularly two species of *Enteromius*, *E. cadenati*, *E. guineensis* (Schmidt et al., 2019) and several freshwater mussels (see Chapter 4). A similar situation exists for the Bagbwe River in Sierra Leone where a hydropower dam has reduced the flow and heavily impacted the former riverine habitats over and below the dam. This is particularly damaging to *Chiloglanis polyodon* (EN), a rheophilic species preferring fast flowing waters.

3.4.5 Agriculture and aquaculture, residential and commercial development

Agriculture, land-based aquaculture, residential and commercial development often lead to increased deforestation and introduction of pollutants to water bodies. General aspects of pollution are covered in section Pollution, so this section is largely focused on impacts of deforestation as associated with land clearance for agriculture and residential and commercial. Deforestation along river courses to make way for agriculture is prevalent across the western Africa region, especially along the Volta, Niger, and Senegal rivers. This most often results in widespread increased levels of sedimentation due to unstable soils combined with high water run-off during the rains. This increased sedimentation



Figure 3.12 Fish farming on Lake Volta, Ghana. © K.A.A. deGraft-Johnson

leads to smothering of critical freshwater habitats. The loss of riparian forest also impacts those fish species that depend on allochthonous food resources dropping from the forest canopy which decline or disappear in these deforested areas.

The reduced ability of deforested catchments to slow the rates of surface water run off leads in turn to increased and higher volume flood events, which impact the usual patterns of sediment deposition which normally create fertile lands for flood plain agriculture and also serve as a valuable food source for illiophagous fish species (specialist sediment feeders). This rapid, high volume flooding will often not allow sufficient time for deposition of sediments or for formation of the complex organic molecules that are characteristic of normal alluvial deposits.

In flood plain wetlands, where the rearing of cattle and small-scale dry season agriculture are traditional practices, overgrazing is leading to soil erosion and, as a result of reduced vegetation cover, flooding is more frequent (World Bank, 2005). (Abban, 1999) reported that while international actions to limit deforestation have been concerned with the depletion of timber and wood products from forests, local demand for fuel wood has been the major cause for the depletion of vegetation cover for fish habitats. As vegetation continues to be cleared to provide more housing, roads and other infrastructure as the economies and populations in most western African countries grow there will therefore be increasing widespread impacts to fishes.

Deforestation and land clearance are also associated with land-based aquaculture where vegetation is cleared for pond construction. However, the larger impact of aquaculture is through the widespread application of drugs to treat diseases, inadvertent escape of non-native invasive species, and spread of disease to wild fishes. A wide range of drugs

(e.g. antibiotics) is used in aquaculture to prevent disease outbreaks and prevent or eliminate parasites. These drugs inevitably enter the nearby rivers and lakes with, in many cases, unknown consequences for fish and invertebrates. When antibiotics enter the natural environment they can lead to a buildup of resistant pathogens which can then infect wild fishes which, if eaten, may also harm people. Concentrating large numbers of fish in a small area means that the fish become more prone to diseases. Such diseases or parasites can easily then be transferred to wild fish that pass by in the case of cage farms in lakes or with escaped farm species. Finally, the application of fish feed leads to nutrient build up in the environment as food waste and fish feces enter the water column, in particular below fish cages in lakes. These additional nutrients, primarily nitrogen and phosphorus, lead to eutrophication and cause algal blooms and overgrowth of other aquatic plants. The overgrowth of algae and other plants will often lead to a depletion of oxygen levels (especially at night) which can lead to large-scale 'fish kills'. There have been periodic occurrences of fish kills in the lower Volta as a result of cage farming.

3.4.6 Invasive alien species

The introduction and spread of non-native invasive species is of particular concern as once they enter a freshwater system it is very difficult, and in many cases impossible, to then eradicate them. The spread of invasive aquatic plants such as water hyacinth (*Eichhornia crassipes*) and Hippo grass (*Vossia cuspidata*) are noted to be of particular concern in the Appolonia River in Ghana and Agnébe River in Côte d'Ivoire where they already pose a threat to some species such as *Notoglanidium walkeri* (NT). Aquatic invasive plants are also a problem in the Tano River in Ghana and Côte d'Ivoire and in the upper reaches of the Oti River in the Volta basin, Ghana.

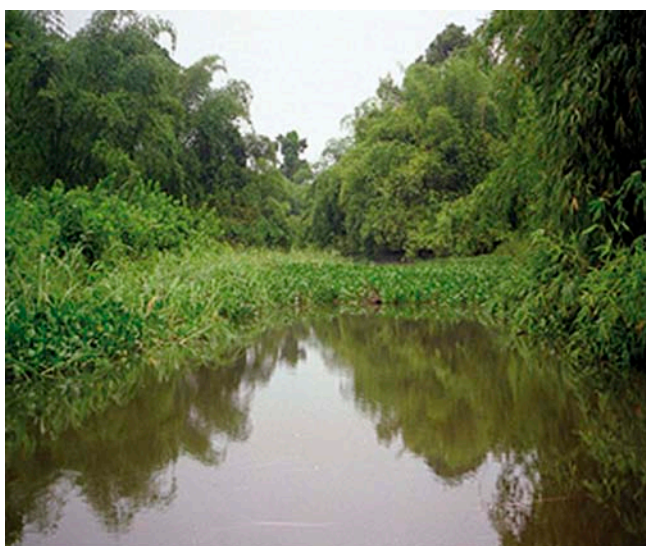


Figure 3.13 Sections of the Lower Tano River infested with the non-native invasive aquatic plant (*Eichhornia crassipes*). © K.A.A. deGraft-Johnson

Infestations of aquatic plants may impede boat transportation, damage equipment used for fishing, block irrigation and water supply and potentially impact the operation of hydroelectric plants with huge associated costs. Invasive plants multiply rapidly and, as for algae, can also lead to reduced light penetration, oxygen depletion, rapid loss of water through evapo-transpiration, and may provide habitat for disease vectors.

Invasive fish species also pose a major threat to native fishes. The best example is the Nile tilapia (*Oreochromis niloticus*) which is not native to many rivers in the region but is widely used in aquaculture. This species inevitably escapes and rapidly establishes itself in the wild. It is however, a highly competitive species, often outcompeting the native species and is also prone to hybridizing with other native *Oreochromis* species, potentially leading to the loss of any pure strains. As an example, *O. niloticus* has established itself in the Bia, Tano, and Pra rivers, and even in the meteoric lake, Lake Bosomtwe, where it threatens the native species *Coptodon coptodon* (NT) through hybridisation, which is likely to affect its genetic integrity and long-term survival. Finally, the Genetically Improved Farmed Tilapia (GIFT) strains of *O. niloticus* are being farmed in Ghana where they have escaped and interbred the local fish populations (Anane-Taabeah, Frimpong & Hallerman, 2019).

3.5 Conservation recommendations and research actions

3.5.1 Conservation recommendations

Freshwater ecosystems worldwide are subjected to a variety of anthropogenic threats. In western Africa it is now accepted

by scientists, development experts and even fishermen that environmental resources are being overexploited, depleted or require active restoration. In addition to the overexploitation of natural resources there are many other threats to western Africans fish such as manmade disturbances to system hydrology when constructing dams, a riverbed is mined, or a wetland is drained for agricultural purposes. Conservation and restoration of freshwater ecosystems therefore increasingly need to be recognised as global and regional priorities (Geist & Hawkins, 2016).

Conservation measures were identified and recommended by the experts involved for 36% of the species assessed. The most frequently recommended measures include *Site/area management* for 17% of species, *Habitat & natural processes restoration* (15% of species) and *Awareness & communications* for 14 % of species (Figure 3.14).

It should be noted that consultations with stakeholders have been initiated but need to be strengthened throughout the region (CEPF, 2015). A number of investment initiatives have also emerged with a focus on the protection of ecosystems in the region (CEPF, 2015).

3.5.1.1 Site/area management and protection

There are nearly 2,000 protected areas in western Africa with most of these being small forest reserves (UNEP-WCMC, IUCN and NGS, 2018), but very few have a focus on freshwater ecosystems, either in relation to their spatial cover or within their management plans. The findings from the assessments reported here highlight a number of areas notably rich in freshwater fish diversity where site protection would be beneficial. These sites include:

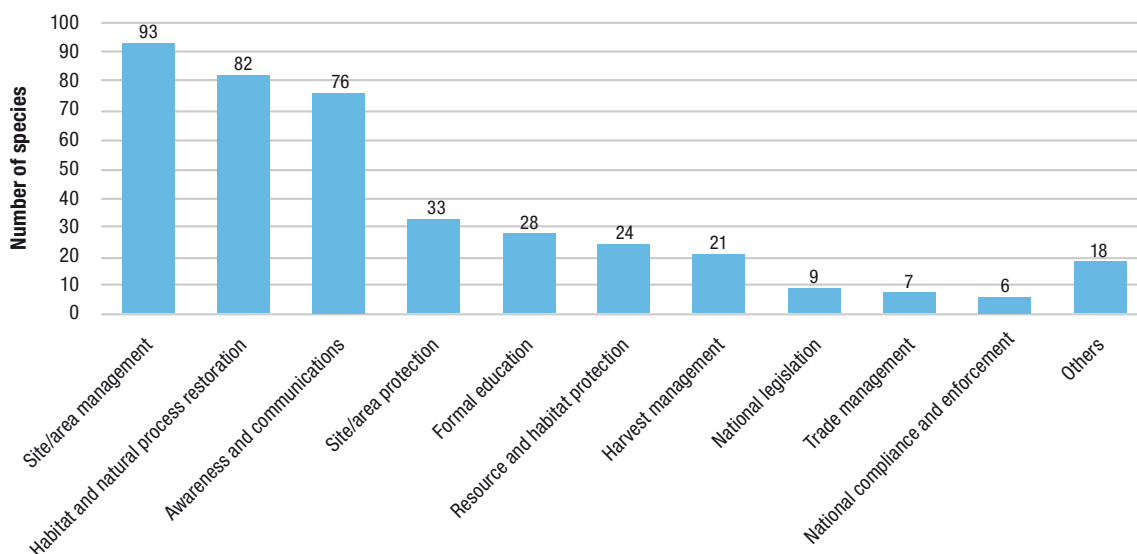


Figure 3.14 Conservation actions coded to fish species as part of the Red List assessment process. Source: Compiled by the report authors using data from the IUCN Red List (2021).

- The forested coastal streams and rivers of Upper Guinea and Southern Guinea. This area is characterised by high species richness and endemism. More than 300 species are known from this area;
- The Lower Niger Benue with its rich fish fauna, which includes around 289 species;
- The Volta Basin, incorporating parts of Burkina Faso, Ghana and small part in Côte d'Ivoire and Benin, which includes around 240 species;
- The interconnected network of rivers and coastal lagoons of the Bight Coastal ecoregion, and;
- The Niger Delta with its rich fish fauna (an estimated 221 species) threatened by oil pollution.

Recommended management actions include:

- The prevention of species extinction by addressing the immediate threats facing the priority sites and species;
- Development and implementation of integrated catchment-based management plans
- A greater focus on the need for transboundary management of those shared and hydrologically connected freshwater ecosystems, such as demonstrated by the Mano River Union comprising Liberia, Guinea, Sierra Leone and the Ivory Coast, jointly managing the transboundary Moa-Makona and Cavalla river basins,
- Identification of additional priority sites as Key Biodiversity Areas for freshwater fish species (see Chapter 9 this volume).
- Awareness campaigns to introduce governments and local populations to the international importance of these sites for fish biodiversity, and;
- Establishment of fish conservation zones which have been demonstrated to be highly effective in other parts of the world (Koning et al., 2020).

3.5.1.2 Habitat restoration

As we enter the UN Decade for Ecosystem Restoration, we need to ensure a focus on the many degraded freshwater ecosystems in the western Africa region. As noted above freshwater ecosystems are being lost and degraded at an alarming rate as the collateral damage of our efforts to support a rapidly increasing human population. This, combined with the growing demands by countries outside of the region for natural resources, which are hugely contributing to the rapid expansion of agriculture and mining, is putting tremendous pressure on these ecosystems. The assessments conducted here have identified where freshwater fish species are threatened due to habitat loss and degradation. We need to use this information now to inform priorities for habitat restoration to benefit freshwater fish species across the region.

3.5.1.3 Awareness and communications

The importance of maintaining aquatic biodiversity resources is not widely appreciated across all levels of society. The concept of biodiversity is still poorly understood and remains unknown to many people, and there is little understanding for the importance of biodiversity conservation amongst those people tasked with the development and management of dams, irrigated agriculture, the extractive industries etc. At the level of local communities and resource-users, the concept of natural resources is well understood but awareness of their own potential role in conserving or degrading these resources is often very limited. It is therefore important to launch public awareness campaigns at all levels on the current and future threats to freshwater biodiversity and the ways in which individual people can contribute to the future conservation of this resource.

3.5.1.4 Research actions

An analysis of the Red List assessments conducted here finds that for 76% of species specific research actions are recommended. Of these, the most commonly requested research themes are to monitor species "population trends" (for 62% of species), and to understand more about species "population size, distribution and trends" (56%), "life cycle and ecology" (49%), and "threats" (45%), Figure 3.15).

While some improvement is noted in our understanding of the diversity of freshwater fishes in western Africa, major gaps in our knowledge persist. This lack of a suitable information baseline represents a major impediment to the conservation of freshwater diversity (Smith et al., 2009). Where information is available on the inventory and distribution of species in a catchment, there is often little additional information such as on species ecology or threats to species and their habitats (Darwall et al., 2011). In the absence of such information, it is difficult to accurately assess the conservation status of the species and propose conservation actions. As noted at the time of the baseline Red List assessment completed in 2009 a major challenge was to reduce the total number of freshwater fish species classified as Data Deficient (55 species, or 10% of all species assessed). Since 2009 the number of species in this category has been reduced leaving just 32 species assessed (6%) as DD recognizing the important role of the ongoing fieldwork and other research in the region. However, these studies need to be continued and expanded alongside environmental and social impact studies which should be required as a prerequisite to any proposed development actions with the potential to impact on biodiversity. Much of the available data on freshwater fish species is also increasingly outdated and incomplete such that it remains difficult to assess changes over time, such as for the Red List Index (see Chapter 8).

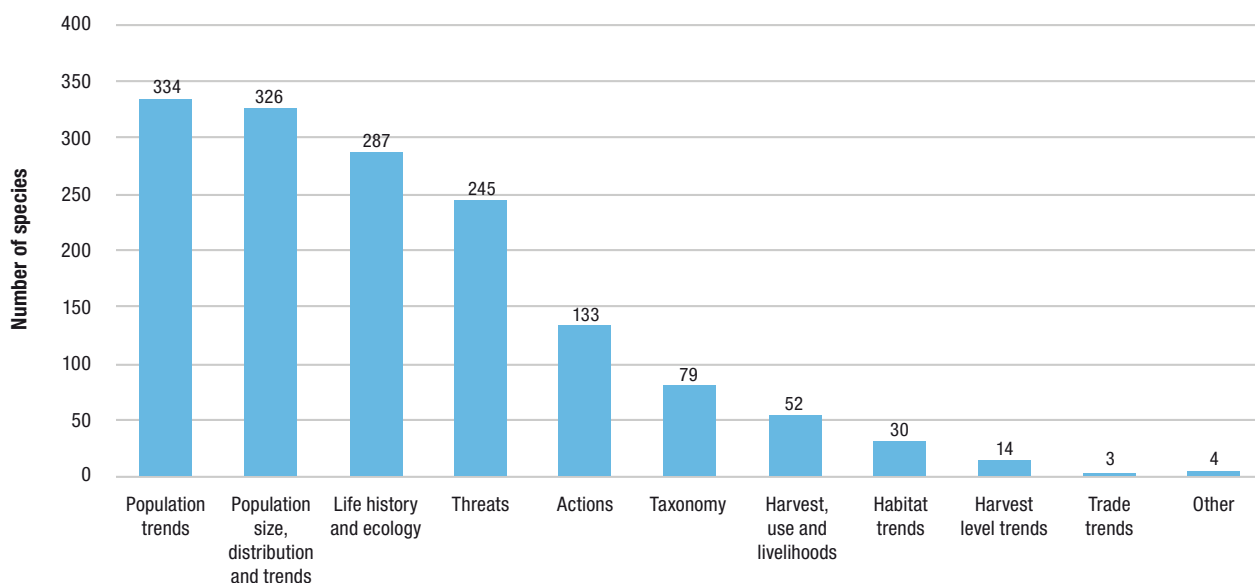


Figure 3.15 Recommended research actions coded to fish species as part of the Red List assessment process. Source: Compiled by the report authors using data from the IUCN Red List (2021).

The lack of recent or ongoing research to inform us on the status of the regions freshwater fish species suggests a paucity of focus on freshwater ecosystem research and conservation within the regions academic institutions. If this should prove to be the case then a strong recommendation would be to ensure greater inclusion of freshwater ecosystem research in academic curricular as an effort to generate a new generation of scientists to conduct this essential research. These studies will ultimately improve our understanding of the ecology and life history of the fishes in western Africa as a key step towards their future restoration and conservation.

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Chapter 4

The status and distribution of freshwater molluscs in western Africa

Van Damme, D.¹, Darwall, W.R.T.²

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4.1 Overview of western African molluscs

In western Africa, freshwater mollusc communities can be subdivided into two distinct freshwater communities that populate the vast region of the arid to hyper-arid savannah in the north and the east, and the western belt of Nigerian and Guinean lowlands. A third species-rich brackish water community comprises the estuaries, lagoons and mangrove forests along the Atlantic coast.

4.1.1 The Sahelian freshwater malacofauna

The Sahelian community includes large parts of Senegal, Mali, Chad, Burkina Faso, Niger and Nigeria and extends to the Atlantic via the Dahomey Gap (Togo and Benin).

Even though the largest natural surface waters of western Africa, namely Lake Chad and the Middle Niger Delta, are found in this savannah, the freshwater malacofauna is poorly diversified and dominated by genera that can survive limited periods of aridity or increasing salinity, such as *Pila*, *Lanistes*, *Gabbiella*, *Melanoides*, *Bulinus*, *Biomphalaria*, *Lymnaea* and *Spathopsis*. This limited diversity stems in large part from climate oscillations which cause the shallow surface waters, such as Lake Chad, to fluctuate from total desiccation about 20,000 years ago during the period of the Glacial Maximum to an enormous surface area (350,000 km²) known as Lake Mega-Chad between 7,000 and 5,000 years ago (Holocene Pluvial). Since then the lake has been shrinking and reached a new minimum size in the years 1970–1980 (Bouchette et al., 2010).

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Therefore, it is not surprising that the present malacofauna consists of species that originally colonised the region of Mega-Chad during the last wet period, then retreating southwards into the Chari and Logone river basins and eastwards into the Nile Basin. Most of these species are hence widely spread either throughout the entire Sahelian belt or over the western part of it, with a few endemics confined to the Middle Niger and the Chari-Logone basins. Some species such as *Gabbiella neothaumiformis* and *Gabbiella tchadiensis* were originally considered endemic to the Lake Chad basin but their status as distinct species needs further investigation, as they are probably local morphotypes belonging to widespread species. As the present study is not focused on solving ongoing taxonomic questions, the treatment of these species as valid full species is therefore maintained until additional material becomes available.

Finally, a recently published checklist of the fresh and brackish water snails of Benin confirms that the freshwater malacofauna occurring in the Dahomey Gap region has low species diversity consisting of largely ubiquitous species (Koudenoukpo et al., 2020). The brackish water snail fauna is comparatively richer.

4.1.2 The Guinean forest freshwater malacofauna

In complete contrast to the Sahelian malacofauna, the Guinean forest supports high species richness and a high degree of endemism to the tropical wetlands and rainforests that formerly extended from Guinea to the Sanaga River in Cameroon.

This ecotope is ancient and, based on its malacofauna, formerly occurred also in eastern Africa. It now forms the last refuge for a malacofauna that predates the disappearance of tropical wetlands over much of Africa during the last five million years. Four gastropod genera, *Afropomus*, *Saulea*, *Sierraia* and *Soapitai*, are endemic to the rivers of this region, while many *Potadoma* species have strongly restricted distributions, being confined to limpid ion-poor forest rivers. The bivalve fauna consists mainly of a high number of Iridinidae. It is remarkable that until the mid-20th Century the malacofauna of these western African wetlands remained free of genera that were dominant and widespread over the rest of the continent such as *Bellamya* (one dubious species excepted), *Melanoides* and *Corbicula*. The type of this non-geographic ecological barrier is generally unknown.

4.1.3 The Atlantic brackish water malacofauna.

The gently sloping coast of western and central Africa is ideal for development of extensive mangrove forests, drowned

estuaries and lagoons. Its malacofauna is quite rich but most species are widespread extending from Senegal to Angola, with some species even present along the South American coast. Some gastropods, such as *Tympanotonus* and *Pachymelania*, and bivalves, such as *Crassostrea* and *Iphigenia*, provide an important staple protein supply for coastal inhabitants.

4.2 The history of scientific research on western African freshwater molluscs

During the period predating 1950 the unique malacofauna of the Guinean tropical wetlands and forests was poorly surveyed, partly due to the inaccessible nature of the terrain and in part because most French missions, such as the Mission Jean Tilho (1906–1909 and 1912–1913), focused on the Chad Basin.

Western Africa is the first part of the continent from where freshwater bivalves (e.g. *Mutela dubia*) and brackish water gastropods (e.g. *Tympanotonus fuscatus*) were collected as early as the middle of the 18th Century (Adanson, 1757). However, the threat of the many disabling tropical diseases and the unwelcoming local populations posed an obstacle for travelling through the region for a long time. During the 19th Century some mollusc specimens occasionally reached Europe, mainly originating from Senegal, such as *Pleiodon ovatus* (Swainson, 1823) or *Potadoma büttikoferi* (Schepman, 1888), but this occurred only occasionally and the specimens rarely had information on exact location, more often having labels such as ‘*originating from streams of tropical Africa*’. It is therefore only around the beginning of the 20th Century that (mostly French) explorers, as part of the colonising armies, started to penetrate inland and collect shells.

These military explorations, such as the Mission Jean Tilho 1906–1909 and 1912–1913, directed their efforts to the more politically and economically interesting Sahel regions, which at that time were still relatively lush. The presence of uncharted large rivers and lakes, like the Niger and Lake Chad, presented attractive goals for officers, who wanted to gain academic publicity and thus further their military careers. The shell collections mostly ended up in the Muséum national d’histoire naturelle de Paris. Here, the French malacologist, Louis Germain, director of the malacological collection, produced an impressive number of taxonomic publications on the molluscs of the Chad Basin, which he enthusiastically pronounced as endemics (see (Lévêque, 1988) for an overview of the literature).

It is, however, only in the second half of the 20th Century that a new generation of French malacologists, such as Eugène

Binder, Jean Daget and Christian Lévêque, started to study the malacology of western Africa in earnest, incorporating population dynamics and other ecological aspects in their studies. Since about 1990, research groups in several western African universities have initiated their own studies on the freshwater mollusc fauna. Currently, however, the main research focus is on human health and aquatic pollution with limited interest in species conservation (Koudenoukpo et al., 2020).

Studies on the malacofauna of the Guinean tropical lowlands had to wait until the late 1960s–1980s when, in relation to the fight against bilharziasis, malacologists from the Danish Laboratory of Schistosomiasis and the British Museum started to collect and describe freshwater molluscs across the continent, including western Africa. The number of new species found during that period clearly shows how poorly the Guinean lowland fauna had been investigated and it can be assumed that there are still new species to be discovered.

Without a solid baseline to work from, we are presently unable to assess the extent of the loss of molluscan biodiversity accurately. However, given the ongoing and rapid rate of forest loss in the region, it can unfortunately be assumed that in countries such as Côte d'Ivoire and Nigeria, components of the malacofauna have already been lost or decimated.

In many cases, the original freshwater molluscan communities were already degraded or extirpated before serious research had started (see Species in the spotlight, 4.7).

4.3 Conservation status

The extinction risk of 100 species of freshwater molluscs native to the western Africa region was assessed according to the IUCN Red List Categories and Criteria: Global Version 3.1, second edition (International Union for Conservation of Nature (IUCN), 2012) (see Chapter 2 for full details on the methodology).

There are 33 native threatened species within the hotspot, of which eight are Critically Endangered, eight are Endangered and four are Vulnerable (Table 4.1, Figure 4.1). There are 10 Data Deficient species within the Hotspot of which one is thought to be endemic. Taking into consideration the Data Deficient species, the best estimate for the number of native species threatened with global extinction is 26 (26%). One endemic species, *Bellamya liberiana*, was last recorded in 1888 and is now considered Critically Endangered (Possibly Extinct).

When compared to the previous baseline assessment by (Kristensen et al., 2009) the number of species in threatened

Table 4.1 Number of native and endemic freshwater mollusc species per Red List category in western Africa. Numbers in parentheses refer to the previous assessment (Smith et al., 2009) and include regional assessments. Source: Compiled by the report authors using data from the IUCN Red List (2021) and Smith et al. (2009).

IUCN Red List Category	Number of native species	Number of regionally endemic species
Extinct (EX)	0 (0)	0 (0)
Extinct in the Wild (EW)	0 (0)	0 (0)
Critically Endangered (CR)	11 (5)	8 (5)
Endangered (EN)	9 (5)	8 (3)
Vulnerable (VU)	4 (5)	3 (5)
Near Threatened (NT)	5 (2)	3 (2)
Least Concern (LC)	63 (59)	8 (11)
Data Deficient (DD)	8 (14)	3 (10)
TOTAL	100 (90)	33 (36)

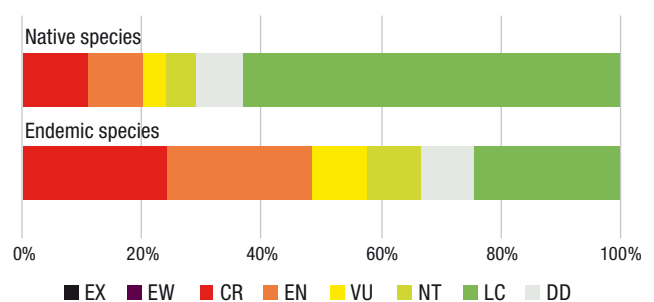


Figure 4.1 Percentage of native and endemic freshwater mollusc species per Red List category in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

categories (CR, EN and VU) has significantly increased, while the number of Data Deficient (DD) species has declined. This observed trend is thought to be due to: (1) increased knowledge on the declining state of the freshwater environment across the region, and; (2) improved taxonomic knowledge, in particular for freshwater bivalves.

Given the backdrop of ongoing and planned large scale agricultural intensification, combined with a rising human population, it is anticipated that the level of threat to freshwater molluscs reported here will increase, leading to more species being listed as threatened over the next 10 year time period.

4.3.1 Gastropoda

4.3.1.1 Prosobranchia

Neritidae and Neritiliidae

Representatives of the families Neritidae and Neritiliidae are confined to coastal fresh and predominantly brackish waters and have been recently divided into the neritid genera *Glypeolum* (*G. owenianum*), *Nereina* (*N. afra*), *Nerita* (*N. ascensionis*, *N. senegalensis*), *Vitta* (*V. adansoniana*, *V.*

cristata, *V. glabrata*, *V. rubricata* and *V. kuramoensis*) and the neritiliid genus *Neritilia* (*N. manoeli*). Other brackish water gastropod families represented in western Africa are Potamididae (*Tympanotonos fuscatus*), Tateidae (*Potamopyrgus fuscatus*), Muricidae (*Thais nodosa*), Ellobiidae (*Melampus liberiana*), Littorinidae (*Littoraria angulifera*) and Hemisinidae (*Plathymelania aurita*, *P. byronensis* and *P. fusca*). All species are Least Concern (LC), being relatively common and/or widespread along the African Atlantic coast from Senegal to Angola or also occurring on oceanic islands or in South America. The three Hydrobiidae that were described from western Africa, namely *Hydrobia accrensis*, *H. guyenoti* and *H. lineata* are endemic to the region. It remains uncertain whether they belong to the genus *Hydrobia* and further research is needed. It is, however, certain that the name *H. lineata*, used by (Binder, 1957, 1968), is assigned to another species and that the shells mentioned from Ivory Coast, Togo and Benin therefore need to be renamed. None of the western African hydrobiids are threatened and were assessed as NT and LC.

Viviparidae

Viviparidae are only represented with certainty by the species *Bellamya unicolor* (LC) occurring in the Sahelian part of western Africa, more specifically in the Senegal, Niger and Chad Basins. The species *B. liberiana* (CR), only found once in Liberia, is based on description of a few empty shells that in all probability have to be placed under the Pachychilidae.

Ampullariidae

There are four genera in western Africa, namely *Lanistes*, *Pila*, *Afropomus* and *Saulea*. The three *Pila* species (*P. wernei*, *P. ovata*, *P. africana*) and three *Lanistes* species (*L. libycus*, *L. varicus*, *L. ovum*) are LC. Only one species (*P. africana*) is endemic to the region. Their taxonomy has not yet been satisfactorily solved. *L. chaperi* from Benin, originally described as a subspecies of *L. libycus*, is considered a distinct species by some recent authors (Cowie, 2015; Koudenoukpo et al., 2020). This is an assumption not currently supported by new solid evidence.



Figure 4.2 Ghanaian postal stamp figuring *Pila africana* (Martens, 1886), endemic to the western African region. This apple snail is relatively common and hence assessed as 'Least Concern' at present. It has, however, become an important food source for rural populations.

The two other genera, *Afropomus* and *Saulea*, are both monospecific and represented by *A. balanoidea* (EN) and *S. vitrea* (VU). Both species are endemic to the Guinean wetlands.

Bithyniidae

This family includes three genera. The wide-spread African genus *Gabbiella* is represented by *G. africana* (DD), whose distribution is insufficiently known, and two species (*G. neothaumiformis* (CR) and *G. tchadiensis* (EN)), that are only known from collections at Lake Chad in the early 20th Century. As only a few empty shells remain, their taxonomic status as either endemic distinct species or local forms of widespread species remains unresolved, so the original IUCN assessment is maintained. The four species of the genus *Sierraia*, namely *S. ocutambensis* (CR), *S. expansilabrum* (EN), *S. leonensis* (NT) and *S. whitei* (LC), are endemic to Sierra Leone, while *Soapitia dageti* (CR), the sole representative of its genus, is only known from its type locality in Guinea.

Assimineidae

This family is represented by *Assimineea hessei*, a species that is recorded from freshwaters in the DRC and Cameroon as well as from brackish waters in Nigeria, on the assumption that the sub-populations all belong to this single species. Given the uncertainty for this being a single species, it is assessed as DD.

Paludomidae

Cleopatra bulimoides (LC) is widespread throughout western Africa, as in other parts of the continent. The two other paludomid species belong to the genus *Pseudocleopatra* and are restricted to the Lower Volta. Both are severely threatened, with *P. togoensis* assessed as CR and *P. voltana* as EN.

Pachychilidae

This family is represented by the genus *Potadoma*. Two species, namely *P. moerchi* (LC) and *P. freethi* (NT), have

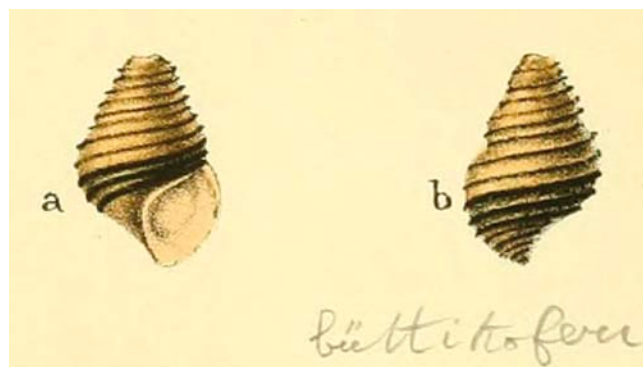


Figure 4.3 *Potadoma büttikoferi* (Schepman, 1888), only known from a few empty shells collected by the explorers Johann Büttikofer and Carolus Sala in 1880.

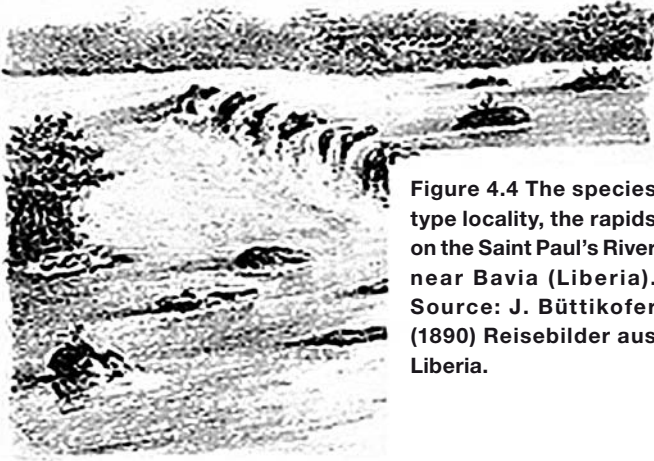


Figure 4.4 The species type locality, the rapids on the Saint Paul's River near Bavia (Liberia). Source: J. Büttikofer (1890) *Reisebilder aus Liberia*.

wide ranges. The first of these two species is endemic to the region and the second extends into Central Africa. Four other species are endemic, localised and severely threatened. These species are *P. bicarinata* (CR) and *P. togoensis* (CR), both of which are restricted to the Lower Volta in Ghana, *P. büttikoferi* (CR) which is only known from the type locality on the St. Paul's River in Liberia and *P. vogeli* (EN) which is restricted to the Agnébi River in Ivory Coast. *P. liberiensis* was assessed as DD because of its confusion in the modern literature with other species.

Thiaridae

This family has three representative species in the region. The first, *Melanoides tuberculata* (LC), is restricted to the Sahelian part of the region where it is widespread. The second *Melanoides* species, *M. voltae* (CR), appears now to be confined to the Lower Volta (Ghana) where it was recently was found at a single location. The third species, *M. manguensis* (DD), is recorded from Ghana and Ivory Coast but needs additional information on its taxonomy and distribution.

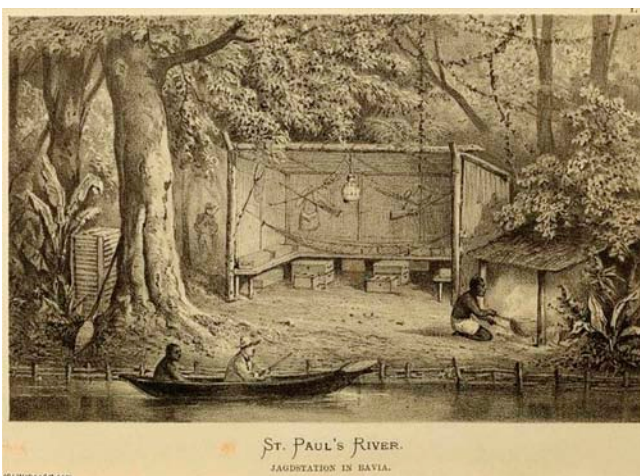


Figure 4.5 An encampment of the explorers Johann Büttikofer and Carolus Sala on the densely forested banks of the St. Paul's River near the village of Bavia (Liberia) in 1880. Source: J. Büttikofer (1890) *Reisebilder aus Liberia*.

4.3.1.2 Pulmonata

Lymnaeidae

The widespread *Radix natalensis* (LC) occurs throughout the region.

Ancylidae

The genus name *Ferrissia* has presently been altered to *Pettancylus* (see below).

Planorbidae

The genus *Biomphalaria* is represented by *B. camerunensis* (LC), *B. pfeifferi* (LC) and *B. tchadiensis* (EN), the latter only known from Lake Chad. The Red List assessment of Endangered (EN) has been maintained; though it could be that *B. tchadiensis* is Critically Endangered or Extinct due to the desiccation of the zones of the lake where it was reported from. The important caveat is that molecular investigation still needs to prove *B. tchadiensis* to be taxonomically distinctive and not a lacustrine morph of *B. pfeifferi*. The species *Hovorbis coretus* is widespread and LC. Formerly it was placed under the genus *Afrogyrus*, subsequently under *Africanogyrus* and currently under *Hovorbis*. The genera *Afrogyrorbis* (formerly *Ceratophallus*), represented by *A. natalensis* and *A. bicarinatus*, *Gyraulus*, represented by *G. costulatus* and *Lentorbis* (*L. junodi*), and *Segmentorbis*, represented by *S. angustus*, occur mainly in the Sahelian part of the region in surface waters that are becoming widely eutrophic. These species are all assessed as LC. The genus *Pettancylus* is represented by three species, *P. chudeaui*, *P. leonensis* and *P. eburnensis*. These species were formerly placed in the genus *Ferrissia* under the family Ancylidae, but are currently placed in Planorbidae (MolluscaBase eds., 2020). The first two of these species are DD, based on insufficient knowledge on their distributions, and the third is LC.



Figure 4.6 The same locality in 2018 now showing the Mount Coffee Hydroelectric Power Installation. The rapids and riparian forest are now gone. (Photo: voith.com)

Bulinidae

Only seven *Bulinus* species occur in the region but, due to their relative resistance to aquatic pollution, they have become dominant in many areas. The species *B. senegalensis*, *B. camerunensis*, *B. jousseaumei*, *B. truncatus* (= *B. guernei*), *B. umbilicatus* and *B. forskalii* are all assessed as LC, while *B. obtusus* is considered EN and is restricted to the Lake Chad Basin. Additional research on this species is recommended.

4.3.2 Bivalvia

It is only at the end of the 20th Century, thanks to the efforts of J. Daget (Daget, 1998) and D. Graf and K. Cummings (Graf & Cummings, 2021), that some clarity was created in the taxonomy of western Africa's bivalves. The few pre-1950 museum collections that were preserved are characterised by a wealth of misidentifications and the absence of precise localities. This unfortunately makes it impossible to define the original distribution of a number of species that have since become rare and localised.

Unionidae

Only two genera occur in western Africa, if the taxonomy of (Daget, 1998) is followed. The genus *Coelatura* is the most common with *C. aegyptiaca* and *C. gabonensis*, being widespread and LC. The third is the threatened *C. essoensis* (CR), which is restricted to the Assinie Lagoon (Ivory Coast). The genus *Nitia* is represented by *Nitia mutelaeformis* (LC), a dubious species recorded from Lake Chad and the Chari River. Most taxonomists presently doubt the distinct taxonomic status of this species stating that it could be a local form of *N. teretiusculus* from the Nile Basin.

Iridinidae

The number of described iridinid species has markedly increased since the publication of Daget's catalogue (Daget, 1998). The family is currently considered to be represented in western Africa by six *Aspatharia*, two *Chambardia*, four *Mutela* and one *Pleiodon* species.

Aspatharia dahomeyensis and *A. chaiziana* have been so confused in the past with other species that their original distribution can no longer be reconstructed and they have to remain DD. The species *A. pfeifferiana* is LC, being widely distributed over both western and central Africa. The ranges of *A. droueti*, *A. rochebrunei* and *A. pangallensis* are becoming so restricted that they are assessed as VU. Only *A. pangallensis* is endemic, the two other species also being found in Central Africa.

The ranges of *Chambardia wismanni*, a predominantly central African species, and of *C. rubens*, a mainly eastern African species, overlap in western Africa. They are both LC.

Of the four *Mutela* species, two, namely *M. dubia* and *M. rostrata*, are widespread in Africa and LC. The species *M. joubini* (EN) is widespread in western and Central Africa but is strongly localised and only known from a handful of museum specimens. *Mutela franci*, however, is restricted to the Middle Niger and is assessed as EN.

Finally, *Pleiodon*, a genus endemic to the northwest part of the region, has become almost extinct (CR) with the exception of a single population recorded from Sierra Leone considered to belong to *P. ovatus* (see 'Species in the spotlight').

Cyrenidae and Sphaeriidae

Cyrenidae is widespread with *Corbicula fluminalis* (LC) its only representative species. *Sphaeriidae* is represented by *Sphaerium hartmanni*, *Pisidium pirothi* and *Eupera ferruginea*, all of which are assessed as LC.

Finally, the brackish water bivalve fauna is very rich with most species widespread from Senegal to Angola, so few are endemic to the region and most are quite common. Four families occur in brackish waters, namely: Ostreidae (*Crassostrea tulipa*) (LC); Dreissenidae (*Mytilopsis africanus*) (LC); Cyrenoididae (*Cyrenoidea dupotetiana*) (LC); Donacidae, with six *Galatea* species (all LC) and four *Iphigenia* species, also assessed as LC except for *I. centralis*. *Iphigenia centralis* is only known from the type specimen, brought back by the French general de Trentinian from a military excursion in Mali and subsequently lost. Since *Iphigenia* is a brackish water genus, the enormous distance between the sea and the type locality (Middle Niger or Bani River), combined with the loss of the specimen, raises doubt as to its true origin. Most likely, the shell was collected at the coast of Senegal and carried inland. The species is therefore assessed as DD.

4.4 Species richness patterns

With 100 species of freshwater molluscs, the western Africa freshwater malacofauna is not particularly rich. This is due to a vast part of this region being turned into desert during the Last Glacial and which remains semi-arid savannah today. The highest diversity of species is found in the forested coastal region stretching from Guinea to Liberia with up to 41 species reported within a single river catchment (Figure 4.7). Threatened species are particularly concentrated around Lake Chad and Sierra Leone (Figure 4.8) and there appears to be a high density of Data Deficient species around the Inner Niger Delta (Figure 4.9). The regionally endemic species are particularly concentrated around southern Côte d'Ivoire, the Inner Niger Delta and Sierra Leone (Figure 4.10).

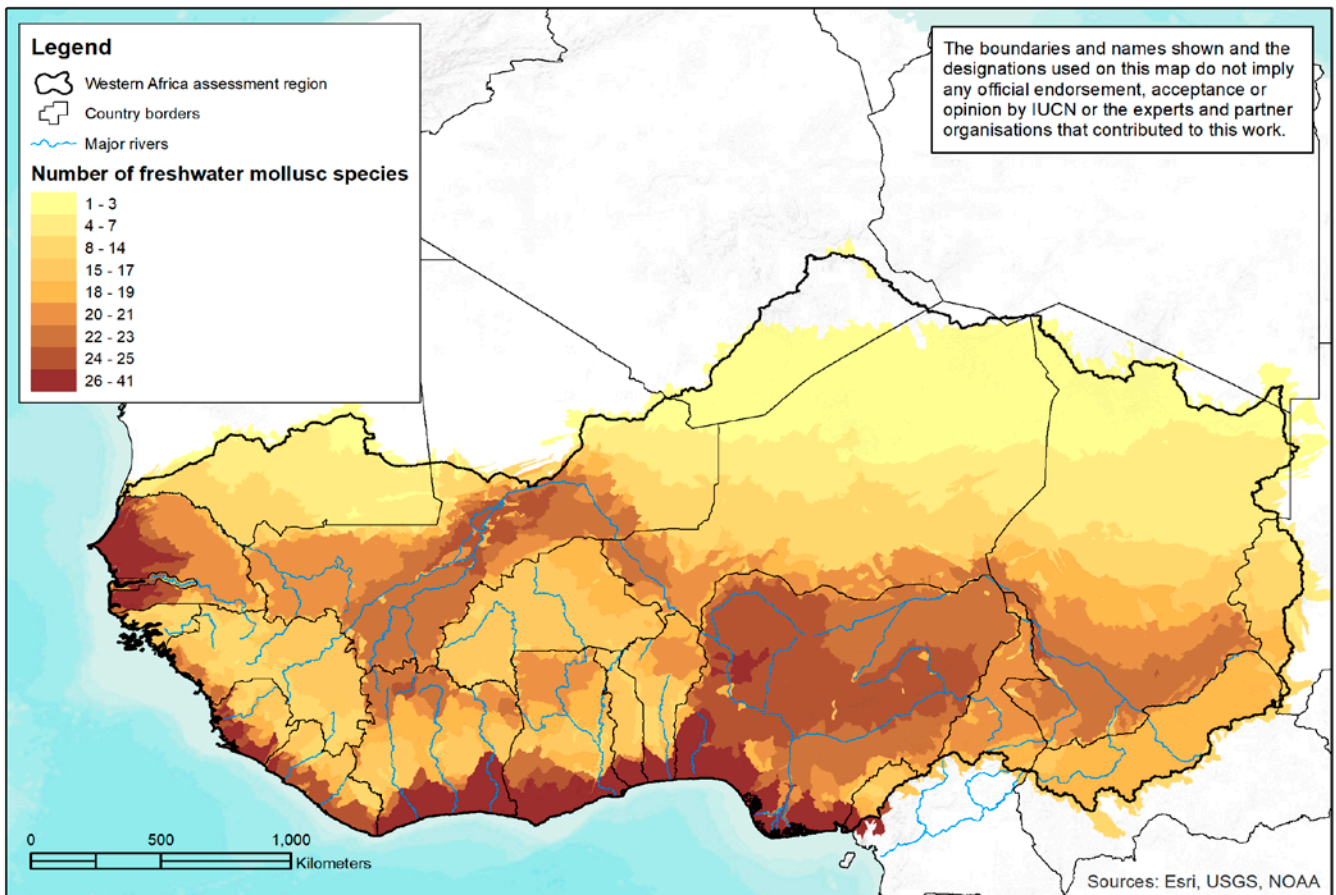


Figure 4.7 Species richness of freshwater molluscs in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

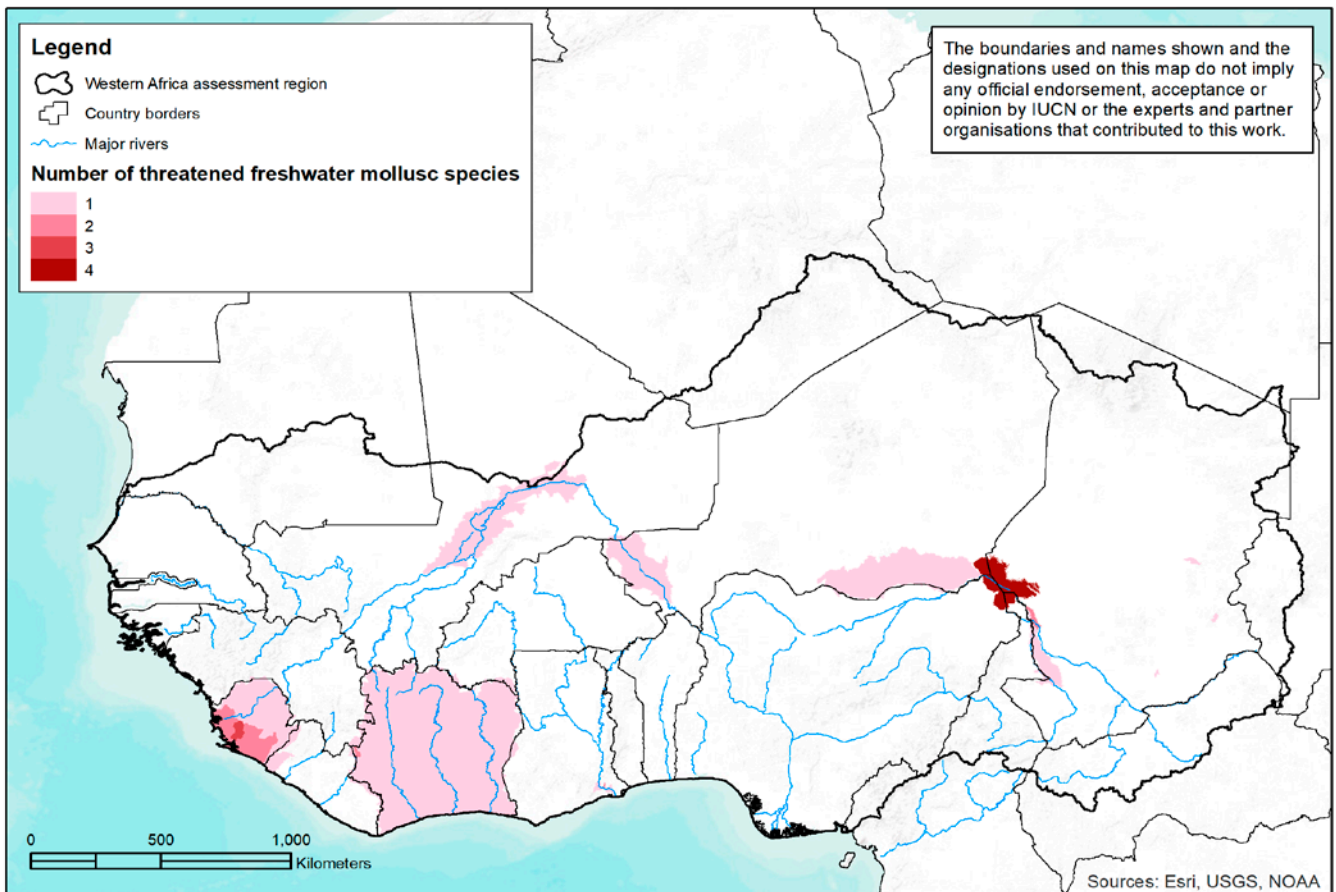


Figure 4.8 Species richness of threatened freshwater molluscs in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

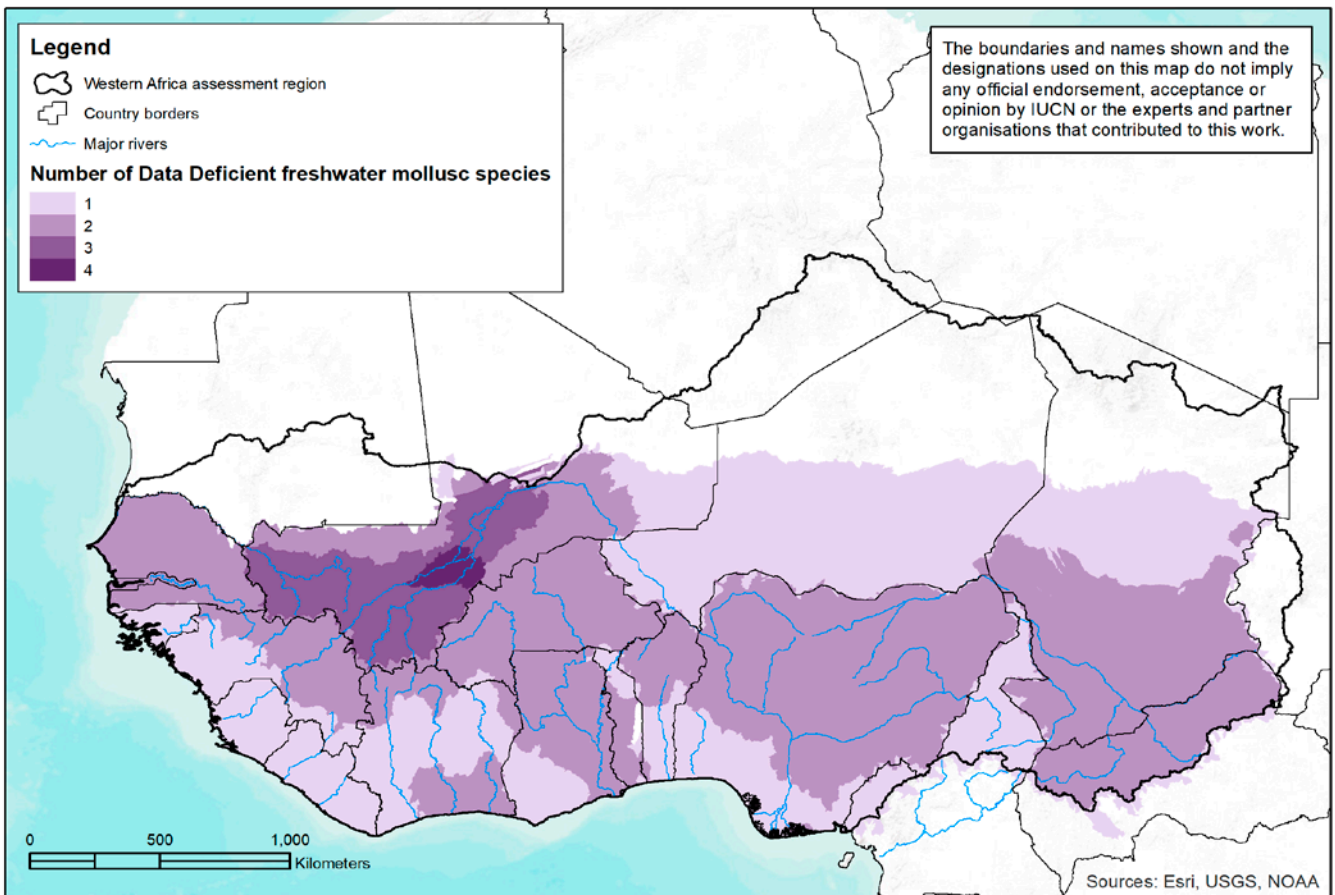


Figure 4.9 Species richness of Data Daeficient freshwater molluscs in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

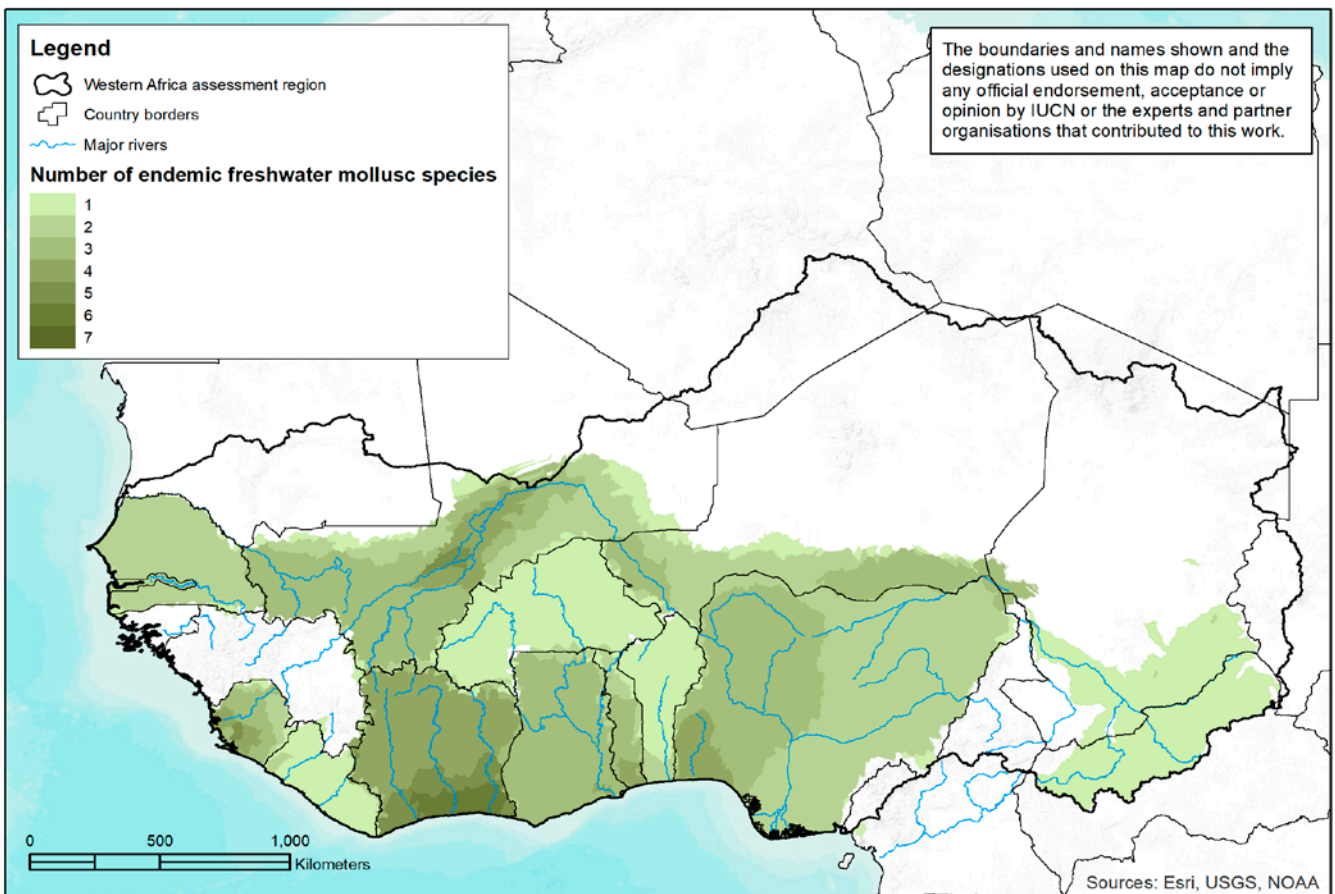


Figure 4.10 Species richness of regionally endemic freshwater molluscs in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

4.5 Major threats to freshwater molluscs

In western Africa, the increasing human population and the unsustainable use of natural resources, especially fresh water, have attained a level that is highly destructive to biodiversity and to human health. Prognoses for the immediate future are not good, with the population having grown from 77 million in 1955 to 404 million in 2020 and predicted to reach 700 million (low projection) to 800 million (median projection) in 2050 (United Nations, 2019). With an average birth rate of 7.2, which is the highest in Africa, combined with climate change, further degradation of the natural environment, in particular fresh water biotopes, appears inevitable.

4.5.1 Pollution

Pollution of surface waters is by far the greatest threat to freshwater biodiversity in western Africa and although there is protective legislation in different countries, it is rarely implemented.

Nigeria, the most populated country in Africa, is in full industrial expansion and can be used as an example where aquatic pollution has become a major problem for people and freshwater ecosystems.

The US Agency for International Development (USAID), starting a water monitoring and sanitation project in northern Nigeria, bluntly stated in 2017: *'Nigeria's water, sanitation, and hygiene (WASH) sector has reached an alarming state of decline, with nearly one-third of the population (about 70 million) lacking access to improved drinking water sources and approximately two-thirds living without adequate sanitation facilities. With one of the fastest-growing urban populations in the world, Nigeria's municipal centres in particular are likely to face increasing difficulty in meeting the water and sanitation service needs of their Oladipupo citizens.'* (DAI, 2017).

The available literature on environmental monitoring of surface water, reviewed by Taibo et al. (2018) fully corroborates the alarming situation, indicating that streams and rivers in Nigeria are showing increasing levels of water pollution due to the rapidly rising population, industrialisation and urbanisation. Waste generation by the industries and households has continued to increase. These waste products are indiscriminately released into the surface waters leading to pollution of the inland and coastal waters with heavy metals, nutrients, hydrocarbons and persistent organic chemicals such as pesticides, polychlorobiphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs).

The impacts of pollution by the oil industries in the Niger-Delta region (Nigeria) on people, nature and surface waters have been well documented. This pollution has led to water scarcity, disruption of socio-economic activities and poor aesthetic quality of most of the water bodies polluted by the oil spills (Egborge, 1994; Oladipupo et al., 2016). Most rivers around the Niger-Delta region were found unsuitable for drinking water due to pollution by crude oil. Mangrove forests and their malacofauna have been destroyed and the bioaccumulation of heavy metals, PCBs and other pollutants has reached dangerous levels.

In the rivers of the Guinean Forest belt, the water was originally ion-poor, being filtered by the forested landscape. The freshwater molluscs of this ecosystem are adapted to live in such conditions and are therefore extremely sensitive to increases of nutrients, pesticides, suspended materials, biological oxygen demand (BOD), and chemical oxygen demand (COD). Even relatively small increases in pollution, such as caused by logging, can lead to eradication of localised species.

4.5.2 Natural system modifications

4.5.2.1 Creation of standing and slow moving waters

The creation of standing waters, whether small pools for pisciculture or large reservoirs such as Lake Volta in Ghana, changes the composition of the mollusc community. Ecologically sensitive groups such as bivalves and pachychilid and paludomid gastropods tend to disappear or rarify, while ampullariid prosobranchs and pulmonates tend to multiply. Such modifications of previously stable natural systems often trigger ecological cascades, leading to new steady state communities in which the diversity of the macrofauna is severely decreased.

4.5.2.2 Deforestation and industrial plantations

Deforestation not only affects forests, but also rivers and their fauna, due to the increased load of organic and inorganic sediments and the elimination of shade. In particular, species of the gastropod genera *Potadoma* and *Pseudobovaria* are vulnerable to these changes. When the deforested areas are converted into industrial plantations, a combination of pesticides and fertilizers is usually employed that contaminates surface waters and their biota (Rengam, 2008) (see also 'Species in the spotlight').

While in many western African countries the damage to Guinean forest streams and their biota has already been done, palm oil plantations are presently expanding in the last relatively unspoiled regions of Liberia and Sierra Leone, where levels of deforestation were 6 to 12 times

greater in 2015 than in 2001, respectively (UNEP-WCMC, IUCN and NGS, 2018). The destruction of molluscan populations downstream of the deforested areas, largely due to increased sediment loading in the rivers, may extend significant distances downstream. The impacts will be even more extensive where pesticides and fertilisers are utilised.

4.5.2.3 Conversion of inland wet valleys into rice paddies

Western Africa is at the beginning of a new agricultural revolution. In an effort to become self-sustaining in terms of food production, many countries are planning to convert their inland valley swamps into rice fields or paddies.

Inland valley ecosystems are estimated to cover about 3.6% of sub-Saharan Africa, corresponding to approximately 85 million ha (Dossou-Yovo et al., 2017). Inland valleys are defined as the upper parts of river drainage systems, comprising the whole of the upland lowland continuum. Inland valleys have until recently been left relatively untouched because they were not suited to agricultural production. This is because inland valley soils are difficult to farm and the valleys are quite inhospitable, being infested with diseases such as bilharzia, river blindness, sleeping sickness and malaria (Dossou-Yovo et al., 2017).

Notwithstanding these obstacles, the recent population increase and climate destabilisation are driving governments and large organisations, such as the West African Rice Development Association as well as European and Asian interest groups, to start large-scale conversion of natural wetlands for rice farming. This entails not only destruction of the original wetland through drainage and canalisation, but any remaining biotopes are then destroyed through the extensive use of fertilisers and pesticides.

An unavoidable side effect of the destruction of this unique ecosystem will be the extinction or rarification of endemic swamp snails, such as *Afropomus* and *Saulea*, which are considered living fossils.

4.5.3 Climate change and severe weather

According to the (IPCC, 2018), global warming will lead to significant changes in the occurrence and intensity of temperature extremes in the Sahel region, which is also experiencing rapid population growth, leading to an increased demand on its water resources.

All rivers and standing waters in the region are affected by this change and its associated extremes of increased flooding and drought. The aquatic fauna is most affected in regions with large natural water bodies, for example, Lake Chad and large rivers such as the Niger, Senegal and Chari-

Logone, where the three economically most important local activities, namely crop farming, cattle herding and fishing increasingly compete for the shrinking water resources.

In the Lake Chad area, for example, intensified crop farming has led to surface water loss due to increased irrigation, and deterioration in water quality due to pollution by fertilisers and pesticides. The crop farmers are in competition with the traditional cattle herders, whose herds cause denudation/erosion of the landscape by overgrazing, and eutrophication. In the extensive shallow parts of the lake, cattle are not restricted to the lakeshore but enter the lake itself to graze in the littoral zone, moving towards the centre when the lake shrinks. Finally, fishing, which has been a main food and income source for the people of the Chad Basin, is also declining and so leading to further pressure to convert more land for farming.

The degradation of Lake Chad's aquatic ecosystem has, however, been countered since 2015 by restrictions such as a total ban on fishing, farming cash crops, such as red peppers and purchase of fertilizers. These measures have been imposed by the central authorities in an attempt to prevent the Boko Haram from accessing food, money and supplies. With large zones now, militarised and closed for civilians the economy of the region has effectively been destroyed (Campagne & Begum, 2017).

In the Inner Niger Delta and the Middle Niger in Mali, the situation is comparable with that in the Lake Chad Basin, with the exception that hostilities are not so severe. However, the increasing weather extremes are rapidly aggravating the situation (SouthWorld, 2019).

4.5.4 Agriculture and aquaculture, residential and commercial development

4.5.4.1 Agriculture

Under section 4.5.2.3 we have already outlined the potential environmental impact of the planned conversion of inland wetlands in the Nigerian forest belt into rice paddies. The second agricultural development that is highly damaging for natural aquatic ecosystems is the construction of dams for irrigation. The effects for the malacofauna include a shift in molluscan communities towards species that thrive in waters with reduced stream velocity, unfortunately mainly pulmonates that are intermediate hosts for diseases such as schistosomes and other parasites. In addition, the fragmentation of rivers so that fish species, that are specific or non-specific hosts for freshwater mussels, will be impeded in their dispersal of mussel species. Finally, as also mentioned above, the significant increase in the use of pesticides and fertilisers for agriculture will lead to many surface waters becoming uninhabitable for mollusc species.

4.5.4.2 Aquaculture

Ghana and Nigeria are two prominent western African countries that depend on fisheries as major sources of animal protein. They possess natural and artificial waterbodies, which have the potential for increasing aquaculture production through cage culture of *Tilapia* and a reduced dependence on capture fisheries. A recent study, however, voices concerns on the sustainability of this economy in the light of changing weather patterns that have led to reduced production and economic yield (Asiedu, Nunoo & Iddrisu, 2017).

4.5.4.3 Residential and commercial development

Residential and commercial developments are mainly concentrated in already degraded areas around the expanding urban centres. These developments have had the greatest impact on lagoons along the Atlantic coast, in particular on the Lagune Ebrié in Ivory Coast where the dumping of domestic and industrial sewage from the town of Abidjan has seriously degraded this wetland.

Development of coastal resorts in western Africa can also impact wetlands but is relatively modest at present and mainly concentrated in Gambia, Senegal, Ivory Coast, Ghana, Togo, Cape Verde and the island of Sao Tomé (Van Egmond & Leijten-Kupers, 2001).

4.5.5 Biological resource use

The already cited conversion of inland valleys in paddy rice fields (see Section 4.5.2.3) represents a clear example of the impacts of unsustainable use of biological resources. In this case it has, as in other African countries, such as Madagascar, led to a significant decrease in molluscan biodiversity and a population explosion of species, such as *Bulinus* and *Biomphalaria*, that are intermediate hosts to *Schistosoma*.

4.5.6 Energy production and mining

4.5.6.1 Energy production

Western Africa possesses Lake Volta, the largest man-made reservoir of the world, and about 6,890 smaller reservoirs of 1 to 1,000 ha, with a combined surface of 27,504 km² (Abobi & Wolff, 2020). The ecological impacts of the formation of Lake Volta have been intensively studied and these studies identify the ecological cascades caused by changes in natural processes. For example, reduction in the flow rate of the river in turn resulted in an invasion of aquatic weeds, which led to an increased density of snail populations that are intermediate hosts to *Schistosoma*. This then led to a massive increase in the use of molluscicides that probably led to extinction of rare gastropod populations such as *Pseudocleopatra* and *Potadoma*, and all Iridinidae (Bivalvia). Increased siltation has also led to a decline in brackish

water mollusc populations in the estuary. Downstream of the reservoir, in the Lower Volta, small populations of *Pseudocleopatra togoensis* and *Potadoma togoensis*, both CR, are still present (Akpabey, Addico & Amegbe, 2017) but populations of mangrove mussels in the brackish water part of the estuary have dwindled following the reduction of fresh water now reaching the estuary (Fobil, Volta Basin Research Project (VBRP) & Attuquayefio, 2008).

4.5.6.2 Mining

Mining (including illegal, traditional and industrial operations) is for many western African countries economically very important and in countries such as Nigeria, Sierra Leone and Mali is highly diverse. The widespread environmental impacts are, however, largely uncontrolled.

Our current knowledge is unfortunately insufficient to assess the full impact of mining on freshwater molluscs in western Africa. In general, however, the major impact of mining on molluscs is threefold. First, increased water turbidity and sediment loading is caused by direct dumping of mining waste and erosion following removal of vegetation around mining sites. Second, increased nutrient enrichment is caused by domestic sewage from mining settlements. Third, bioaccumulation of toxic and/or persistent substances such as heavy minerals and derivatives like sulphates comes from coal and mercury used in gold mining.

In Nigeria, one of the most important mining countries, observed mining impacts include pollution and land degradation through mining sand, clay, marble, coal, tin, lead, cadmium and gold. The effects not only affect biodiversity during active exploitation of the mines but also can persist for long periods after mining has ceased (Gyang, 2010; Merem et al., 2017). On the Bukuru Plateau in Nigeria, for example, the surface area of standing water bodies, formed when abandoned open mines filled with (usually toxic) water increased from 31.52 km² in 1975 to 88.59 km² in 2005 (Musa & Jiya, 2011). As a rule, these waters do not support molluscs except for some hardy species, such as *Bulinus* and *Biomphalaria*, which are intermediate hosts of *Schistosoma*.

The western African molluscs most vulnerable to mining activities are the *Potadoma* species that are endemic to the ion-poor lowland forest streams.

4.6 Conservation recommendations

4.6.1 Site/area protection

In the Sahel part of western Africa the number of threatened freshwater molluscs is limited, giving few options for site based conservation. The most interesting Sahelian

waterbodies are the large lakes such as Lake Chad and Lake Léré, and the large rivers such as the Niger and Chari. However, the large size of these water bodies, the significant fluctuations in water levels and extent, combined with the large numbers of people living there makes the planning and implementation of site/area protection measures challenging.

The most suitable areas to consider for site based protection are the smaller lakes such as Lake Léré (41 km²) and Lake Tréné (12 km²) in southern Chad, interconnected by the Mayo Kébbi River. It is however difficult to find sites that remain in a suitable condition to warrant protected area status in the traditional sense. In these cases, management at the catchment scale would be most appropriate.

In contrast, protection of Guinean Forest sites poses severe problems because the ever-increasing fragmentation (logging, burning, and creation of open areas or corridors through this tropical rainforest) is already sufficient to create a domino effect of environmental changes due to decreasing air temperature in the originally very wet forests. This in turn will lead to dryer soils and leaf litter, which in turn will alter the quantity (less water) and quality (more soil and litter) of rivers.

Site protection will in these cases only be effective if the protected sites remain part of areas that are vast enough to form a buffer against aridification which otherwise will alter the Guinean Forest fauna including its aquatic fauna rapidly and irreversibly in a few decades due to climate change. Focus on Liberia is warranted here as it holds the largest remnants of the Upper Guinea Forest.

4.6.2 Resource and habitat protection

In recent years, experimental studies have been carried out on cage raising the freshwater oyster, *Etheria elliptica*, in Benin (Akélé, Montcho & Lalèyè, 2017) as well as growing *Aspatharia* spp. in Egypt (Goda et al., 2015).



Figure 4.11 Nigerian postal stamp of the Mangrove Oyster (*Crassostrea tulipa*, not *C. gasar*), considered a delicacy by the inhabitants living along the forested littorals of the western African Atlantic coast. (Photo: B. Sojka, Pinterest)



Figure 4.12 Water colour painting by the British artist Tina Bone titled 'Guardians of the Mangrove Oyster' (2015) depicting Gambian women processing mangrove oysters (*Crassostrea tulipa*) at the edge of a mangrove forest. Source: T. Bone, Artists & Illustrators.

Although successful, these have not yet led to any follow-up studies. In particular, aquaculture of freshwater and mangal gastropods and particular bivalves is still in its infancy. If developed in a sustainable way, such types of aquaculture could result in the ecological positive evolution of medium sized rivers (culture of *Etheria elliptica*), shallow standing waters (culture of *Aspatharia*) and mangroves (culture of Mangrove oyster). The possible negative and positive impacts of aquaculture need to be studied but considering the ecological sensitivity of the species mentioned; they should not cause the highly destructive environmental effects that generally resulted from the breeding of *Tilapia* and catfish, namely eutrophication due to overstocking. The bivalves cited do function as important natural water filters and hence improve the water quality.

A number of brackish water molluscs are collected along the western African coasts, mainly in mangrove forests. In particular, gastropods of the genus *Pachymelania* and of the bivalve genus *Iphigenia* are semi-professionally collected locally and sold on local markets. The only economically important bivalve is the Mangrove oyster, *Crassostrea tulipica* (often erroneously referred to as *C. gasar*) which has provided a stable source of protein for many coastal communities since prehistoric times. It is traditionally collected by women at low tide by cutting the mangrove roots to which the oysters are attached in clusters, and then transported to the place of processing.

In order to preserve mangrove trees from destructive harvesting methods, strings bearing oyster shells are

sometimes hung just in front of the mangroves, for settlement and growth of the oysters. Shells are equally widely used for the lime industry or for paving in villages, as well as in traditional medicine. This is a species of great potential interest for industrial farming, and aquaculture experiments for this purpose are ongoing in Sierra Leone and Senegal (Poutiers, 2016).

Resource and habitat protection is an essential requisite to avoid destruction of the malacofauna of the Guinean forest

rivers in the coming 25 years. It is of particular importance to protect these rivers from the impact of agriculture expansion, such as the oil palm plantations mentioned in Section 4.5.2.2. We can learn from the studies in other parts of the world, such as Malaysia, how these plantations have affected the aquatic fauna. We can also learn how the creation of buffer zones of protected natural riparian vegetation between these monocultures and the rivers can bring significant benefits (see species in the spotlight, 4.7).

4.7 Species in the spotlight – unravelling the mysterious decline of *Pleiodon ovatus*

Pleiodon ovatus (Swainson, 1823) is a large freshwater mussel endemic to western Africa, belonging to the endemic African family Iridinidae. The oldest representatives of this genus are known from Upper Cretaceous deposits in Egypt (Van Damme, Bogan & Dierick, 2015) and, apparently, they survived the meteor impact that killed off the dinosaurs.

Until around 4 million years ago, *Pleiodon* remained the dominant iridinid, but it was then replaced by *Mutela* throughout tropical Africa with the exception of just two remaining species. Namely, they were *Pleiodon spekii*, endemic to Lake Tanganyika and *P. ovatus* (CR), endemic to the forest belt of the Upper Guinea Coast region in western Africa (the region stretching from Senegal to Sierra Leone).

Pleiodon ovatus was one of the first freshwater mollusc species to be described from western Africa, by the British naturalist/artist William Swainson in 1823. The description was based on a single valve from an unknown locality, which is preserved in the British Museum of Natural History (Graf & Cummings, 2021).

Combined information on the localities for the roughly 100 specimens remaining in European and American museum collections was used to reconstruct the most probable range of the species around 1890 (Graf & Cummings, 2021). In that period *P. ovatus* specimens were mainly collected in Senegal, its range extending eastward to the Bafing River in western Mali and southwards into Gambia, Guinée-Bissau, Guinée, Sierra Leone and possibly northern Liberia. Unfortunately, more than half of the museum specimens have labels with dubious, vague or erroneous type localities. Highly dubious are the few shells whose labels state that they were collected in northern Nigeria (one specimen), Niger (one specimen) and Gabon (two specimens). Of these, the first two records suggest that *P. ovatus* also occurred in the Niger River, which would greatly extend its original range, and the third that it also occurred in Central Africa (Gabon). Although these locality records cannot be excluded, these locations are quite distant from the heartland of this species.

The very attractive shells of *P. ovatus* were apparently in high demand by 19th Century western shell collectors and museums. This appears to have led to a flourishing trade by shell dealers, who solved the lack of information about their shells' origins by using vague references such as 'Africa,' or 'West Africa' or purely fictitious records such as South Africa, Egypt, Tanzania, Peru and Mexico (Graf & Cummings, 2021).

Around 1910 this shell trade stopped, for unknown reasons. Possibly the demand for shells had reduced or the supply had diminished. The second possibility, that *P. ovatus* was becoming increasingly rare since the start of the 20th Century,



Figure 4.13 *Pleiodon ovatus* (Swainson, 1823, Iridina). Specimen originally described as a syntype of *Iridina splendida* Chenu, 1848 from Senegal (length 100 mm). (Source: Graf & Cummings, 2020)

seems to be confirmed by there being only a single mention in the literature of field collection of shells between 1910 and 1948, that being an expedition to the Casamance River (Senegal) (Paulus & Paulus, 1948). After that, the species disappears from the records completely, to re-emerge 43 years later in a publication by Karl-Otto Nagel (Nagel, 1991) on freshwater molluscs in Sierra Leone. This German malacologist discovered in 1986 a population of the species in a narrow river stretch on the Gbangbar River near Moyamba. This is the only time the species has been recorded from Sierra Leone. It is not known if *P. ovatus* still exists at that locality today.

The reason for the disappearance of *P. ovatus* over most of its former range in the Upper Guinean Coast region has never been determined and apparently, this was not noticed by contemporaneous scientists.

One possible explanation for the disappearance of this species could be the extensive use of DDT and other persistent toxic chemicals in the western African agro-industry. This suggestion is, however, unsubstantiated given that the widespread use of DDT only started in the 1960s. However, the near-extinction of this species does coincide with the intensification of anthropogenic landscape change in the early 20th Century, and more specifically with the conversion of vast stretches of riparian forests into monoculture plantations such as oil palm and peanuts. This was the outcome of the agricultural expansion that began in the Upper Guinea Coast region in the 1830s, in response to an increasing demand for oils and fats from industrialised countries (Brooks, 1975). In the first half of the 20th Century with the introduction of larger and more efficient agricultural machinery, improved cultivated varieties and modernised transportation, the monoculture boom took off (Bonneuil, 1999) and has continued to expand since that time.

So what is the most plausible cause for the loss of most *P. ovatus* populations in the period 1900 to 1950? Recent limnological studies in eastern Asia and the Amazon, representing the two regions in the world with the highest concentration of oil palm monocultures, provide some insight. These studies have shown that in rivers where the original riparian vegetation was removed to make way for oil palm plantations there was an average 42% reduction in aquatic species diversity (Giam et al., 2015). This dramatic loss of biodiversity was particularly noticeable in the fish fauna (Wilkinson et al., 2018). In contrast, in plantations where riparian forest vegetation was preserved the effect was not as dramatic and in some cases was negligible. It could therefore be proposed that *P. ovatus* was not directly impacted, such as by a decline in water quality and increased turbidity as caused by erosion and run-off from the plantation soils, but was indirectly impacted due to the widespread disappearance of its fish-host(s) following such habitat alterations. In this case, it may therefore be proposed that the decline of fish species in turn has led to the disappearance of a mollusc species.

Although no studies were found which have focused on the impact of anthropogenic landscape change on the riparian forests of the Upper Guinea Coast, it can be assumed that the impact on the aquatic fauna will be similar to that observed in Asia and South America. It is strongly recommended, therefore, that a study be carried out on the fish hosts and genetics of the last known population of *P. ovatus* in Sierra Leone, before the ongoing expansion of oil palm plantations moves forward to impact this last extensive part of the Guinean forest.

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Chapter 5

The status and distribution of freshwater odonates

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5.1 Introduction

Odonates include the conspicuous, colourful and diurnal “damselflies” (Zygoptera) and “dragonflies” (Anisoptera). Commonly the term “dragonflies” is used to refer to all odonates, as here in this report. They are often referred to as “flying jewels” because of their beautiful colouration and agility in the air. Dragonflies are the dinosaurs of the insect kingdom, pre-dating them with ancestors emerging over 300 million years ago. Giants from the Carboniferous period had wingspans of 70 cm or more, although 5–10 cm is typical of modern dragonflies. Adult dragonflies are usually found along or close to waterbodies where females lay their eggs and their larvae hatch and develop. On sunny days, dragonflies can easily be observed patrolling water sites or perching on exposed sticks. Males may hold territories for several days or even weeks and display courtship behaviour such as flashing their bright colours when females arrive. Males are capable of removing sperm from a female’s previous mate, which is why they often guard females during egg laying and fight furiously with other males.

Dragonflies are a good taxon to use in biodiversity studies as they are easy to collect, sensitive to changing environmental conditions, and are comparatively well studied taxonomically, ecologically and ethologically (Clausnitzer, 2001). Due to their presence both below water as larvae and above it as adults, they are great indicators of overall wetland health, acting as environmental sentinels and as “whistle-blowers” for declining habitats. Studies of dragonfly biodiversity can be used to minimise or mitigate impacts of future development in site conservation planning across freshwater systems, while species level-assessments can be used to monitor the possible impacts of growing threats such as climate change. Their study can help us to understand the past and future of rapidly changing environments. Their attractive appearance makes them key candidates as flagships for wetland conservation.

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5.2 Conservation status

Just before the publication of this report, the IUCN SSC Dragonfly Specialist Group updated the Odonata Database of Africa (ODA) with a considerable batch of new records from recent field trips in the region. These new data could not be included in this analysis, but these new records data bring the species total for the region up to 360 species.

At the time of publishing this report, the western Africa region included 307 species of freshwater odonates belonging to 13 families according to the Red List. Of these 307 species, 50 species are endemic to the region. These endemic species are largely forest dependent, either along streams or in swamp forests and are concentrated in the lower areas.

Of the 307 species of odonate addressed in this work, five are Critically Endangered, seven are Endangered and two

are Vulnerable, amounting to 14 globally threatened species (Table 5.1). Since the previous report on the western African odonata in Dijkstra et al. (2009), 19 species have changed Red List category due to new information (nongenuine changes). There have been no genuine status changes during this time.

Eight species have been moved from DD to LC, due to new information concerning their status and distributions, and one from DD to NT; *Phyllomacromia lamottei* is thought to be endemic to the Nimba Mts region. One species – *Trithemis dubia* – was moved from LC to DD due to unresolved taxonomy. *Azuragrion buchholzi* has moved from NT to LC due to a number of additional localities extending its known range in Cameroon and Gabon.

Three species have been downlisted from VU to LC due to new records improving the prospects of these species; they are *Agriocnemis angustirami*, *Nubiolestes diotima* and



Figure 5.1 Pygmy Basker *Aethriamanta rezia* near Yekepa, Nimba County, Liberia. It is known from pools, slow streams and rivers, and lakeshores with dense aquatic vegetation. © K.-D. Dijkstra

Table 5.1 Number of native and endemic odonate species per Red List Category in western Africa. Numbers in parentheses refer to the previous assessment (Smith et al., 2009) and include regional assessments. Source: Compiled by the report authors using data from the IUCN Red List (2021) and Smith et al. (2009).

IUCN Red List Category	Number of native species	Number of regionally endemic species
Extinct (EX)	0 (0)	0 (0)
Extinct in the Wild (EW)	0 (0)	0 (0)
Critically Endangered (CR)	5 (7)	5 (7)
Endangered (EN)	7 (6)	3 (3)
Vulnerable (VU)	2 (14)	1 (5)
Near Threatened (NT)	2 (3)	2 (3)
Least Concern (LC)	281 (217)	29 (24)
Data Deficient (DD)	10 (40)	10 (19)
TOTAL	307 (287)	50 (61)

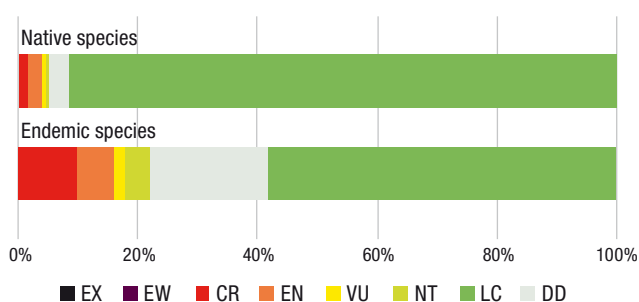


Figure 5.2 Percentage of native and endemic odonate species per Red List category in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

Paragomphus sinaiticus. Conversely, three species have been uplisted from VU to EN, citing new information on threats to these species; they are *Africocypha centripunctata*, *Ceriagrion citrinum* and *Umma purpurea*. One species, *Neodythemis takamandensis*, has been downlisted from CR to LC due to several new records in Gabon significantly extending its range.

The numbers in parentheses in Table 5.1 are taken from the previous regional report on western African freshwater biodiversity (Dijkstra et al., in Smith et al., 2009), and were based partly on regional assessments. Besides a number of new species being assessed since that time, the difference between the numbers reported is partly due to the use here of Global rather than Regional assessments e.g. *Afroaeschna scotias* is globally LC although it was assessed in 2006 as regionally VU, and partly due to status changes e.g. *Agriocnemis angustirami* has undergone a nongenuine status change from VU to LC.

One CR species *Pseudagrion mascagnii* was not included in this analysis because its entire range is marked as ‘Presence uncertain’ in the Red List. However, the Red List assessment (Dijkstra, 2010c) states that the species is known from type pair collected at Regent in Sierra Leone, described in 2004 (Terzani & Marconi, 2004).

A study on biodiversity hotspots and threatened dragonfly species in Africa did show that only 58% critically endangered and 60% endangered dragonfly species are found in formally protected areas, whereas 80% of species listed as vulnerable occur in protected areas (Simaika et al., 2013). Especially in western Africa there is a lack of protected areas in the biodiversity hotspots, especially of rare species (Pinkert et al., 2020).

5.2.1 Critically endangered species

All of the five species of Critically Endangered Odonates native to the western Africa region are essentially known only from their type localities. Most have not been seen for many years and surveys are urgently needed to confirm their persistence at these localities and surrounding areas. Two of these species are flagged as Possibly Extinct.

Chlorocypha jejuna

The Togo Red Jewel *Chlorocypha jejuna* (CR (Possibly Extinct)) is known only from its type locality, recorded in the 1890s – an unknown location in Misahohe – a forested range near present day Kpalime (Dijkstra & Tchiboza, 2020). Despite being a conspicuous insect occurring in a reasonably surveyed area (both the Ghanan and Togolese side of the area have been surveyed), it has not been rediscovered and could be extinct.

Elattoneura pluotae

Elattoneura pluotae (CR) has not been assessed since the previous report (Dijkstra, Tchiboza & Ogbogu, 2009) and remains Critically Endangered (Dijkstra, 2010b). It is only known from the type locality, recorded in 1982; a stream near Kedougou, near the Senegalese border with Guinea. The proposed Sambangalou dam is cited in the Red List assessment for this species as posing a serious threat to its survival (Dijkstra, 2010b). This dam has recently been approved in 2021 (see Chapter 8).

Neurolestes nigeriensis

Gamble’s Flatwing *Neurolestes nigeriensis* (CR) is known only from the type locality (“Obudu”) in Nigeria, 1961, and one possible additional location in Kilum Ijim Forest in Cameroon, recorded in 1967 (Clausnitzer & Dijkstra, 2018b). The Kilum Ijim Forest has no legal protection, but there are community efforts to protect the forest. It is not known whether the species is still present in the Kilum Ijim Forest.

Pentaplebia gamblesi

Gamble’s Relic *Pentaplebia gamblesi* (CR (Possibly Extinct)) is known only from the type locality at Obudu in Nigeria (Clausnitzer & Dijkstra, 2018c) and has not been seen again despite numerous surveys, including a survey at the type locality in 2005. However, the species may occur south

of Obudu, where further surveys are needed. This is one of only two species of the Pentaplebiidae family in Africa. Both occur only in the southern Cameroon-Nigeria border region and have their nearest relatives in South America.

Zygonychidium gracile

The monotypic Streamertail *Zygonychidium gracile* (CR) has not been re-assessed on the Red List since the previous assessment in 2006 (Clausnitzer & Suhling, 2010). The species is only known from a 100 km stretch of the Bandama River north and east of Korhogo in northern Cote d'Ivoire.

5.2.2 Endangered species

Africocypha centripunctata

The Banded Jewel has been recorded from a few locations in Cameroon (Mt Kupe and Bakossi Mts (Kodmin/Kumin) in adjacent SW Cameroon, and Baba II Forest near Babenda. The species is also known from the Obudu Plateau of SE Nigeria (type locality), but these records are from 1961 and 1962.

Allocnemis vicki

The Blue-shouldered Yellowwing has been recorded from very few point localities in the Northwest and Southwest Provinces of Cameroon and from the Bakossi Mountains in Nigeria (a doubtful record far away from the Bakossi Mountains is not considered valid). It seems to be restricted to forest streamlets between 1,500 and 1,900 m altitude (Dijkstra, Kipping & Mézière, 2015).

Ceriagrion citrinum

The EN Yellow Waxtail (*Ceriagrion citrinum*) is only found in Nigeria and Benin, where it inhabits open swamp forest habitats. It has triggered impressive conservation efforts by local Odonatologists / Conservationists Ojonugwa Ekpah in Nigeria (Ekpah, 2021) and Sévérin Tchibozo in Benin (Tchibozo, 2021).

Mesocnemis tisi

The Liberian Riverjack is only known from the Sinoe River and a tributary, within a 5,000 km² area of forest habitat, which is threatened by selective logging and clearing for agriculture.

Sapho puella

The Clear Broadwing is only known from Takamanda in Cameroon more recently (2001), where all localities are expected to deteriorate due to deforestation for oil palm plantation and urbanisation.

Umma mesumbei

The Cameroon Sparklewing is only known from deeply shaded seeps and springs (and streams that run from these) in Cameroon highlands at 900 to 1,800 m, possibly lower; endangered due to this narrow range and habitat.

Umma purpurea

There is hardly any information on the Purple Sparklewing, but probably inhabits streams shaded by forest; up to 1,000 m. Endangered due to limited range.

5.2.3 Vulnerable species

Elatoneura dorsalis

The Yellow-fronted Threadtail is known from four sites in Sierra Leone (villages): Yana, Kamakoni (Kimmins, 1938), Newton and Kasewe (Marconi and Terzani unpubl.). within a 20,000 km² area of lowland forest habitat, which is expected to deteriorate in the future due to agricultural expansion (Dijkstra, 2010a).

Pentaplebia stahli

The Red Relic is estimated to occur in less than ten locations, based on the threat of destruction of its forest habitat, and even though its extent of occurrence is 25,247 km², this includes records over 50 years old and its AOO is 112km², even within the EN threshold. Since the species is not a good flier and dispersal is rather limited paralleled with the ongoing forest destruction, most of the locations are isolated. The current decline in the area and quality of its habitat is expected to continue to deteriorate in the future due to illegal logging (Clausnitzer & Dijkstra, 2018a).

5.3 Patterns of species richness

Of the 307 odonate species assessed, 50 are endemic to the western Africa region. Of the 14 threatened odonate species, nine of these are endemic to the region.

5.3.1 Overall species richness

The diversity of dragonflies in Africa is strongly correlated with lotic forest habitats in a heterogenic landscape (Clausnitzer et al., 2012). In western Africa, the coastal areas and the lower slopes of Mt. Cameroon are the most species rich areas. Biodiversity decreases towards the drier areas in the north.

5.3.2 Threatened species richness

Of the 14 globally threatened species, only four species have mapped ranges. Nearly all globally threatened species are found in the lowland areas close to the coast. These are the areas with the highest population pressure by humans: agriculture, settlements and industries are growing as well as the pollution and extraction of water.

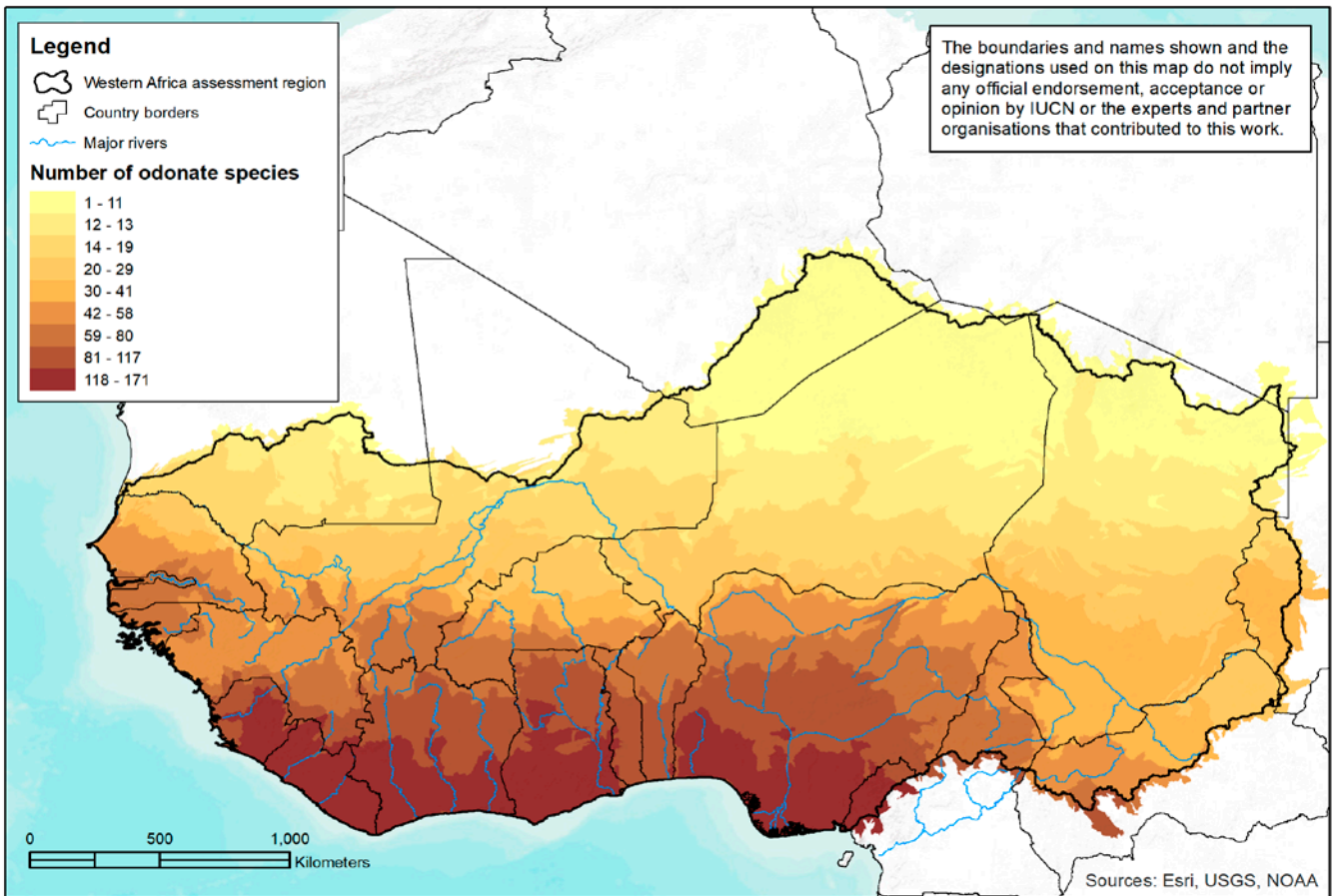


Figure 5.3 Species richness of odonates in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

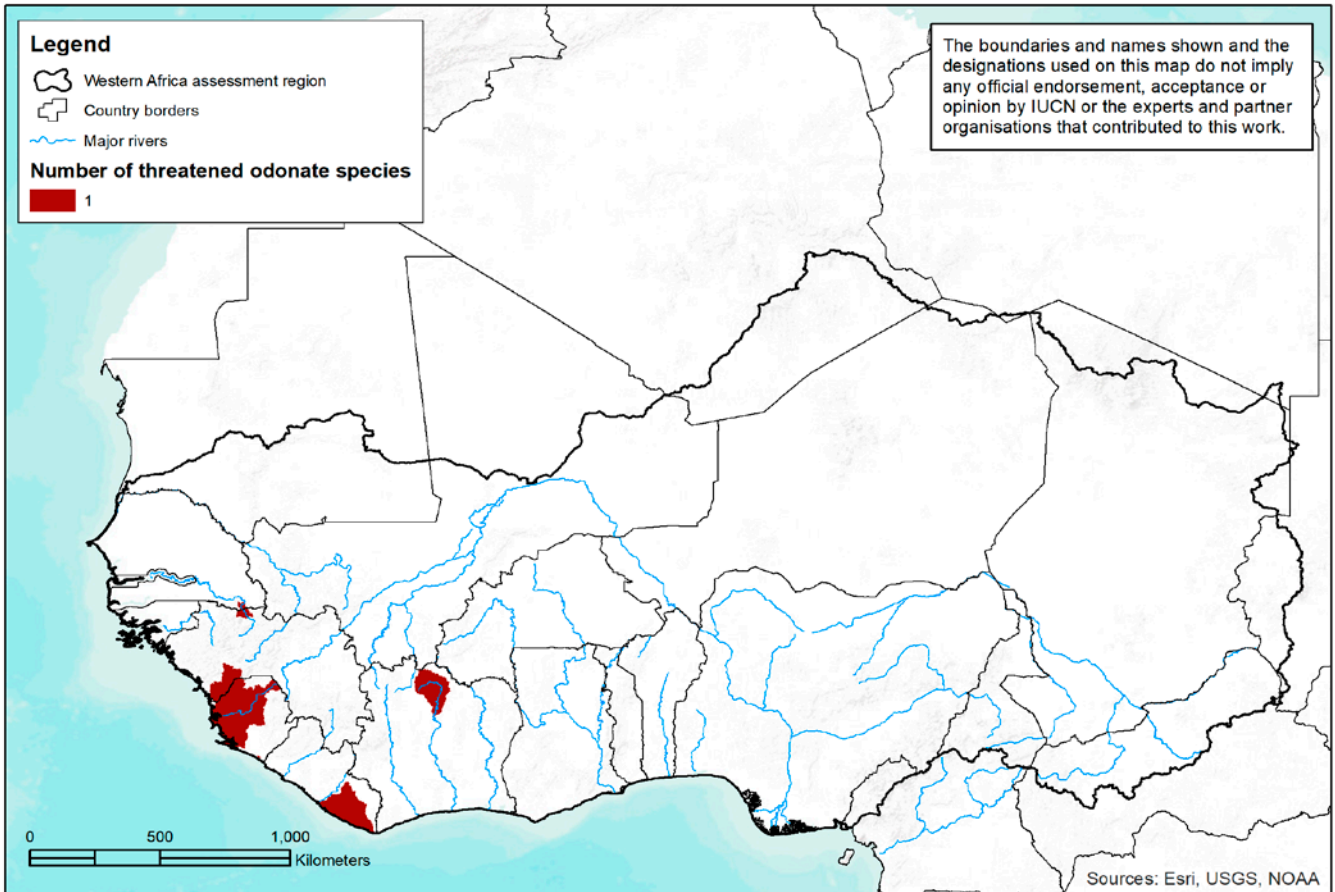


Figure 5.4 Species richness of threatened odonates in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).



Figure 5.5 *Ictinogomphus fraseri*, known from few but widespread records across western Africa, here is pictured near Mogbaima, Gola Forest. © K.-D. Dijkstra

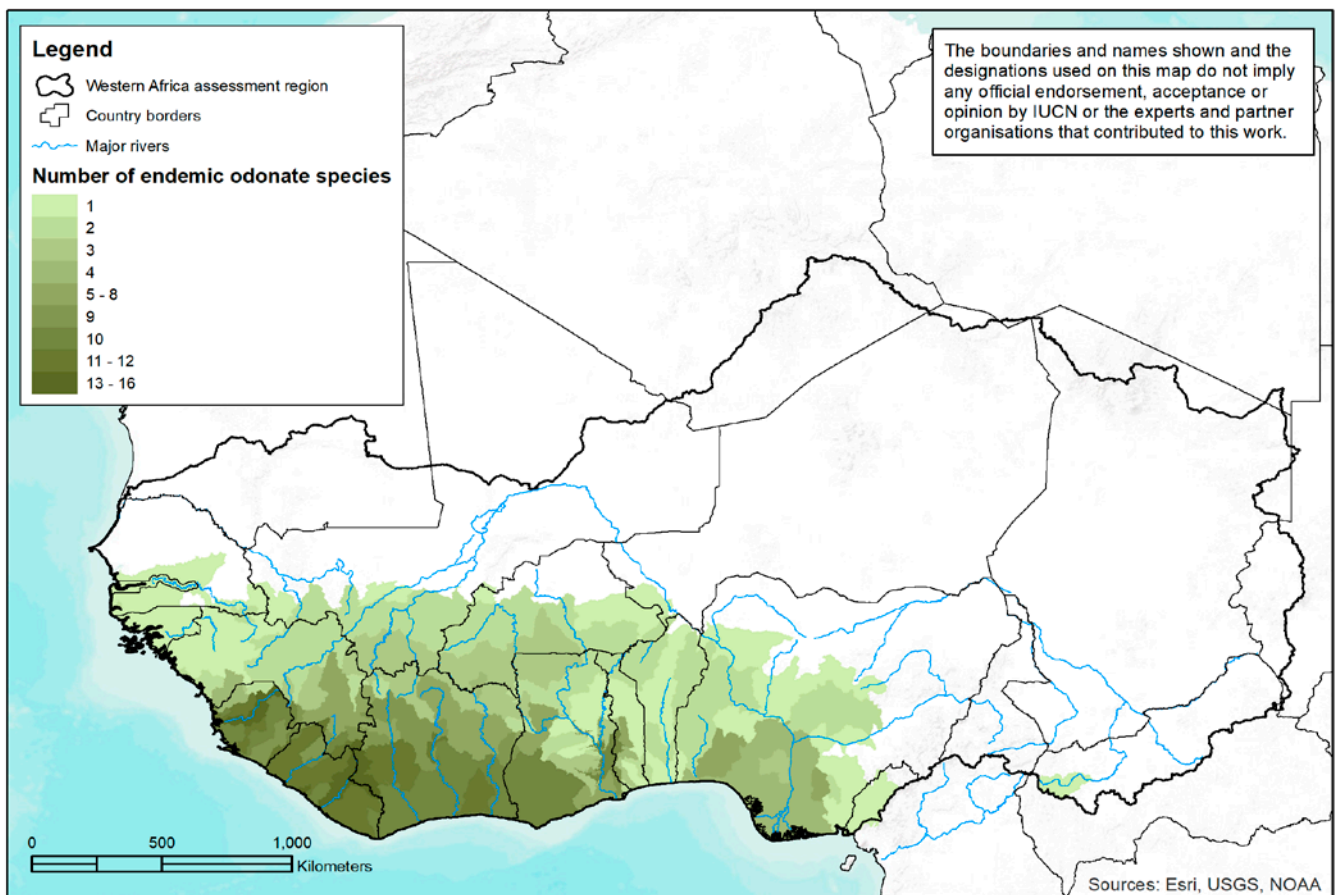


Figure 5.6. Species richness of regionally endemic odonates in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

5.3.3 Regionally endemic species richness

Of the 307 species of odonate native to the western Africa region, 50 species are endemic to it based on their mapped range and localities. Of these, 31 species have a mapped range on the Red List and these were used to produce the endemic species richness map (Figure 5.6). Some 19 of the regionally endemic species have mapped point localities but have no mapped ranges, and they are not represented in the map of endemic species richness. Regionally endemic species richness appears low around the Northern Gulf of Guinea Drainages in southeast Nigeria, but that is likely to be an artefact based on the delineation of the western Africa assessment region on which species endemism was calculated.

5.4 Major threats to freshwater odonates

Species' threats are identified as part of the Red List assessment process. Threats are identified for 226 of 307 odonate species. It should be noted that these are global assessments and the threats identified are not spatially explicit but describe the threats facing these species throughout their global range. Therefore, because the odonates tend to have particularly widespread ranges, we highlight the number of regionally endemic species affected by each threat, which we can be certain are within the western Africa region.

5.4.1 Agriculture and aquaculture

The single most frequently cited threat facing the global populations of odonates native to western Africa is from

agriculture & aquaculture, affecting 191 species or 62% of all species, and 22 (40%) of the regionally endemic species. Red List assessments cite draining of swamp forests for shifting agriculture (*Ceragrion citrinum* (EN)), removal of gallery forest and siltation of rivers (*Zygonychidium gracile* (CR)) and clearing of forest areas along riparian streams among these threats.

5.4.2 Biological resource use

Logging and wood harvesting affects over half (52%) of species, 159 species. Red List assessments citing this threat include clear cutting and selective logging, usually for agriculture.

5.4.3 Pollution

Pollution, especially from domestic and urban wastewater, affects 88 species (29%), such as *Pentaplebia gamblesi* (CR). This species and several other CR odonates are considered to be under threat from the Obudu resort that has recently been upgraded to an International Tourist Centre by the Cross River State Government of Nigeria. Consequently, resort expansion and possibly water extraction to satisfy its water needs are major threats to the species.

5.4.4 Other threats

Other threats include modifications to natural systems including from dams, ground water and surface water abstraction, and from residential and commercial development leading to degradation of habitat.

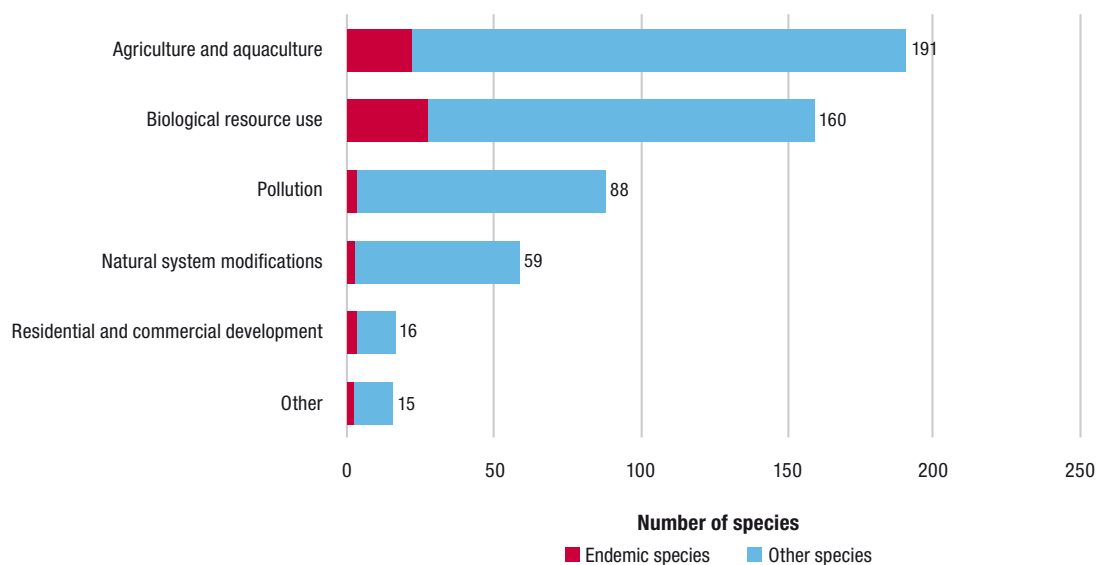


Figure 5.7. Major threats to freshwater odonates in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

5.5 Recommended research and conservation actions

Recommended research and conservation actions are documented as part of Red List assessments, representing a good starting point for guiding relevant conservation strategies.

5.5.1 Research recommended

In contrast with the other groups, the status and distribution of the odonates is relatively well understood. Out of the 307 species assessed, only ten species (3%) are Data Deficient. However, these species are all considered regionally endemic and they make up 20% of all regionally endemic odonate species, highlighting the need for further research

on these species within western Africa. There is a need for research on *population trends* (recommended for 233 species, although population trend is unknown for 297 species), *life ecology & history* (189 species), *population size, distribution & trends* (184 species) and *threats* (165 species), as well as *taxonomy* (60 species), *actions* (48 species) and *habitat trends* (44 species).

5.5.2 Conservation actions recommended

Site/area management was identified most frequently as a recommended conservation action for odonates native to western Africa, recommended for 74 species (24%) (Figure 5.9). Recommendations include control of water pollution and preservation of stream water quality through reserve management and policy-based actions.

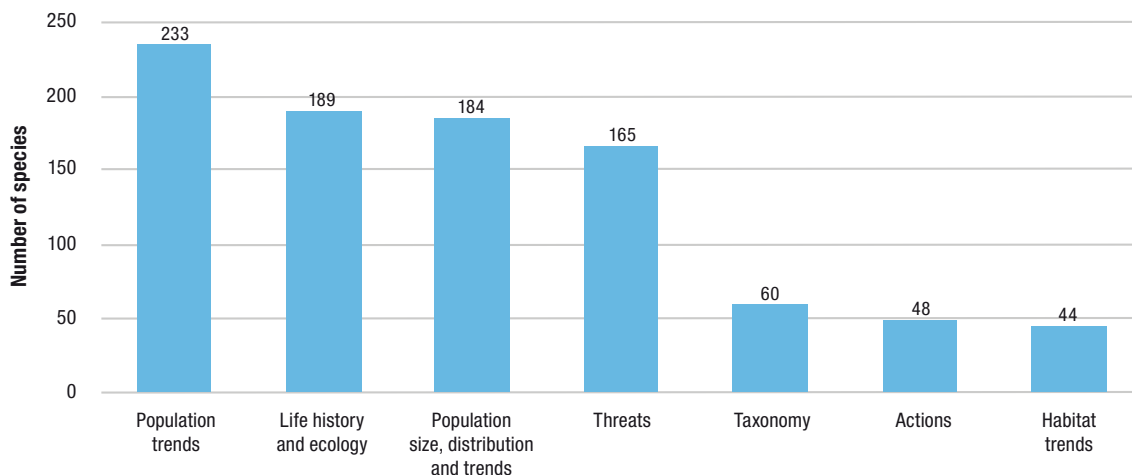


Figure 5.8. Research recommended for freshwater odonates of western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

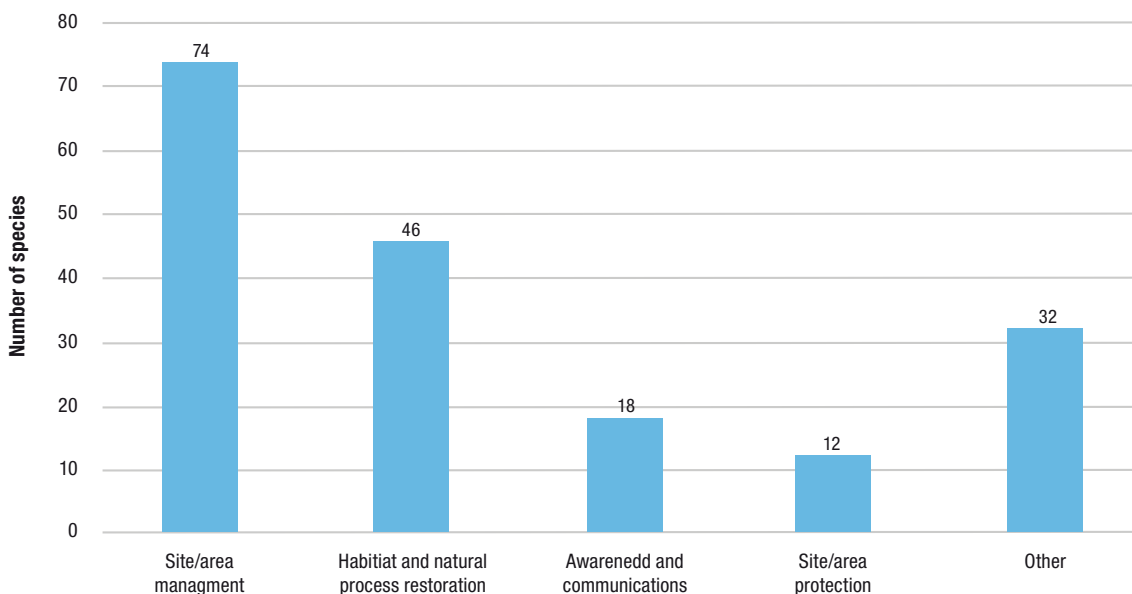


Figure 5.9. Conservation actions recommended for freshwater odonates of western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

Other recommended conservation actions include *habitat restoration* (46 species) and *awareness & communications* (18 species), such as in Benin where there was a community based conservation project for the Yellow Waxtail *Ceriagrion citrinum* (EN) at Foret de Lokoli, aiming to educate and raise awareness of the sustainable use of swamp forest habitat (Dijkstra & Tchiboza, 2020; Tchiboza, 2021). *Site/area protection* is recommended for 12 species, to incorporate ranges of threatened odonates. Currently, some species' ranges are not incorporated into any established protected areas.

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Chapter 6

The status and distribution of freshwater decapods

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The previous assessment for the freshwater biodiversity of western Africa included only the 25 species of native freshwater crabs (Smith et al., 2009), as the freshwater shrimps had not been assessed at the time. Here we include 28 species of freshwater shrimps, which have since been assessed on the Red List, bringing the total number of freshwater decapods to 54. There are no native freshwater crayfish in the region. Many decapod species from the western African region are represented by only a handful of individuals, while those species that are more abundant

have often proved problematic to identify. These large and conspicuous crustaceans are present in almost all freshwater habitats in western Africa, from montane habitats with mountain streams to large lowland rivers and small water bodies (Cumberlidge, 1999). In addition, species that live in seasonally arid areas tend to be semi-terrestrial, live in burrows, and move about on land at night (Cumberlidge, 1999). Isolation related to complicated topography and the fragmentary nature of wetland habitats in much of western Africa, and limited dispersal abilities due to reproduction by

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direct development, are probably responsible for much of the diversity and endemism of these crabs (Cumberlidge et al., 2009). Distribution data are largely derived from specimen records, but are still likely to be incomplete. Some species are still known only from the type locality or from a few localities, and many species have not been seen for several years or decades. Further collections are necessary to ascertain their actual distribution.

6.1 Overview of western Africa freshwater decapods in relation to the freshwater ecoregions

The western Africa assessment region as defined in this report includes 53 species of freshwater decapods belonging to five families of shrimp: Alpheidae (n = 2), Atyidae (n = 12), Desmocarididae (n = 2), Euryrhynchidae (n = 3), Palaemonidae (n = 9) and one family of freshwater crabs Potamonautidae (n = 26). Of these 53 species (26 crabs and 27 shrimps), 49 have mapped ranges in the Red List (26 crabs and 23 shrimps) and 27 species are endemic within the assessment region (22 crabs and 5 shrimps).

6.1.1 Widespread endemics of western Africa

6.1.2 Xeric systems

6.1.2.1 Dry Sahel

The Dry Sahel ecoregion contains three species of freshwater decapods (two shrimps and one crab) all of which are assessed as LC.

6.1.2.2 Lake Chad catchments

The Lake Chad ecoregion contains six species of freshwater decapods (three shrimps and three crabs) all of which are assessed as LC. This ecoregion includes approximately one third of the global range of two species of crabs; *Sudanonautes monodi* and *S. floweri*.

6.1.3 Savannah dry forest rivers

6.1.3.1 Senegal-Gambia catchments

There are three species of freshwater shrimps and four species of freshwater crabs found in this ecoregion. All are assessed as LC except for two of the crabs, *Potamonautes lipkei* and *P. senegalensis*, which are both listed as Data Deficient.

6.1.3.2 Lower Niger-Benue and Inner Niger Delta

These two ecoregions together contain 15 species of freshwater decapods: eight crabs and seven shrimps. Three of these species, the freshwater crab *Potamonemus sachsii*, and two shrimps (*Euryrhynchina edingtonae*

and *Potamalpheops haugi*) are Endangered, the rest are Least Concern. One LC species, the freshwater crab *Sudanonautes kagoroensis* is endemic to the Lower Niger-Benue ecoregion. This species is known only from seven sites and less than four localities in central Nigeria and is restricted to the fast flowing streams and rivers draining the Jos Plateau. The estimated extent of occurrence (EOO) of *S. kagoroensis* is small (8,826 km²) as is its estimated area of occupancy (AOO) (32 km²). *Sudanonautes kagoroensis* is listed as Least Concern because there are no known major widespread threats to this species. However, this situation could change if human activities (such as mining) increase in the area, in which case it would be likely to qualify in a threatened category.

6.1.3.3 Volta

The Volta ecoregion contains 10 species of decapods: three shrimps and seven crabs. One of the crab species, *Potamonautes triangulus*, is assessed as VU, while the other species are all assessed as LC.

6.1.3.4 Bight Drainages

The Bight Drainages ecoregion contains 16 freshwater decapod species including nine crabs and seven shrimps. Of these, three species of freshwater shrimp are Endangered: *Desmocarid bislineata*, *Euryrhynchina edingtonae* and *Potamalpheops haugi*.

6.1.4 Highland and mountain systems

6.1.4.1 Fouta Djallon

Four species of freshwater decapods are found in the Fouta Djallon ecoregion: three shrimps (*Caridina togoensis*, *Caridinopsis chevalieri* and *Desmocarid trispinosus*) and one crab (*Liberonautes latidactylus*), and all are LC.

6.1.4.2 Mount Nimba

Ten species of decapods are present within the Mount Nimba ecoregion: five shrimps and five crabs. Of these, two species of freshwater crabs (*Liberonautes nimba* and *L. rubigimanus*) as assessed as Vulnerable.

6.1.5 Moist forest rivers

6.1.5.1 Northern Upper Guinea

There are nine species of freshwater decapods found in the Northern Upper Guinea ecoregion: four shrimps (all LC), and five crabs (four threatened and one Data Deficient). Three of the threatened species of crabs, *Afrithelphusa leonensis* (CR), *A. afzelii* (CR) and *A. monodosa* (EN), are endemic to this ecoregion, as is *A. gerhildae* (DD). The fifth species of freshwater crab, *Globonautes macropus* (EN) although not endemic to this ecoregion, has a significant proportion of its range that occurs within it.



Figure 6.1 *Liberonautes rubigimanus* is found in fast-flowing mountain streams on Mount Gibi, Liberia and Mount Nimba, Guinea.
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6.1.5.2 Southern Upper Guinea

Liberonautes lugbe (CR) has a restricted distribution and is known only from a single locality (Lugbe in Nimba County, Liberia), where it was collected from a freshwater stream habitat in the rainforest. As a result, this species has a very small area of occupancy (AOO) and extent of occurrence (EOO) (both estimated to be 4 km²). The threats to this species include habitat destruction relating to agriculture associated with the expanding human population, and more intensive deforestation. The locality in Lugbe, Liberia is not in a protected area.

6.1.5.3 Eburneo

There are eleven species of freshwater decapods found in this ecoregion: five species of shrimp and six species of crabs. All of these species are assessed as LC except for two species of shrimp, *Caridina ebuneus* and *Macrobrachium thysi*, which are both Data Deficient and potentially endemic to the ecoregion.

6.1.5.4 Ashanti

There are six species of freshwater decapods found in this ecoregion: one species of shrimp and five crabs. All of these species are assessed as LC except for the threatened freshwater crab species *Potamonautes triangulus* (VU), where 80% of its range occurs in this ecoregion.

6.1.5.5 Upper Niger

Five species of freshwater decapods inhabit this ecoregion: two crabs and three shrimps, all of which are assessed as Least Concern

6.1.6 Floodplains, swamps and lakes

6.1.6.1 Inner Niger Delta

There are two species of freshwater decapods in this ecoregion, the freshwater shrimp *Caridina togoensis* and the river crab *Potamonautes ecorseii*, both of which are assessed as LC.

6.1.7 Large river deltas

6.1.7.1 Niger Delta

Twelve species of freshwater decapods are found in this ecoregion: six species of shrimps and six species of crabs. Four of these are threatened species: the crab *Potamonautes reidi* (VU) and three shrimps, *Desmocaridina bislineata* (EN), *Potamalpheops haugi* (EN) and *Euryrhynchina edingtonae* (EN). The crab *Sudanonautes nigeria* (DD) is endemic to this ecoregion.

6.2 Conservation status

The conservation status of western Africa's decapods (26 species of crab and 28 species of freshwater shrimp) was assessed using the IUCN Red List Categories and Criteria at the global scale (IUCN, 2012).

Of the 26 species of freshwater crabs assessed in this work, 12 (46%) are threatened with extinction: four (15%) are Critically Endangered, four (15%) are Endangered, and four (15%) are Vulnerable (Table 6.1, Figure 6.2). One CR species

Table 6.1 Number of native and endemic freshwater decapod species per Red List category in western Africa. Numbers in parentheses refer to the previous assessment for crabs only (Smith et al., 2009) and include regional assessments. Source: Compiled by the report authors using data from the IUCN Red List (2021) and Smith et al. (2009).

IUCN Red List Category	Number of native species			Number of regionally endemic species		
	Crabs	Shrimps	All decapods	Crabs	Shrimps	All decapods
Extinct (EX)	0 (0)	0	0	0 (0)	0	0
Extinct in the Wild (EW)	0 (0)	0	0	0 (0)	0	0
Critically Endangered (CR)	4 (2)	0	4	4 (2)	0	4
Endangered (EN)	4 (4)	3	7	4 (4)	2	5
Vulnerable (VU)	4 (4)	1	5	4 (4)	0	4
Near Threatened (NT)	0 (0)	0	0	0 (0)	0	0
Least Concern (LC)	10 (10)	15	25	6 (6)	1	5
Data Deficient (DD)	4 (5)	9	13	4 (5)	5	9
TOTAL	26 (25)	28	53	22 (21)	5	27

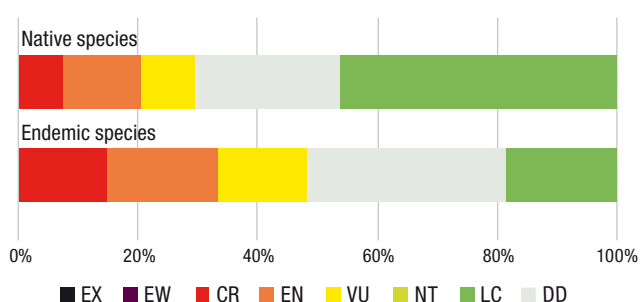


Figure 6.2 Percentage of native and endemic freshwater decapod species per Red List category in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

of freshwater crab from Sierra Leone, *Afrithelphusa afzelii* was previously thought to be CR-Possibly Extinct (Smith et al., 2009) but a new population has recently been discovered. Of the 28 species of freshwater shrimps, four (14%) are threatened with extinction: three (11%) are Endangered and one is Vulnerable. Nine of the shrimp species (32%) are assessed as Data Deficient.

6.2.1 Species assessed as Critically Endangered

6.2.1.1 Critically Endangered crabs

Afrithelphusa afzelii (CR)

Until recently, this species was known only from an unspecified locality in Sierra Leone from specimens collected 1790–1800 and, in the absence of any new records, there were concerns that it was at a high risk of extinction and might even be extinct. New field surveys in 2021 in Sierra Leone have now rediscovered a population of this ‘lost’ species, so at least it is not extinct. However, the habitat where this species was collected is heavily disturbed and under pressure from expanding human populations and intensive agriculture. Recent political unrest in Sierra Leone has left some protected areas without effective oversight, although

Kangari Hills Forest Reserve, which is within the range of this species, remains relatively intact. These immediate threats are causing a continuing decline in habitat quality.

The collection site of *A. afzelii* in 1790 was unrecorded, and so its rediscovery at least provides a single known locality for this species, albeit with low estimates (4 km²) for both the area of occupancy (AOO) and the extent of occurrence (EOO). The good news of its rediscovery is tempered by the knowledge that it might still be on the brink of extinction. It is clear that additional surveys are urgently required to determine its current population status, exact distribution, ecological requirements, and long-term threats for this CR species (Cumberlidge & Daniels, 2020a).

Afrithelphusa leonensis (CR)

This species was originally known only from three specimens collected in 1955 from a single locality on Sugar Loaf Mountain in Sierra Leone. New field surveys in 2021 in Sierra Leone have rediscovered an additional population of this ‘lost’ species. However, the habitat where it was collected is heavily disturbed and under pressure from expanding human populations, encroaching agriculture, and forest erosion and loss. The single locality means that *Afrithelphusa leonensis* has a low estimated area of occupancy (AOO) and a low estimated extent of occurrence (EOO) (both 4 km²). More surveys are urgently required to determine the exact distributional range, ecological requirements, population size and trends, and long-term threats for this little known CR species (Cumberlidge & Daniels, 2020c).

Liberonautes grandbassa (CR)

This species is endemic to central Liberia where it is known from a few specimens collected in a single rainforest locality. This species is assessed as CR because it is threatened by the habitat disruption associated with deforestation driven by expanding human populations and periods of political unrest. There are no known conservation measures in place

for this species, and it is not found within a protected area (Cumberlidge & Daniels, 2020d).

***Liberonautes lugbe* (CR)**

This species is endemic to northern Liberia where it is known from only two specimens collected from captured in rainforest habitat in Lugbe in Nimba County. The specimens were collected by hand when the crabs were walking on land close to a stream. This species is assessed as CR because it is threatened by the habitat disruption associated with deforestation driven by expanding human populations and periods of political unrest. There are no known conservation measures in place for this species, and it is not found within a protected area (Cumberlidge & Daniels, 2020e).

6.2.2 Species assessed as Endangered

6.2.2.1 Endangered crabs

***Afrithelphusa monodosa* (EN)**

This species is endemic to Guinea where it is known from fewer than 20 specimens from two localities. *Afrithelphusa monodosa* lives in farmland, swamps, and year-round wetland habitats in the semi-deciduous moist forest Guinea savanna zone of north-western Guinea (Cumberlidge, 1999). Specimens were collected from cultivated land from burrows dug into permanently moist soil, each with a shallow pool of water at the bottom. The natural habitat is still unknown but presumably this cultivated land was originally a permanent freshwater marsh. There were no nearby sources of surface water and it is evident that these crabs do not need to be immersed in water (as do their relatives in the genus *Liberonautes* that live in streams and rivers). *Afrithelphusa monodosa* can stay hydrated with the small amount of muddy water that collects at the bottom of its burrow. This species is clearly a competent air-breather. Despite the recent discovery of a new population of this species in 2005, it is still currently known from only a few specimens from two localities. Threats to the species include habitat loss/degradation (human induced) due to human population increases, deforestation, and associated increased agriculture in north-west Guinea. It is not found within a protected area. The recent discovery of new subpopulations (and the promise of finding others) has led to its Red List status being recently downgraded from CR to EN.

***Globonautes macropus* (EN)**

This species is endemic to the Upper Guinea rain forests of western Liberia (Bong, Lofa, and Mesurado Counties) and Guinea, and is presumably also found in the forested parts of Sierra Leone that lie between these two populations. This species is restricted to rainforests where it requires a specialised habitat of rainwater-filled natural holes found in suitably sized trees within closed canopy rainforest. Despite the recent discovery of new populations, it is still

currently known from only a handful of specimens and a few localities. The species is far from abundant, and it was estimated in 1989 that there were between 5–10 crabs per km² in closed canopy rainforest. This density may well be declining as deforestation progresses. Threats to the closed canopy rainforest habitat of *G. macropus* are ongoing due to human population increases, deforestation, political instability and increased agriculture in Liberia. This species is not found within a protected area. The discovery of new populations of this species in 1988 led to the downgrading of its Red List status from CR to EN, but this could change if the threats persist.

***Liberonautes nanoides* (EN)**

This species is endemic to Liberia where it is known only from one locality in Bong County (the St. Paul River at the Bong Mine Fishing Club near Haindi). It lives in the rocky parts of the fast-flowing waters of the St. Paul River which is a major river that flows through the rainforest zone of Liberia. *Liberonautes nanoides* is never found in the small streams that drain into the St Paul River. The species serves as the second intermediate host to the lung fluke *Paragonimus uterobilateralis* but the incidence of infection is low, indicating that the species does not play an important role in the transmission of the parasite to humans. Threats to its river habitat are ongoing due to human population increases, deforestation, political instability and increased agriculture in Liberia. It is not found within a protected area. The species is a locally important food source and is subject to a small local fishery.

***Potamonemus sachsi* (EN)**

This species is included here because although most of its range is in the highlands in southwest Cameroon (and therefore outside of the western African region), it occurs on the high altitude Obudu Plateau in southeast Nigeria that rises steeply out of the rainforest. The updated estimations of the extent of occurrence (~24,000 km²) and area of occupancy (16–500 km²) decrease its known range and justify its uplisting from VU to EN. The threats to this species include deforestation and habitat degradation due to encroaching agriculture linked to increases in the human population that are causing a decline in habitat area and quality (Cumberlidge, 2020). No conservation measures are in place for this species and it is not found in a protected area.

6.2.2.2 Endangered shrimps

Three species of Endangered freshwater shrimps represent three families.

***Desmocaridus bislineata* (EN)**

The species is only known from three sites in the Niger Delta (Powell, 1977), which is impacted by extensive environmental

degradation due to repeated oil spills, loss of mangroves and the impact of extensive Water Hyacinth populations which are degrading the species' quality of habitat (reducing the number of known localities to between 1 and 3 locations). The species' EOO is less than 3,000 km² and the AOO less than 500 km², but as it is restricted to tidal freshwater, both the EOO and AOO are in reality likely to be much smaller. However, based on current calculations and the level of threat to the Niger Delta, the species is considered to be Endangered.

***Euryrhynchina edingtonae* (EN)**

The species was originally described as occurring throughout the western half of the Niger Delta (Powell, 1976), although the only recent record is from the Ikpoba River, which flows through Benin City. The Niger Delta is impacted by extensive environmental degradation due to repeated oil spills, loss of mangroves and the impact of extensive water hyacinth populations, which are degrading the species' quality of habitat. The single recent location from which the species has been recorded, the Ikpoba River, is highly polluted due to domestic and industrial effluent from Benin City. The species' EOO is less than 3,000 km² and the AOO less than 500 km², but as it is restricted to small rivers and pools in swamp forest, both the EOO and AOO are in reality likely to be much smaller. However, based on current calculations and the level of threat to the Niger Delta, the species is considered to be Endangered.

***Potamalpheops haugi* (EN)**

The species is known from the type locality in Gabon, based on material collected in 1906, as well as more recent collections (1975–1977) in the Niger Delta. In Nigeria, the species is known to inhabit pure freshwater in larger rivers, where it lives between roots of fallen trees and other

submerged vegetation (Powell, 1979). The Niger Delta river system is heavily impacted by oil spillages and extensive mangrove deforestation, which is likely to impact the species. In addition to the type locality in Gabon, this species is known from two closely-positioned sites (one locality) within the Niger Delta, making a fragmented distribution. As the species' EOO is less than 5,000 km² and with a currently known AOO of less than 500 km², the species is considered as Endangered. Urgent surveys are required to establish its presence (or lack of) in the between Gabon and Nigeria, notably in Cameroon and Equatorial Guinea.

6.2.3 Species assessed as Vulnerable

6.2.3.1 Vulnerable crabs

***Liberonautes rubigimanus* (VU)**

This species is native to Liberia (Mount Gibi, Margibi County) and Guinea (Mount Nimba). The reassessment of this species (Cumberlidge & Daniels, 2020h) was based on additional localities reported by (Daniels et al., 2016) that increased the extent of occurrence (EOO) to 13,537 km², and moved it from EN to VU. It is still in a threatened category, however, because of the continuance of the threats to this species (loss and degradation of its mountain stream habitat associated with deforestation, mining, intensive agriculture with accompanying pollution, and human population increases). Parts of its range lie within a protected area, the Mont Nimba National Park.

***Liberonautes nimba* (VU)**

This species is known from nine localities on the slopes of Mount Nimba, Mount Gangara and Mount Yuelliton in Guinea and from Mount Nimba in Liberia. The reassessment of



Figure 6.3 *Liberonautes nimba* is named for Mount Nimba – the mountain range to which this Vulnerable species is confined.

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this species (Cumberlidge & Daniels, 2020g) was based on additional localities reported by Daniels et al. (2016) but it remained in the VU category. Threats to this species include a decline in extent and quality of its habitat due to the long-term threats of mining disturbance and pollution (especially in West Nimba), plus deforestation, human population increases and encroaching subsistence agriculture. Despite this, it is found in two protected areas (Mount Nimba National Park and Western Mount Nimba Nature Reserve).

***Potamonautes reidi* (VU)**

This species is currently known only from about 20 specimens collected between 1977 and 1983 from under 10 localities from rivers draining the rainforest zone of in southeast Nigeria, and from museum specimens from the neighbouring forest in Cameroon. The extent of occurrence (EOO) for this species is estimated at 18,486 km² with an estimated area of occupancy (AOO) of 48 km² due to its restriction to rivers and streams draining rainforest habitats within its range. It is assessed as VU because of threats from habitat destruction and pollution associated with deforestation, encroaching agriculture (Cumberlidge & Daniels, 2020j). No conservation measures are in place for this species and it is not found in a protected area.

***Potamonautes triangulus* (VU)**

This small species of freshwater crab is endemic to Ghana where it is known from six localities within the same stream from a locality about 90 km north of Accra. It was last seen in 1950. This species is listed as Vulnerable because it has a restricted distribution, with an extent of occurrence (EOO) of 6,130 km² (Cumberlidge & Daniels, 2020l) and is threatened by continuing declines in the extent and quality of its habitat due to human induced degradation driven by human population increases and agricultural development. No conservation measures are in place for this species and it is not found within a protected area.

6.2.3.2 Vulnerable shrimps

***Caridina sodenensis* (VU)**

This species was recently described (Richard & Clark, 2010) from a single sample collected in 1963 from Lake Soden (=Lake Dissoni), Cameroon. The crater lakes in the Cameroon highlands have either no outflow systems or very steep ones, effectively isolating them from each other and nearby river systems, supporting a highly endemic aquatic fauna. It is therefore highly probable that *Caridina sodenensis* is endemic to Lake Dissoni, making the AOO for this species 3.6 km². Although no immediate threats to the lake could be identified, the general area suffers from deforestation, whilst several lakes suffer from excessive water extraction and the introduction of exotic species.

6.2.4 Species assessed as Least Concern

Some 25 species were assessed as Least Concern, comprising 10 species of freshwater crabs and 15 species of freshwater shrimps.

6.2.5 Species assessed as Data Deficient

Of the 54 species of western African decapods assessed, 13 (24%) were judged to be Data Deficient (four crabs and nine shrimps), indicating the need for further research on these species and their conservation status.

6.2.5.1 Data Deficient crabs

***Afrithelphusa gerhildae* (DD)**

This species is known only from a single locality in Guinea. It is listed here as Data Deficient in view of the absence of further information on its distribution, ecological requirements, population size and trends. *A. gerhildae* is known only from three specimens all collected from a single locality in Guinea (Kindia), and it is of concern that that no new specimens have come to light since then. There are potential threats from increased habitat destruction relating to expanding human populations and more intensive agriculture in this part of Guinea. However, there is not enough known about this species to make a thorough assessment at this time and surveys are urgently required (Cumberlidge & Daniels, 2020b). As a consequence, the conservation status of this species was changed recently from CR to DD but if the threats to the locality of this species increase then a reassessment of the status of this species should be carried out.

***Potamonautes senegalensis* (DD)**

This species is known only from two specimens collected in 1960 from an unspecified locality in the dry savannah zone of northern Senegal associated with the Senegal River. Given that freshwater crabs are never found in saltwater habitats, it seems likely that this species was collected upstream of the saltwater influence in this river in the freshwater zone upstream of Podor. *Potamonautes senegalensis* is listed as Data Deficient in view of the absence of further information on its distribution, ecological requirements, population size, and population trends (Cumberlidge & Daniels, 2020k). It is of concern that this species was last collected in 1960, and that no new specimens have come to light since then.

***Potamonautes lipkei* (DD)**

This species has a relatively restricted range and is known from fewer than five specimens from two localities in Niokolo Koba National Park, Senegal collected in 2010 (Đuriš & Koch, 2010). Within the Park it has been recorded on Mount Assirik

slope at 151 m asl and at the Gambia River embankment at Smenti (tourist centre) at 34 m asl. The Mount Assisik specimens were collected from burrows in the banks of small seasonally dry streams with large pools that flow through a valley covered by a gallery forest. One of the specimens was collected from the banks of the Gambia River which flows year round and does not dry up seasonally. There is no information on population size or trends, or on potential threats to the species (Cumberlidge & Daniels, 2020i). Additional surveys are needed to better understand the distribution of this species. Further research may support the adoption of the existing Parc National du Niokolo-Koba KBA for this species (see Chapter 9).

***Sudanonautes nigeria* (DD)**

This species is known only from a single locality and was last collected in 1973 in the rainforests of southeastern Nigeria in the western part of the Lower Guinea forest block. There have been no recent attempts to recollect the species. It is listed as Data Deficient in view of the absence of further information on its distribution, ecological requirements, population size, population trends, and long-term threats.

6.2.5.2 Data Deficient shrimps

***Caridina ebuneus* (DD)**

The species was described in 2009 (Richard & Clark, 2009) from samples collected between 1946 and 1954 from various locations in Côte d'Ivoire. The exact ecological requirements of this species are not known, as no habitat information is specified in Richard & Clark (2009). As such, the species is considered Data Deficient.

***Caridina ghanensis* (DD)**

The species was recently described from two samples, both collected in 1949, from "Pond Vume", Ghana and La Sio, near Lomé, Togo (Richard & Clark, 2009). Neither locations could be georeferenced, but it seems likely that "Pond Vume" refers to a pond in the town of Vume. As the exact distribution of the species is not known due to this uncertainty, nor its exact ecological requirements and no specific threats could be identified, the species is considered as Data Deficient.

***Caridina messofluminis* (DD)**

This species was recently described on the basis of 14 specimens collected in "Mess stream", Cameroon (Richard & Clark, 2009). As this location cannot be traced nor georeferenced, the species is considered as Data Deficient.

***Caridina okiamnis* (DD)**

This species was recently described (Richard & Clark, 2009) on the basis of 14 specimens collected in "Okia stream", Cameroon. As this location could not be traced nor georeferenced, the species is considered as Data Deficient.

***Euryrhynchoides holthuisi* (DD)**

The species is only known from the type series collected before 1976, from a single site in Sierra Leone. The type description mentions the species was collected from the River Taja at Njala, a location in the south of Sierra Leone. It also provides a georeference (8°06'N 12°04'W), which is in the north of the country. In view of this uncertainty, the species is considered as Data Deficient.

***Macrobrachium felicinum* (DD)**

Due to extensive confusion with other West African taxa, the species is only known with certainty from two sites, one in Ghana and one in Angola. As the further distribution of the species is not known and no specific threats could be identified, the species is considered as Data Deficient.

***Macrobrachium raridens* (DD)**

This poorly known species has been recorded from the northern part of tropical West Africa (Holthuis, 1951), from Guinea to Nigeria. The majority of records pre-date 1947 and although the species has been mentioned in more recent literature, the identifications are not certain. As the species is so poorly known, it is considered to be Data Deficient.

***Macrobrachium thysi* (DD)**

The species is only known from the type series, collected in 1966–1968 from two sites near Banco, Côte d'Ivoire, both within the Banco National Park. As the wider distribution of the species is not known and no specific threats could be identified, the species is considered as Data Deficient.

***Euryrhynchina puteola* (DD)**

The species is only known from the type series (seven specimens), collected in 2012 (described in 2017) from a small, drinking water well in Mbanga City, Littoral province, Cameroon (De Grave et al., 2017). As the potentially wider distribution of this species is not known and in view of its very recent description, and as no threats could be identified, this species is considered to be Data Deficient.

6.3 Patterns of species richness

There is a clear centre of diversity around the Cross River / Oyono in southeastern Nigeria and the Meme River in neighbouring Cameroon, with up to 14 species co-occurring in each of these river catchments. There are secondary centres of diversity in the Ochi-Nakwa River basin in Ghana and the Cavally and St Paul Rivers in Liberia, each with up to 11 species. Of the 26 crab species assessed, 19 (73%) are endemic to the western Africa region based on their mapped ranges, and the 12 species threatened with extinction are all endemic to the western Africa region.

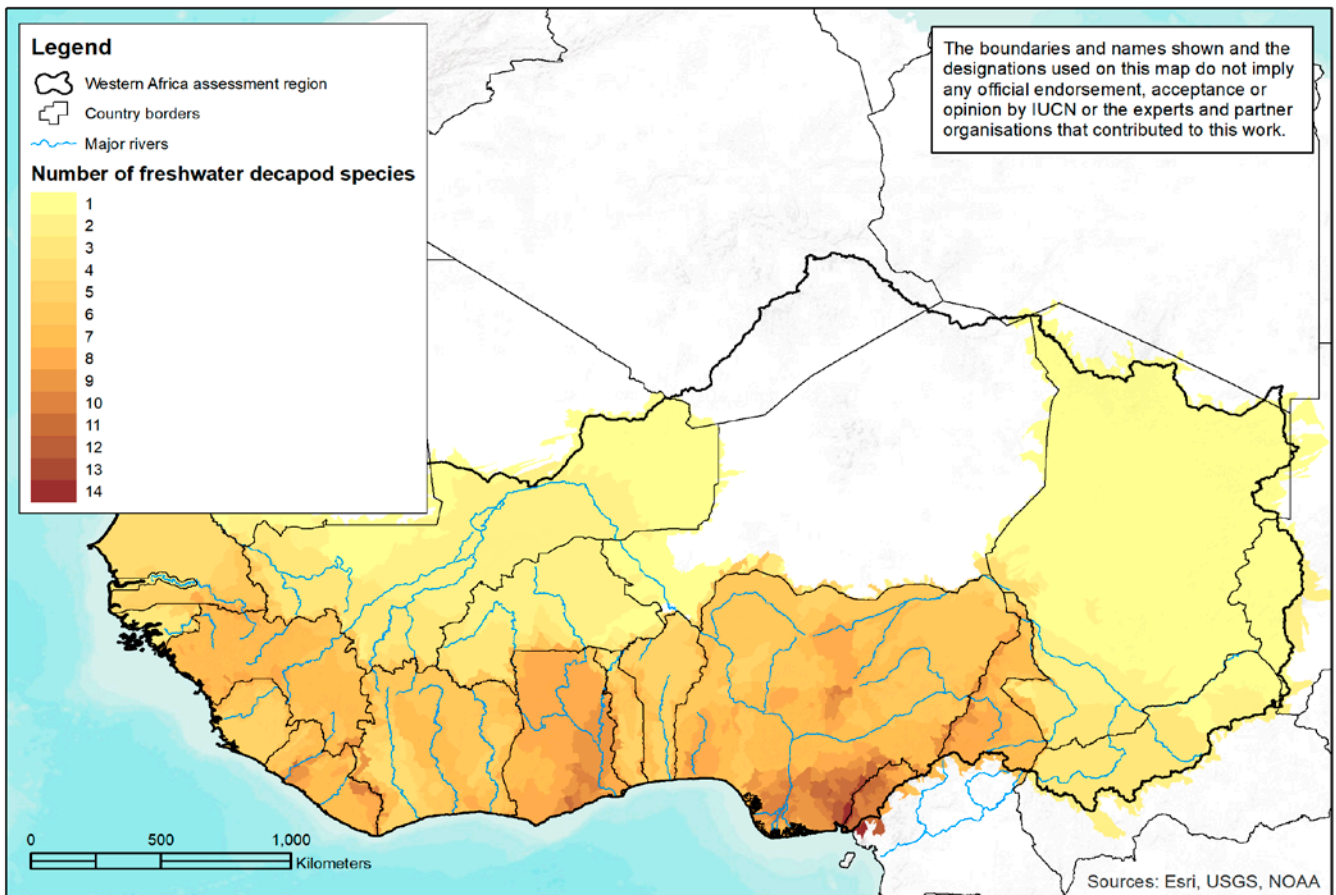


Figure 6.4 Species richness of freshwater decapods in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

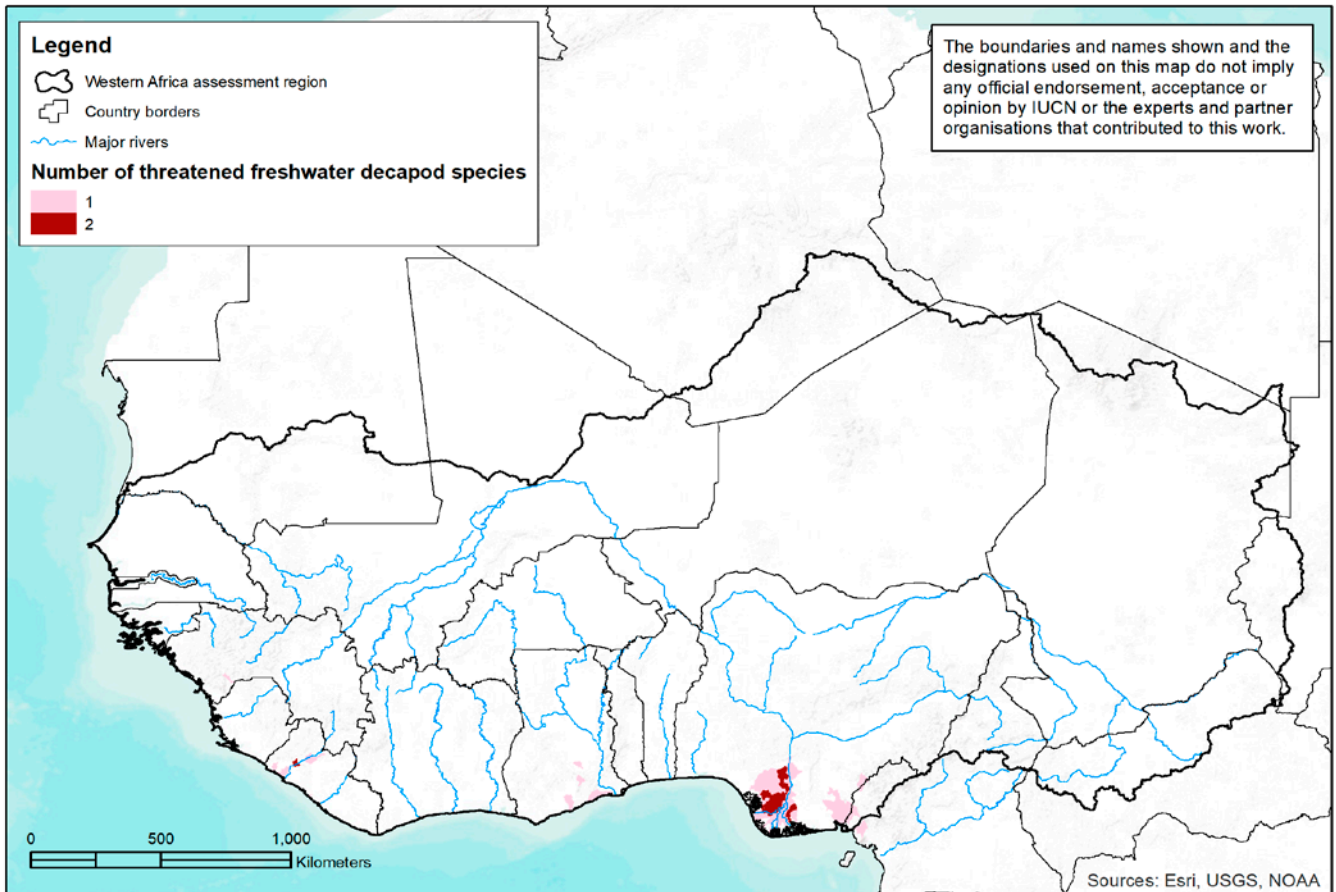


Figure 6.5. Species richness of threatened freshwater decapods in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

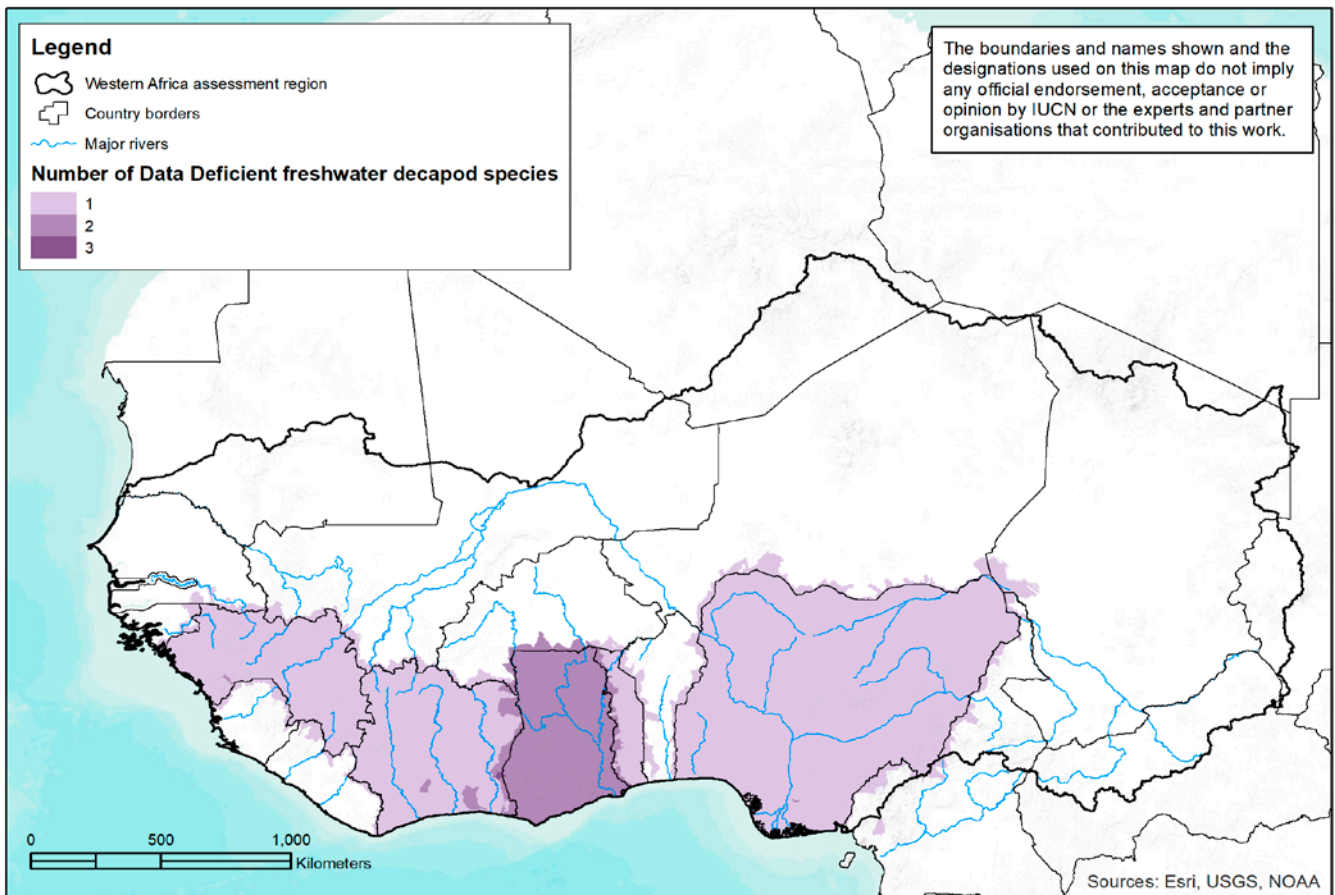


Figure 6.6. Species richness of Data Deficient freshwater decapods in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

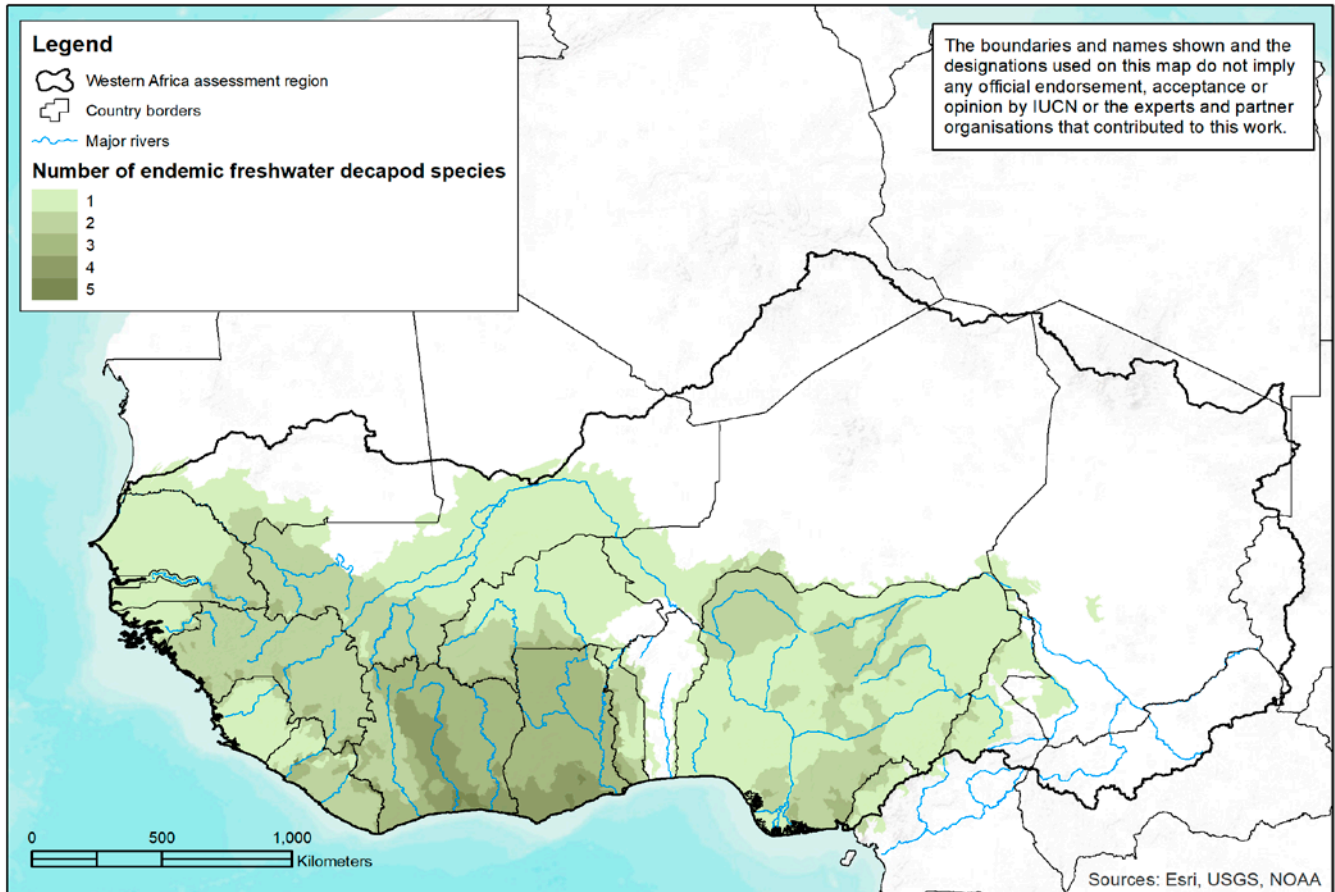


Figure 6.7. Species richness of regionally endemic freshwater decapods in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

6.3.1 All freshwater decapods

From the species richness map of all native freshwater decapod species, a clear centre of diversity emerges within the Niger Delta ecoregion. As well as being a major centre of species diversity, the area is also highly impacted by oil spills, which contribute to the level of threat faced by many of these species.

6.3.2 Threatened species

From mapping the ranges of threatened species, a clear centre of threat emerges focussed on the Niger Delta. All three Endangered species of shrimp from three families are found here: *Desmocarlis bislineata* (Desmocarididae), *Euryrhynchina edingtonae* (Euryrhynchidae) and *Potamalpheops haugi* (Alpheidae), as well as one Vulnerable crab species *Potamonautes reidi*. Another area associated with the St Paul River near Bong Mine Town in Liberia hosts two EN species of freshwater crabs: *Globonautes macropus* and *Liberonautes nanoides*. *Globonautes macropus*, the tree hole crab, is found only in closed canopy rain forest habitat, while *Liberonautes nanoides* is a river crab known from a single locality in the large St. Paul River (Cumberlidge & Sachs, 1989) but it is likely that it may also occur up and downstream of this site (Cumberlidge & Daniels, 2020f).

6.3.3 Restricted range species

Of the 48 decapod species with mapped extant ranges, 21 have ranges of less than 10,000 km² making them restricted-range species for the purpose of KBA identification. Fifteen species of crabs have a known range of less than 10,000 km², 10 species of which are threatened and four species are Data Deficient. Six species of shrimp also have a range that is less than 10,000 km², two species of which are threatened, and three are Data Deficient.

A population of *A. afzelii* (CR) in Sierra Leone has recently (2021) been discovered. It qualifies as a range restricted species because it is only known from a single locality. It is no longer thought to be extinct. Its habitat is facing the immediate threats of destruction by encroaching agriculture and by deforestation. The assessment of CR is still supported.

Caridina gaesumi is the only species with a mapped range ≤ 10,000 km² and yet not endemic to the western Africa region. The species was described in 2009 (Richard & Clark, 2009). It was collected from two rivers in Nigeria in 1975, as well as an irrigation ditch on a plantation in Zambia in 1981, indicative of considerable ecological plasticity. In view of the reputed wide distribution of the species known from two locations over 3,000 km apart, with no known major threats, the species

is considered as Least Concern (De Grave, 2013). However, only the known extant range is mapped, based on these three localities, making it range-restricted until further records are confirmed or a putative 'possibly extant' range is mapped.

6.3.4 Data deficient species

See Figure 6.6. on previous page.

6.3.5 Regionally endemic species

Of the 48 species with mapped ranges, 30 species are restricted to the western Africa region, including 20 of the 21 restricted-range species (excluding *Caridina gaesumi*) plus 10 species with wider ranges. Of the 10 additional regionally endemic species with ranges greater than 10,000 km² there are seven crabs (one threatened species *Potamonautes reidi* (VU) and six Least Concern species), and three shrimps, *Caridinopsis chevalieri* (LC), *Euryrhynchina edingtonae* (EN) and *Macrobrachium raridens* (DD).

6.4 Major threats to freshwater decapods

Threats to species are identified as part of the Red List assessment process. Threats are identified for 25 of 26 crab species (all but *Potamonautes lipkei* (DD)), and for four threatened species of shrimp. It should be noted that these are global assessments and the threats identified are not spatially explicit but describe the threats facing these species throughout their global range. Nevertheless, the majority of species have their entire global range restricted to the region and so any threats are implicitly played out within the region. The numbers in Figure 6.8 represent the number of freshwater decapod species for which each threat is identified.

6.4.1 Agriculture and aquaculture

Agriculture & aquaculture is the single greatest threat facing the freshwater decapod species of western Africa, affecting 35 species (65%) according to assessors. These threats are predominantly posed by agro-industry farming and small-holder farming.

6.4.2 Biological resource use

Biological resource use affects 28 species (52%), with the main threats coming from logging & wood harvesting affecting 22 species and small scale harvesting.

6.4.3 Pollution

Pollution is explicitly identified as a threat to 25 species (46%), with agriculture, domestic & urban waste water

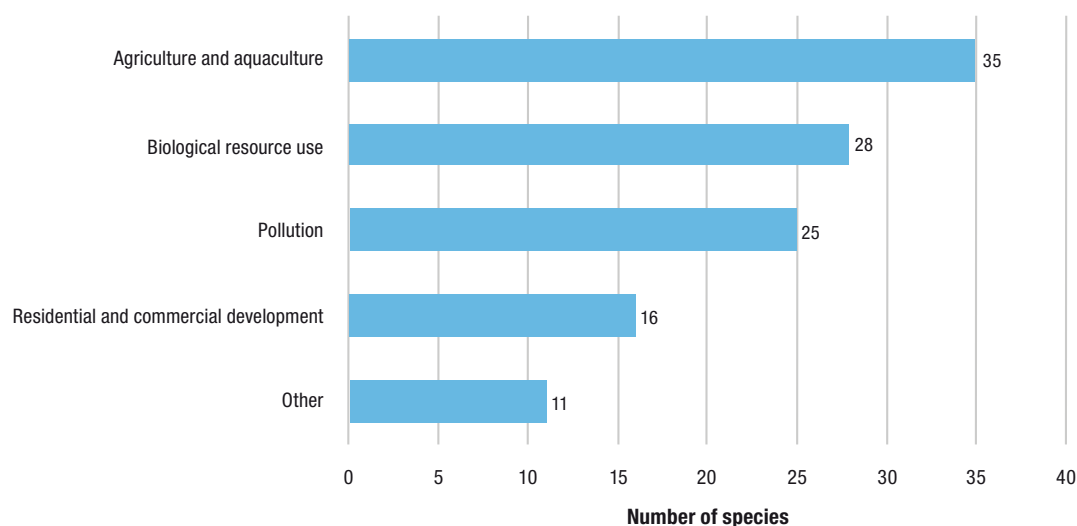


Figure 6.8. Major threats facing freshwater decapods in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

and industrial effluents cited as the common threats. The Niger Delta in Nigeria in general suffers from extensive environmental degradation due to repeated oil spills. Any oil spillages may disproportionately impact species with restricted ranges within the delta, such as the shrimps *Desmocarlis bislineata* (EN) and *Euryrhynchina edingtonae* (EN). The single recent location from which the latter species has been recorded (the Ikpoba River) is highly polluted due to domestic and industrial effluent from Benin City.

6.4.4 Residential and commercial development

Residential & commercial development is listed as a threat in 16 (30%) of the freshwater decapod Red List assessments.

6.4.5 Other threats

Other threats include *Energy production & mining* (3%), *Natural system modifications* (3%), *Invasive and other problematic species, genes & diseases* (3%) and *Human intrusions & disturbance* (2%).

6.5 Recommended research and conservation actions

6.5.1 Research recommended

As with the other freshwater taxonomic groups assessed, very little is known about the distribution of many of the freshwater decapod species in western Africa. Without this basic information, it is difficult to make informed judgements as to their current conservation status. Testament to this is the fact that 25% of the known species in the region are assessed as Data Deficient (Table 6.1). Furthermore, without

recent distribution data, it is difficult to monitor any changes in the species' conservation status. The most frequently cited research topics recommended for freshwater decapods were *population size and trends, and distribution* (24% of all recommended research), *life history and ecology* (23%), and *threats* (22%) (Figure 6.9).

Recent surveys have rediscovered several 'lost' species of freshwater crabs such as *Afrithephusa afzelii* (CR), *A. leonensis* (CR), *Liberonautes rubigimanus* (VU) and *L. nimba* (VU), and there is still potential for new species discovery, e.g. *Euryrhynchina puteola* (DD) collected in 2012, described in 2017. However, several species have not been observed for half a century; *Potamonautes triangulus* (VU), 1950; *Potamonautes senegalensis* (DD), 1960; *Sudanonautes nigeria* (DD), 1973. Even for those species recently re-discovered, we do not sufficiently understand their population sizes, distributions and trends, and they remain highly threatened. Further research in these areas will be vital to ensure their continued survival.

6.5.2 Conservation actions recommended

Some 63% of the conservation actions recommended by assessors were gene-banking of these species (Figure 5.9). This would help to ensure the preservation of genetic material as an insurance policy against extinction, but also by sequencing these species' genomes and adding them to a genomic library would allow for them to be identified more readily using eDNA surveys.

Site management was identified as another recommended conservation action. Several potential Key Biodiversity Areas (KBAs) were identified for decapod species (see Chapter 9) but are not able to be confirmed until recent confirmation of the species' presence at these sites comes to light.

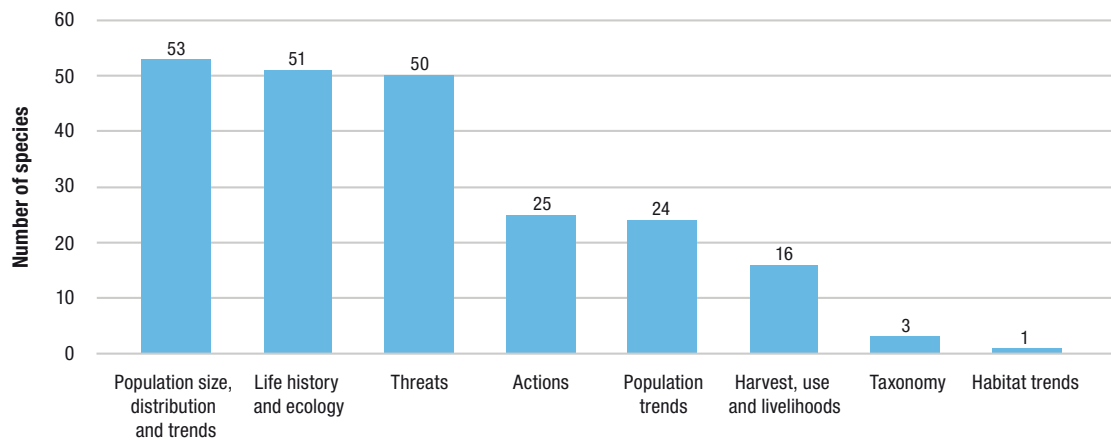


Figure 6.9. Research recommended for freshwater decapods of western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

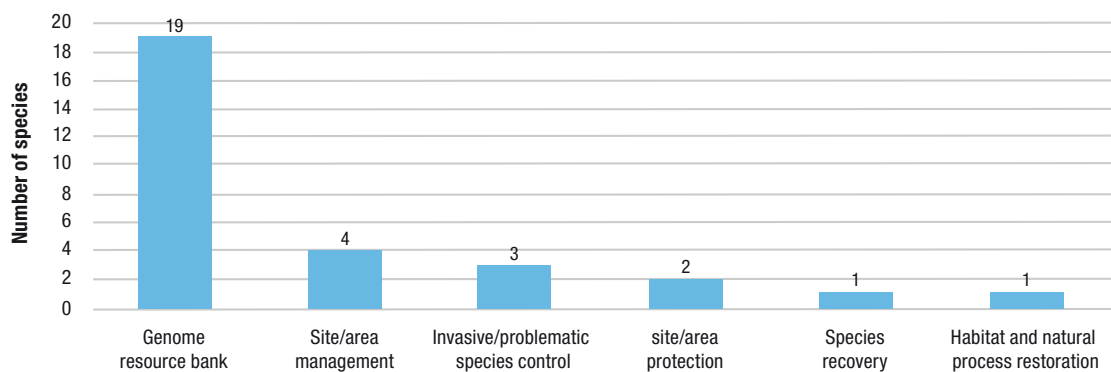


Figure 6.10. Conservation actions recommended for freshwater decapods of western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

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Chapter 7

The status and distribution of aquatic plants in western Africa

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7.1 Overview of the western Africa aquatic flora

The varied habitat types and high levels of precipitation in parts of the western Africa give rise to a high diversity of aquatic and semi-aquatic flora in the region. The Upper and Lower Guinea ecoregions contain some of the highest levels of plant diversity and endemism in Africa (Linder, 2001).

There are various definitions of aquatic plants or hydrophytes, as they are sometimes termed, but they all include those plants that are adapted to grow in waterlogged habitats. These range from deep water to bogs and marshes, and include seasonally and perennially flooded areas. Both physiological and morphological modifications enable these plants to flourish in places where others would die. Although morphologically diverse with adaptations to aquatic habitats in many different plant groups, some basic growth forms are prevalent and can be classified under two broad habitat types. The first of these, the helophytes, are rooted underwater but produce emergent stems that bear leaves and reproductive parts above water and the second are the hydrophytes, adapted for living submerged in water

or at the water surface. The latter are divided into species that have roots fixed in the underlying substrate, are free-floating, have leaves and/or reproductive parts immersed underwater or at the water surface, or have leaves and/or reproductive parts above water (Ranarijaona, 1999). Plants adapted to survive saline conditions such as salt marshes, referred to as halophytes, are excluded from this study.

The occurrence of aquatic plants is largely dependent on the depth and speed of water flow, and water quality. Some species prefer stagnant or at least calm waters (lentic conditions) – lakes, ponds, marshes and bogs. These lentic species, such as the water lilies (*Nymphaea* spp.), are rooted in the bed of the water body. Floating species include the duckweeds (*Lemna* and *Wolffia* spp.) and the water hyacinth (*Eichhornia crassipes*). Other species proliferate in running waters (lotic conditions) – rivers, streams, torrents and waterfalls, where floating species are generally absent. Finally, some species are attached to submerged rocks and are able to withstand exceptionally high rates of water flow, notably members of the Hydrostachyaceae and Podostemaceae.

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Figure 7.1 *Nymphaea micrantha*, a water lily native to western Africa. © Fatima Niang-Diop

Table 7.1 Number of native and endemic aquatic plant species per Red List category in western Africa. Numbers in parentheses refer to the previous assessment (Smith et al., 2009) and include regional assessments. Source: Compiled by the report authors using data from the IUCN Red List (2021) and Smith et al. (2009)

IUCN Red List Category	Number of native species	Number of regionally endemic species
Extinct (EX)	3	(0)
Extinct in the Wild (EW)	0	(0)
Critically Endangered (CR)	9 (2)	3 (2)
Endangered (EN)	5 (0)	2 (0)
Vulnerable (VU)	3 (5)	3 (2)
Near Threatened (NT)	2 (5)	0 (2)
Least Concern (LC)	449 (356)	169 (11)
Data Deficient (DD)	15 (104)	9 (25)
TOTAL	486 (472)	186 (42)

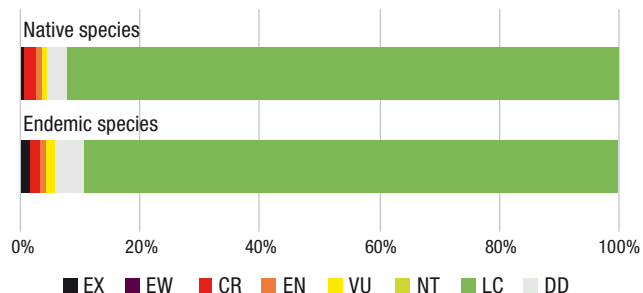


Figure 7.2 Percentage of freshwater plant species assessed according to the IUCN Red List categories in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

7.2 Conservation status

This summary refers to the assessment of freshwater species in the western African region based on the IUCN Red List categories and criteria (International Union for Conservation of Nature (IUCN), 2012). Some 486 plant species growing in freshwater areas and wetlands are included in this analysis (Table 7.1). Red List assessments were conducted for 382 species. The remaining 104 species were already recently assessed in 2015. A further 43 species of aquatic plants, 13 Lentibulariaceae and 30 Podostemaceae were ultimately not assessed in this work.

Of the 486 assessed species, 17 species are within one of the threatened categories: nine species are assessed as Critically Endangered (CR), five species are Endangered (EN) and three species are Vulnerable (VU) (Table 7.1).

Three species have been assessed as Extinct (EX). These are *Scleria chevalieri* (extended from Burkina faso to Senegal), *Eriocaulon inundatum* (distributed from Senegal to Mali to Senegal) and *Eriocaulon jordanii* (distributed from Benin to Togo) (Table 7.1).

In total 449 species or 92% of all aquatic plants native to the region are assessed globally as Least Concern (LC) (Table 7.1, Figure 7.2). This majority of species is higher in comparison to species in this category assessed in freshwater ecosystems in North Africa where only 266 taxa are identified as LC. On the one hand, this finding reveals a



Figure 7.3 *Dopatrium senegalense* is a widespread species with no known major threats, assessed as Least Concern. This species colonises wet places such as rice paddies. This plant in Senegal is in full flower. © Attila Mesterházy

positive aspect in relation to the current state of freshwater plant biodiversity, especially as the threats present continue to intensify as they multiply. On the other hand, the efforts that will be made in the protection of this flora will be less directed in their entirety, towards this majority.

There is good documentation on the state of the extinction risk of freshwater plants assessed so far in this region. However, few of them (15 species or 2%) were classified in the Data Deficient (DD) category. In the Western African region, an evolution in the availability of plant data was indicated in that the species classified as DD was at the time of the last assessment about seven times higher than those obtained in this study. It should be mentioned, however, that the absence of information on these taxa in no way excludes the existence of a threat, the degree of which remains to be determined. The insufficiency of data on this DD category constitutes a limit on the knowledge of West African aquatic flora.

7.2.1 Critically Endangered species

***Wahlenbergia tibestica* (Campanulaceae)**

Wahlenbergia tibestica is an annual or hydrophyte found in seasonal or intermittent freshwater lakes, marshes and pools. This species has been collected only once, in Tibesti (Chad). Its ecology is not clear, but the plant is considered endemic to the region. It has an Area of Occupancy (AOO) of 4 km². In view of the severe climate in the north of Chad,

particularly for an aquatic plant, we project a continuing decline of the area, extent and/or quality of habitat.

***Bolboschoenus grandispicus* (Cyperaceae)**

Bolboschoenus grandispicus has only been reported from Senegal, Guinea-Bissau and Cabo Verde. However, it is now considered restricted to Senegal. This species is found at the edge of swamps in freshwater depressions behind the coastal dunes. The species is assessed as Critically Endangered based on a restricted AOO of 4 km² and occurrence at one location, based on the threat of habitat degradation, which is resulting in a continuing decline in habitat. The only recently confirmed and currently extant subpopulation is near Dakar (Rufisque), which was found in 2014 (A. Mesterházy pers. obs. 2014).

***Elatine fauquei* (Elatinaceae)**

The plant is known only from the type locality, the Ravin Balassogo (Balasoko) in Mali, in or around a fountain (spring) in a stony valley. Its AOO is very low at 4 km² and it occurs in one location based on the threat from recreational activities. Because this type of habitat is very fragile, we infer a continuing decline in the area of occupancy and area, extent and/or quality of habitat.

***Eriocaulon adamesii* (Eriocaulaceae)**

Eriocaulon adamesii (CR (Possibly Extinct)) is a rare endemic in West Africa, known from few collections from Sierra Leone

(Hepper, 2000) and one from Liberia, collected mainly in the 1960s. Recently, none of these collections have been reconfirmed. However, some potential sites need surveying for this species because there are still some remaining natural habitats which can be found near type locality. The most significant threat is habitat degradation as a consequence of increasing human activity, such as the building of houses, farms and plantations, and this has resulted in a continuing decline in habitat extent and quality. If extant, the species is expected to have an AOO of, at most, 8 km².

***Eriocaulon obtriangulare* (Eriocaulaceae)**

Eriocaulon obtriangulare (CR (Possibly Extinct)) has only been collected once from Côte d'Ivoire in 1967. Although the type locality is in Comoé National Park, where the influence of human activities is low, this species has not been found since the initial collection. The type locality was visited in 2013, but this species was not found (A. Mesterházy pers. obs. 2013). As the site is in the north forest-savanna region, dry periods might become longer in the future with lower annual rainfall due to climate change, which might cause a negative effect to temporary pools. As this species has not been found since 1967, but suitable habitats remain at Comoé National Park where the species might appear in the future, it is assessed as Critically Endangered (Possibly Extinct). Further surveys are needed to look for this species in Comoé National Park. The type specimens are all incomplete and so the taxonomic status of this species is not clear, and further research is recommended.

***Inversodicraea abbayesii* (Podostemaceae)**

Inversodicraea abbayesii (CR (Possibly Extinct)) was previously assessed as *Ledermaniella abbayesii* (DD) in 2008 (Diop, 2010). Since that time, the species has been transferred to the genus *Inversodicraea* (Cheek et al., 2017), and a targeted survey for Podostemaceae including this species was made in January 2018 resulting in new data allowing a revised assessment (Cheek & Diop, 2018).

Inversodicraea abbayesii is endemic to Guinea, collected by Des Abbayes c. 1950, and known only from the single collection that he made at that time from the Grandess Chute de Kinkon, near Pita in the Fouta Djallon Highlands. Des Abbayes observed that it emerged to flower from the white water of the falls themselves. In January 2018, a team from the National Herbarium of Guinea with RBG Kew (funded by a Darwin Initiative project on Guinea Important Plant Areas), with expertise in Podostemaceae, visited the falls at the best season to rediscover this species (Couch et al., 2019). They found the species to be absent, probably because a hydro-electric dam constructed after the species was collected, has diverted much of the river flow around the falls, and has probably altered the natural hydrological pattern. In addition the river supplying the falls carries large amounts of silt (deposited on the rocks of the bank) and is contaminated

on its journey through the town of Pita where it is used for laundry and other purposes. Although locally extinct at the type locality, the species may yet be found at other sites, since several falls in Guinea have never been sampled for their plants. However, many species of this family are single-site endemics so it cannot be ruled out that this species is globally extinct. The species is therefore assessed as Critically Endangered (Possibly Extinct) (Cheek & Diop, 2018).

***Inversodicraea pygmaea* (Podostemaceae)**

Inversodicraea pygmaea (CR (Possibly Extinct)) is only known from a single locality: the Grandes Chutes de Kindia waterfalls in Guinea. In January 2018, a team of four from the National Herbarium of Guinea with RBG Kew with expertise in Podostemaceae, visited the falls at the best season specifically to rediscover this species (Cheek, 2018). They found this species and all other Podostemaceae species to be absent, including even the most widespread, common and ecologically tolerant, *Tristicha trifaria*. A hydro-electric dam constructed in 1962 after the species was discovered, has diverted much of the river flow around the falls, and has altered the natural hydrological pattern. In addition, the stream below the dam is contaminated where it is used for laundry and as a latrine, explaining high algal growth, inimical to Podostemaceae, which are associated with clean, nutrient poor water.

***Stonesia fascicularis* (Podostemaceae)**

Stonesia fascicularis (CR (Possibly Extinct)) is known only from the type locality, Grandes Chute de Kinkon, near Pita in the Fouta Djallon Highlands, c. 1950 (Cheek & Ouedraogo, 2018a), as per *I. abbayesii* (Cheek & Diop, 2018).

***Stonesia gracilis* (Podostemaceae)**

Previously assessed as DD by (Ouedraogo, 2010) on the basis of sparse and erroneous information, the assessment of *Stonesia gracilis* was updated and revised to CR (Possibly Extinct) in 2018 by Cheek and Ouedraogo (2018b). This species, together with *Inversodicraea pygmaea*, is only known from the Grandes Chutes, Kindia but was recently found to be absent from the site (Cheek and Ouedraogo, 2018b). There appears to be no evidence for records of this species in Cameroon and Sierra Leone, although occurrence in the latter is possible.

7.2.2 Endangered species

***Commelina ascendens* (Commelinaceae)**

This plant, known from Nigeria and Ghana, is a herb found in secondary or open primary forests, often by rivers. It has an AOO of 60 km² and is threatened by severe drought, which is exacerbated by climate change. A continuing decline in its AOO and the quality of its habitat is inferred.

***Cyperus lateriticus* (Cyperaceae)**

This species was known from only the type specimen collected in 1953. However, it has recently been recorded both at the type locality (near Tambacounda) and at one other location (near Kédougou) (A. Mesterhazy pers. obs.). The most significant threat is habitat degradation as a consequence of increasing human activities (e.g. agriculture and urban expansion), and the increased occurrence of droughts decreasing habitat quality and increasing frequency and impact of bush fires during the dry season. The area in which this species is known to occur (the Kédougou and Tambacounda regions of Senegal) is impacted by mining (in particular artisanal gold mining). It is not recorded from any protected areas, though it could be present in Niokolo-Koba National Park since this protected area is located near the two known locations in Senegal. More research is needed to confirm whether this species is endemic to Senegal, or whether it also occurs across the border in Guinea, as well as to assess the population trends and study the threats posed to this species.

***Aldrovanda vesiculosa* (Droseraceae)**

The Waterwheel *Aldrovanda vesiculosa* (EN) is a carnivorous, perennial, free-floating, rootless aquatic herbaceous plant known from 379 natural historical collections from 43 countries (Cross and Adamec 2020). However, this species has declined over the last century to only 50 confirmed extant localities. Two thirds of these are found in one region in Poland and the Ukraine, with the remaining 18 sites thinly spread across four continents. In western Africa, historic localities are known from Togo, Ghana, Chad and Cameroon, but none of these have been recently confirmed.

In Cameroon, the species has previously been recorded from the shores of Lake Fianga near the border with Chad in the Extreme North region (unverified since 1963), and from the vicinity of Lake Bamendjing on the border between the rugged and mountainous West and Northwest regions (unverified since 1974). In Chad, the species was known from four sites near Sarh, formerly Fort Archambault, in the Chari River delta, between 1962 and 1968. With *A. vesiculosa* known from Lake Fianga's northern reaches in Cameroon, it is possible that the species' occurrence extends across the border into swampy areas fringing the lake in southwest Chad. In Ghana, the species was known from swampland near Kete Krachi, in the northern reaches of the expansive Lake Volta, and in swamps of the Volta River delta, east of Dabala, in the Keta Lagoon protected area unverified since 1963. A second ambiguous location is in Lake Volta. As the wetlands surrounding this immense lake are numerous, it is possible that a number of populations may exist in the region (unverified since 1965). In Togo, the species was known from the Koumongou River, near the town of Sansanné-Mango in the northeast (unverified since 1984).

Aldrovanda vesiculosa is not protected by legislation in any African nation, and is not included in any regional conservation initiatives.

***Najas hagerupii* (Hydrocharitaceae)**

Najas hagerupii (EN) has been collected in one locality in each of Cameroon, Ghana and Mali. These represent three locations based on the threat of climate change and severe weather. The AOO is 16 km². This species occurs in temporary and permanent marshes and pools, in both shallow and deep waters. Threats include human intrusions and disturbance, especially recreational activities, natural system modifications, invasive of non-native species, and climate change and severe weather, characterised by droughts and temperature extremes.

***Pandanus senegalensis* (Pandanaceae)**

This species is a small tree that grows along rivers and waterfalls in a small area of southeastern Senegal, Mali and Burkina Faso. This species occurs in a specific habitat of gallery forest and there is likely increasing pressure on this type of vegetation for housing, urbanisation and smallholder agriculture from an increasing human population over its distribution area. While one specimen (the type) is from in or near a protected area, the Niokolo-Koba National Park in Senegal, it is unclear if the site is actually in the protected area, and the tree has not been re-collected there since 1960 (Beentje, 2020).

7.2.3 Vulnerable species

***Aneilema mertonii* (Commelinaceae)**

This species is endemic to western Africa where it is recorded in Ghana and Togo. This species occurs in open grassland, scrambling among grasses beside ponds, on marshy ground and in savanna, and is potentially impacted by pollution from agricultural development, invasive species and drought. The species' low AOO of 48 km² is thought to be an underestimate based on low collecting effort.

***Blyxa senegalensis* (Hydrocharitaceae)**

This species is a hydrophytic herb of temporary pools in lateritic outcrops. The plant is recorded from 20 herbarium specimens from six countries; Senegal, Gambia, Guinea-Bissau, Guinea, Mali and Sierra Leone. Despite its widespread distribution, it has a restricted area of occupancy (AOO) of 28–500 km². This species is thought to be endemic to the western part of western Africa, where it is potentially impacted by agricultural development, invasive species and drought, all of which are leading to continuing declines in habitat quality and extent.

***Rhytachne furtiva* (Poaceae)**

This perennial species grows in savanna, mostly on disturbed



Figure 7.4 *Blyxa senegalensis* is an uncommon species confined to western Africa, where it can be found in temporary pools. This specimen was recorded in Senegal. © Attila Mesterházy

secondary sites, but also in marshy savanna on floodplains. It can also be found around the edges of small pools on clay soil. It is known only from southeast Burkina Faso and west Ghana from six locations. These locations are threatened by an increasing frequency of fire and drought, which are leading to continuing declines in its habitat extent.

7.2.4 Extinct species

***Scleria chevalieri* (Cyperaceae)**

Scleria chevalieri was previously found in a freshwater swamp near the coast. These are called 'niayes'. This species is known only from the type locality from a collection in 1929. The type locality was revisited in the 1970s, by a cyperologist (Jean Raynal), and the species was not found. The type locality can still be found near Rufisque, but it is currently in bad condition. There are gardens near the swamps, where local people use the water for irrigation. This has resulted in most parts of the swamp being drained, primarily for cultivation. Only the deepest part of the swamp remains, with *Typha* vegetation (A. Mesterházy pers. obs.). Although there is another collection from Casamance, there is no date or locality information. There are swamps in good condition in Casamance, but there is no evidence that *S. chevalieri* is still extant there after a number of botanical excursions.

***Eriocaulon inundatum* (Eriocaulaceae)**

Although most of the habitats on the Saloum river estuary are brackish, there are some inundated freshwater pools,

which are separated from flooded saline habitats by an impermeable clay layer. As species in the genus *Eriocaulon* do not prefer saline habitats, this species might have occurred in these inundated pools.

The only confirmed occurrences of this species were from Senegal, near the estuary of the Saloum River (Hepper, 2000) where they were collected in 1943. Recent fieldwork at the type locality did not find this species (A. Mesterházy pers. obs. 2014) and most potential habitats in the area surrounding the type locality (near Palmarin) have been destroyed by local salt mining.

***Eriocaulon jordanii* (Eriocaulaceae)**

This species was known only from two sites: recorded near the coastal region of Sierra Leone at the beginning of the 1950s. Recent fieldwork at the type locality, and the other previous collection site, did not find this species (A. Mesterházy pers. obs. 2012). *Eriocaulon jordanii* was originally collected at the edge of a swamp. There are still many rice fields in the region, but natural wet habitats have mainly been converted to rice fields. As this species has not been seen since the 1950s, despite surveys in all known and suitable habitats, it is assessed as Extinct. There are still many rice swamps which occur in the coastal region of Sierra Leone, but few natural wet habitats remain. Due to the increasing human population, most aquatic habitats have been converted to rice fields in the coastal area of Sierra Leone.

7.3 Species richness patterns

This section discusses the distribution of freshwater plant species across the western Africa region. The species richness maps do not include all species assessed, because of the paucity of data on their spatial distribution.

For plant species, accurate range maps are rarely possible and therefore they tend not to be included in Red List assessments. Rather, point localities are mapped where possible, but they also are usually incomplete. Therefore, the maps of plant species richness presented here should be interpreted with caution, as they may be affected by sampling bias.

Overall, 388 species of freshwater plants were mapped in the Western African region, either to HydroBASINS or as point localities, or both. Species richness maps were created using level 8 the HydroBASINS as the spatial unit, and counting the number of species present according to mapped ranges and point localities. By contrast, species richness maps in Smith et al. (2009) are based on country-level distribution information.

Of the 486 species considered here, 361 of these had a combination of point locality data, mapped range polygons, or both. Some 125 species have no mapped distribution.

7.3.1 Overall species richness

The greatest diversity of aquatic plants is found to the southwest of the western Africa region. Senegal and Nigeria in particular emerge as centres of species richness for aquatic plants with up to 90 species per subcatchment (Figure 7.5). Ghana, Benin and Nigeria and, to a lesser extent, Togo, have high plant species richness. Compared to the 2009 assessment (Smith et al., 2009), species mapping shows a wider range span in many countries. Indeed, the presence of wetlands including waterfalls, streams as well as shady areas, has led to a flourishing of the pediflore dominated by ferns (Paterne & Mathieu, 2017). Lakes such as Chad (Magrin & Lemoalle, 2019) and Komadougou Yobé (Zairi, 2008), for example, drain large areas of watersheds that supply wetlands with permanent open water. At these bodies of water, the bowls flood for much of the year allowing the establishment of aquatic flora.

7.3.2 Threatened species richness

The distributions of threatened aquatic plants species are poorly mapped and further research is needed on their distributions (Section 7.5). Seven threatened species' ranges are mapped, including three CR species; *Elatine fauquei* (CR) near Bamako in Mali, on the Upper Niger, *Bolboschoenus*

grandispicus (CR) in Dakar, Senegal and *Wahlenbergia tibestica* (CR) from the Dry Sahel. Possibly extant and extinct locations are not mapped here.

Threatened plant species such as the Podostemaceae lost from their type localities at Grandes Chute de Kinkon and Grandes Chute de Kindia in Guinea can be restricted to very small areas such as a single waterfall.

7.3.3 Regionally endemic species richness

The number of regionally endemic species was determined based on a combination of mapped ranges and point localities representing extant species. Using this approach, 186 species were identified to be regionally endemic. Point localities were not used in the endemic species richness map (Figure 7.7) because they are representative of collection effort and do not accurately reflect the true distribution of aquatic plant species. Only species with mapped ranges i.e. where the Red List assessor is confident about the species' range, were included in the map (Figure 7.7). Areas emerging as centres of endemic species richness include Mount Nimba at the intersection of Liberia/Côte d'Ivoire/Guinea and the neighbouring Eburneo ecoregion, Fouta Djallon and the Upper Gambia River around Kedougou and the Dindefello Natural Reserve KBA, and the Kwara, Niger and Kaduna states of western Nigeria.

7.3.4 Data Deficient species richness

The choice to narrow the study of the country-wide assessment of freshwater plant species based on IUCN criteria, among other aspects, was not sufficient to obtain information in order to place these species in a Red List category. About 15 species are found in this situation (DD) in the Western African region (Table 7.1). Côte d'Ivoire and Guinea have the highest number of species (3 species) of the DD category. Also, Nigeria, Ghana, Sierra Leone, Senegal and Burkina Faso have a high level of DD species (2 species).

7.4 Threats to species

Some 157 assessed species are affected by *climate change & severe weather* (32% of species) (Figure 7.9). This subset of threats contributes to the alteration of natural habitats and the transition to degradation of plant resources through drought-related impacts. Conservation measures then become necessary for endogenous species studied. Beyond the impacts of climate, human activities contribute significantly to the increase in problems related to the loss of aquatic biodiversity in the Western African region. (Figure 7.9). *Agriculture & aquaculture* account for 20% of all species threats, affecting some 127 species. As well as

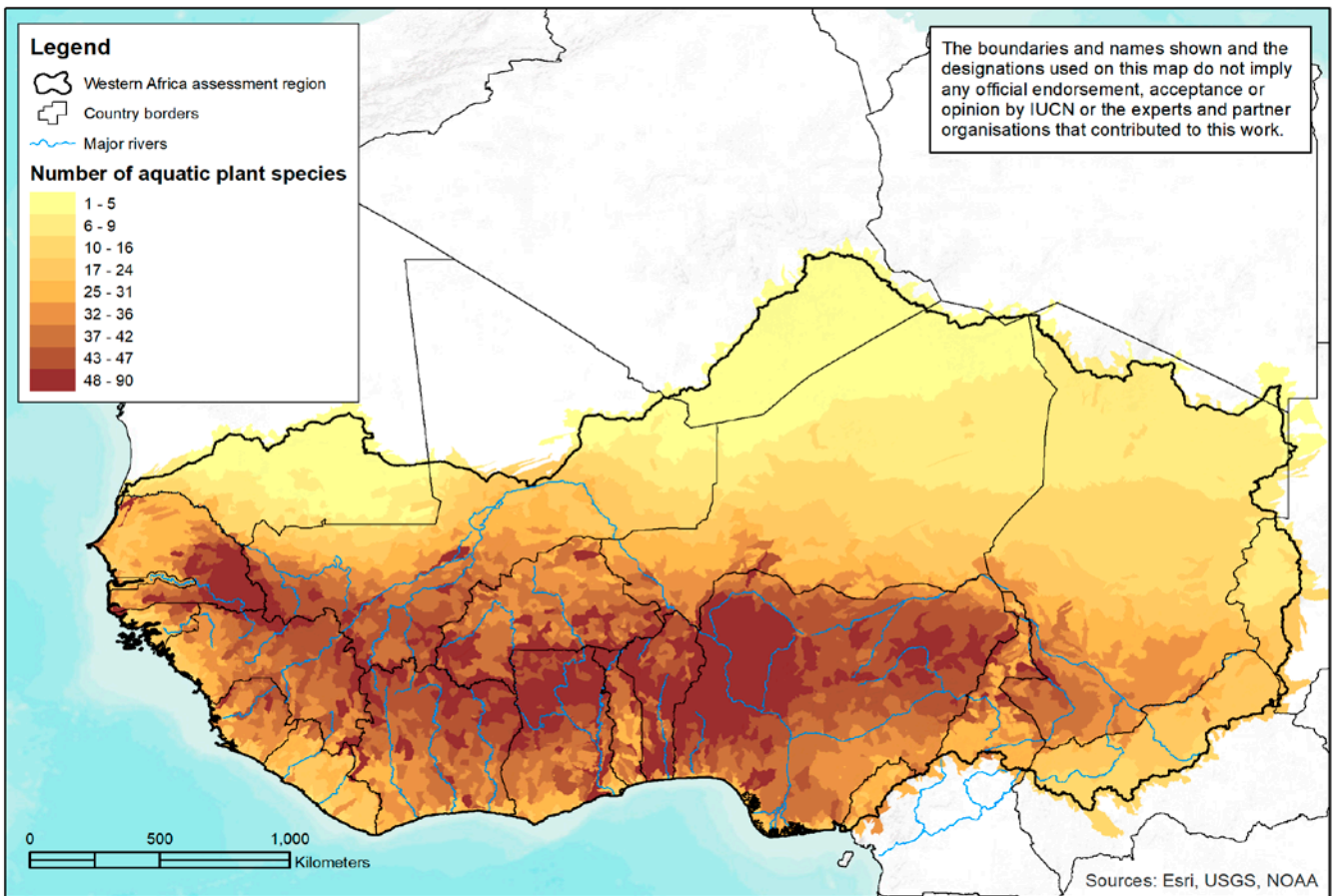


Figure 7.5 Species richness of aquatic plants in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

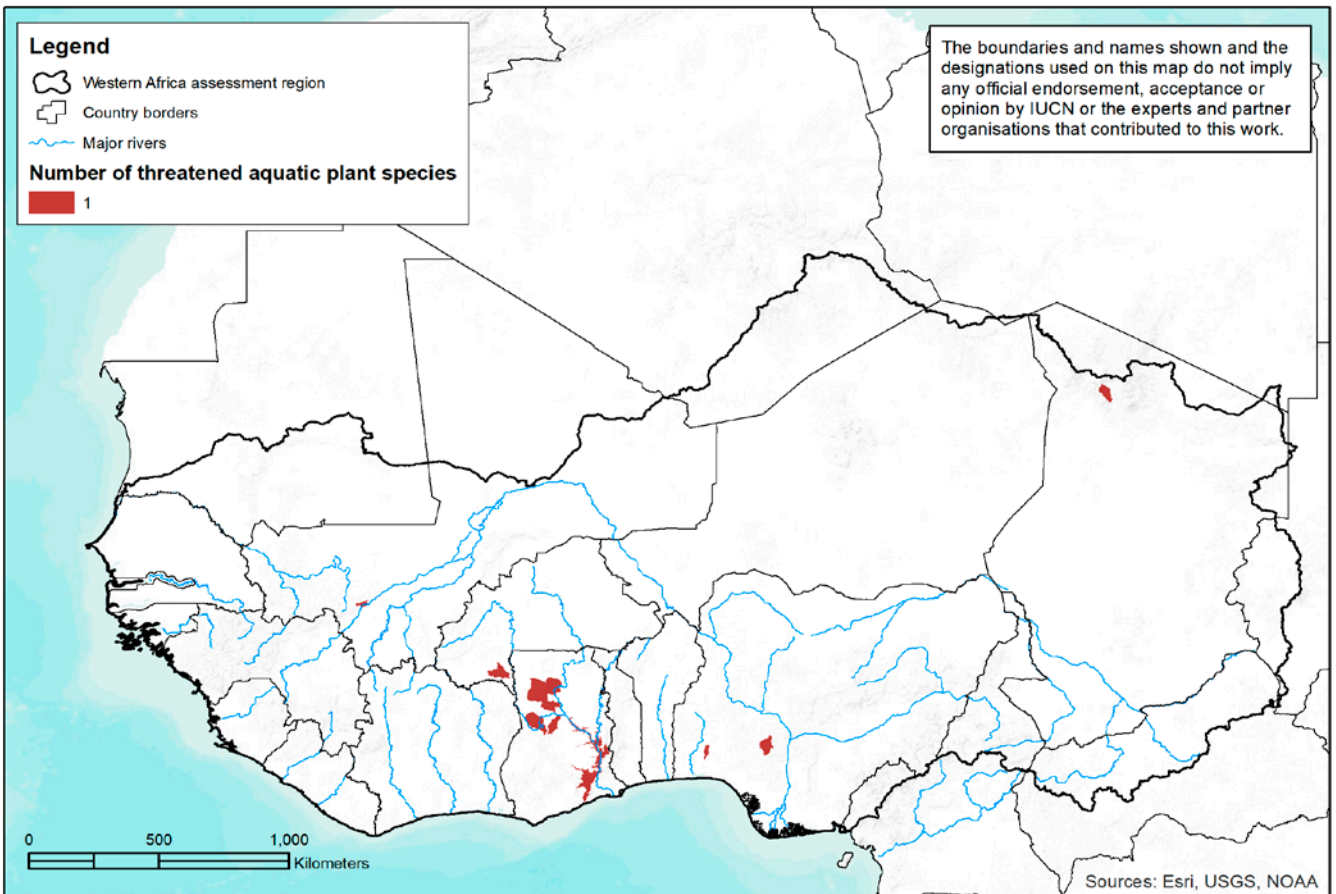


Figure 7.6 Species richness of threatened aquatic plants in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

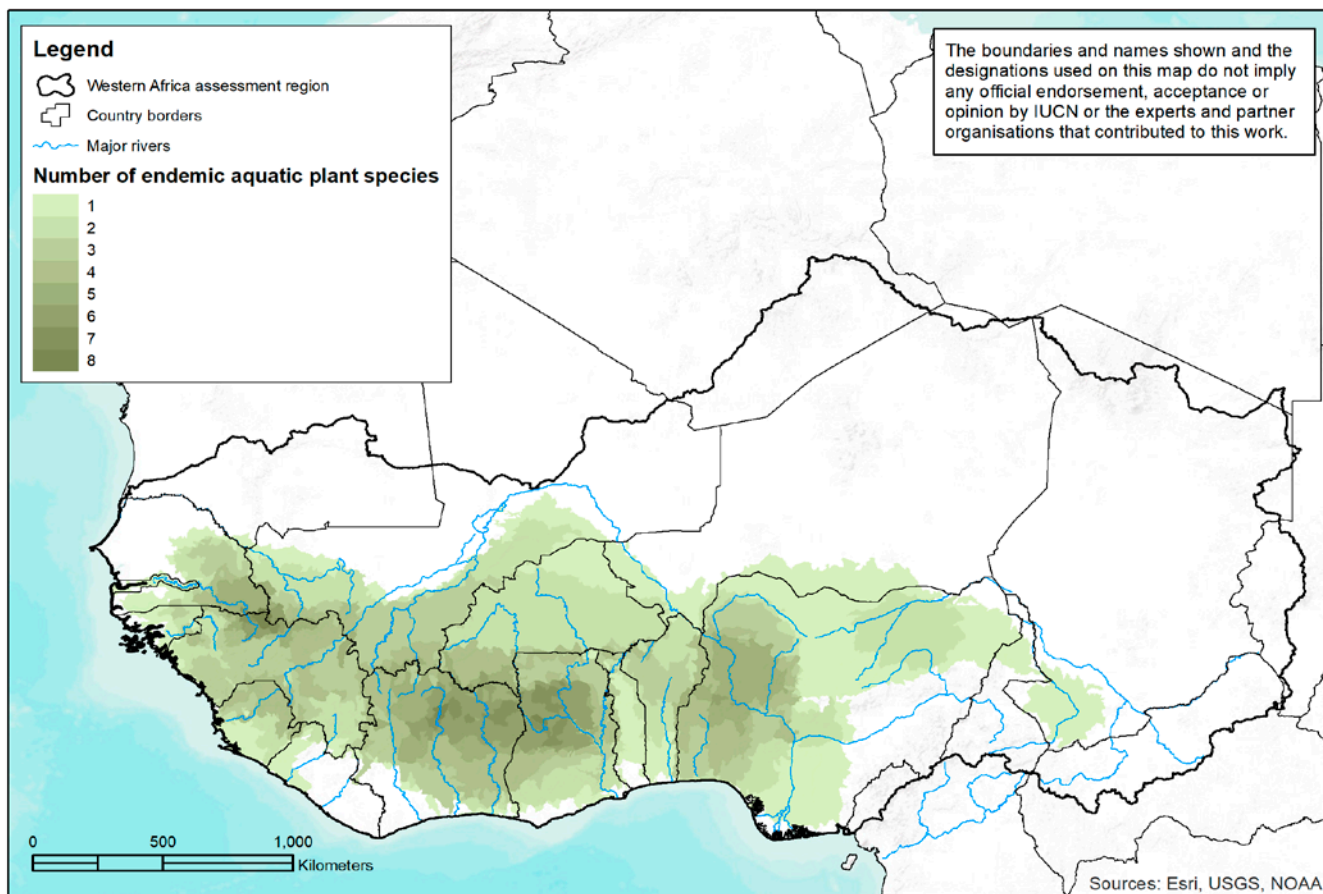


Figure 7.7 Species richness of regionally endemic aquatic plants in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

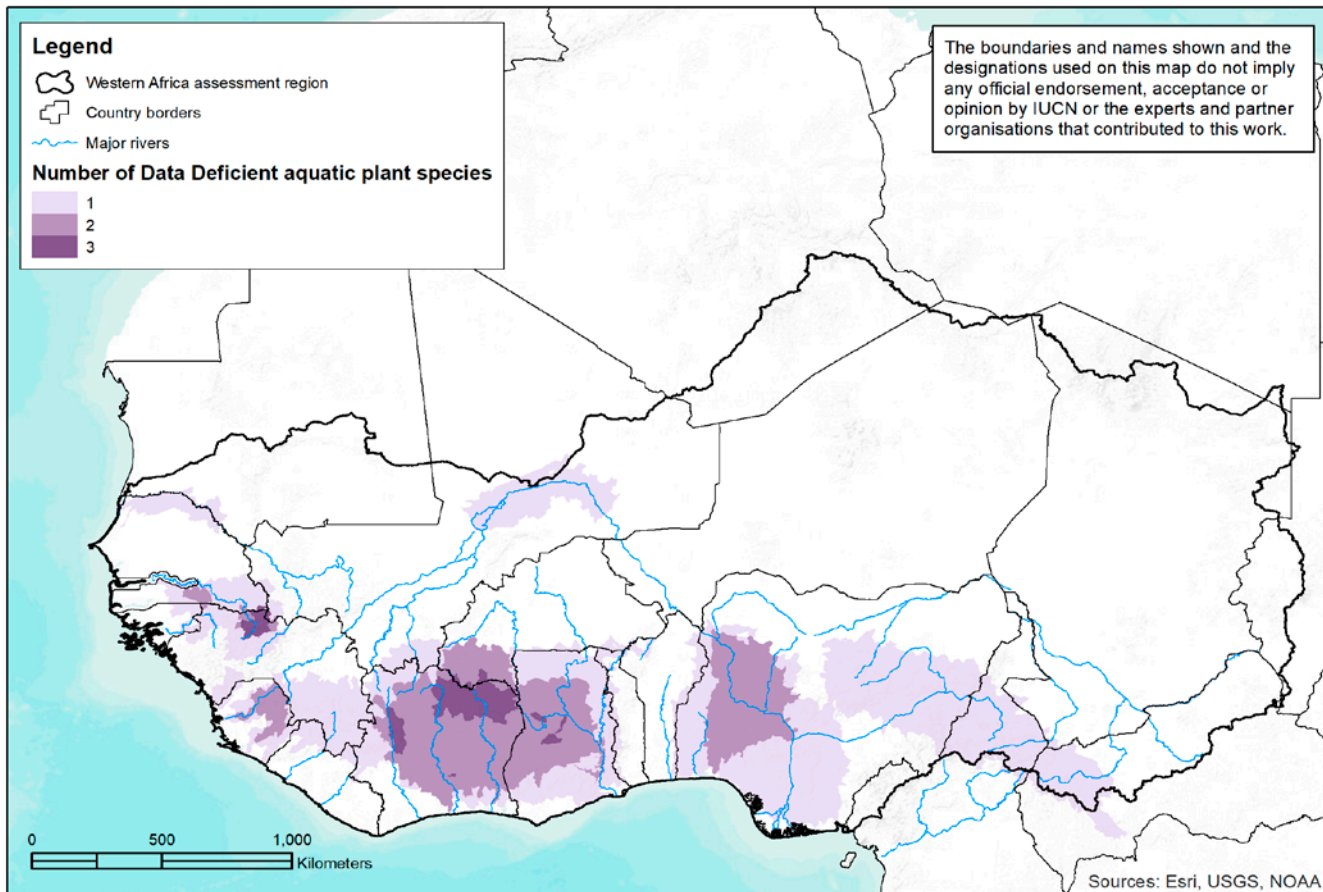


Figure 7.8 Species richness of Data Deficient aquatic plants in western Africa based on Red List range maps. Source: Compiled by the report authors using data from the IUCN Red List (2021).

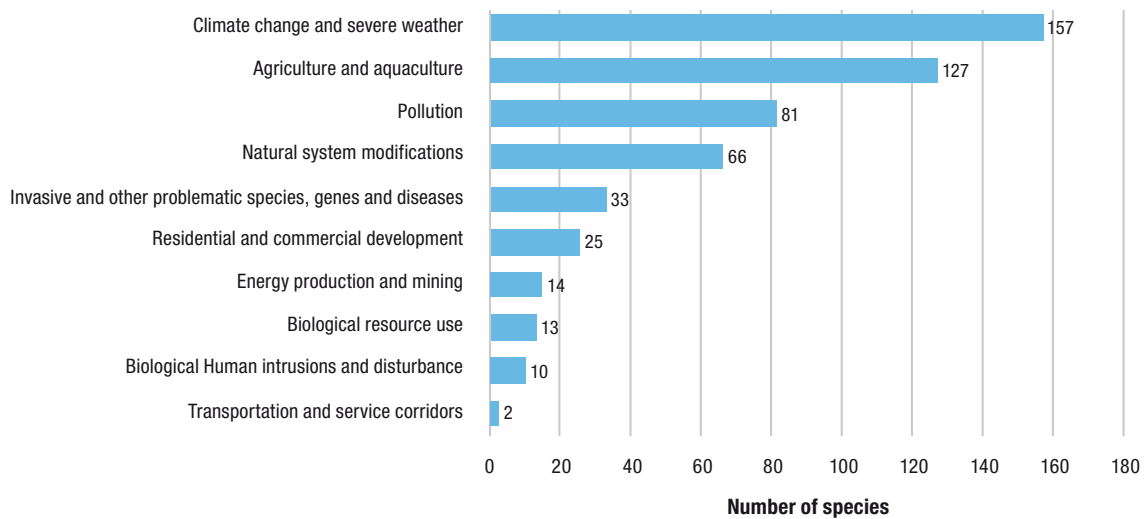


Figure 7.9 Threats to West African Freshwater Plant Species. Source: Compiled by the report authors using data from the IUCN Red List (2021).

forest ecosystems, the expansion of cropland and the renewed interest in fish farming with the extension of aquaculture, aquatic ecosystems are threatened. Waste produced from the use of environmentally unfriendly techniques and means poses a risk to plant development (81 species). Pollution affects 17% of species. The sources of pollutants are agricultural and forest effluents (45 species), industrial and military effluents (19 species), domestic and urban wastewater (16 species). Natural systems have undergone often-continuous changes (groundwater and surface water extraction, dams) have been identified as threat factors for 48 species (10%).

7.5 Conservation actions and recommended research

The issue of freshwater plant resources in West Africa is a major challenge. The destruction of the living environments of species, which is a major factor in biodiversity loss, has severely affected their survival. In this context, *resource & habitat protection* remains the most frequently recommended action, for 95 species (20%) (Figure 7.10). The level of degradation of known freshwater plants could be further than currently understood, and reach extinction given the multiplicity and combination of threats to plant biodiversity in the region.

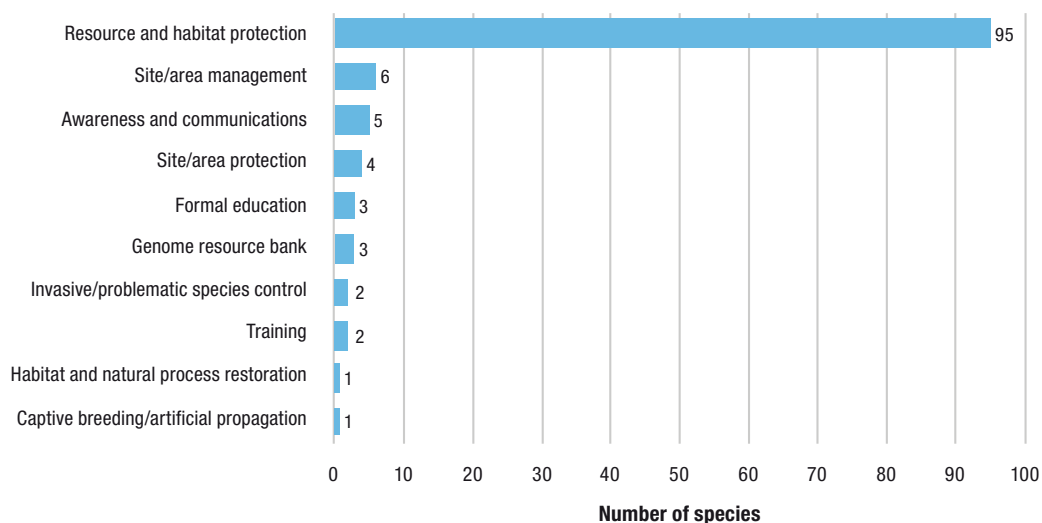


Figure 7.10 Recommended Conservation Actions for West African Freshwater Plant Species. Source: Compiled by the report authors using data from the IUCN Red List (2021).

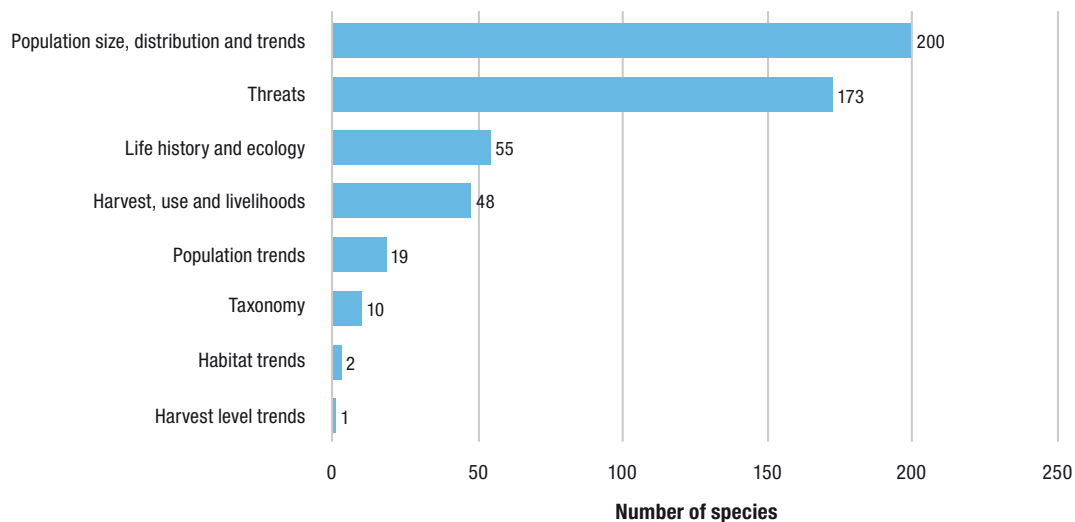


Figure 7.11 Types of Freshwater Plant Species Research Recommended for West African Freshwater Species. Source: Compiled by the report authors using data from the IUCN Red List (2021).

Further research is recommended for half of the native aquatic flora, 241 species (50%). This research should focus on *population size, distribution & trends* (for 200 species, 41% or all species, or 83% of species for which research is recommended) and on *threats* (173 species or 36% of all species) (Figure 7.11).

Freshwater biodiversity in general tends to be underrepresented in biological surveys and species' distributions tend to be poorly known. Of the freshwater taxonomic groups considered, the aquatic plants are themselves poorly understood in many cases. This is reflected by the recommendation for research into the populations of half of the native aquatic plants of western Africa. The overall conservation status of the native aquatic flora as a whole paints a relatively optimistic picture as compared to some of the other freshwater taxonomic groups (Figure 7.2, see also Chapter 8). However, three endemic species have been declared Extinct Table 7.1 (Table 7.1, Section 7.2.4) and several of the Critically Endangered species are flagged as Possibly Extinct (Section 7.2.1). Urgent work is needed to relocate these species and to recognise their remaining localities through recognition as Tropical Important Plant Areas (TIPAs), such as in Guinea (Couch et al., 2019) and/or as KBAs. These sites should then be conserved either as formal protected areas or as other effective area-based conservation measures (OECMs).

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Chapter 8

Synthesis

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8.1 Introduction

In this chapter, we bring together the information from the previous taxonomic chapters (Chapters 3–7) and discuss the status and distribution of the western African freshwater biodiversity overall. We present a combined analysis of the freshwater fishes, molluscs, odonates, molluscs and selected aquatic plants native to the western Africa region, including their extinction risk (Red List status), species richness patterns and status trends through a Red List Index. We consider the major threats affecting these species, as well as the research and conservation actions that could help to improve their conservation status. The combined information presented here provides a representation of the status and distribution of the freshwater biodiversity of western Africa overall.

In total, we consider the 555 species of freshwater fishes, 100 species of freshwater molluscs, 307 species of odonates, 54 species of freshwater decapods and 486 species of aquatic plants, representing the majority, if not all, described species in these taxonomic groupings within the western Africa region.

8.2 Red List assessments

Of the freshwater taxonomic groups considered in this study (freshwater fishes, molluscs, odonates decapods and selected aquatic plants), 1,502 taxonomically described species were considered to be native to western Africa as defined in this study (see Chapter 1).

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Three species of aquatic plants have been assessed as Extinct (EX). This is the only taxonomic group with species assessed as Extinct. However, these numbers potentially underestimate the true number of species extinctions in the region. Many of the regionally endemic threatened and Data Deficient (DD) species have not been observed in many years, sometimes in decades. Surveys are urgently needed to determine whether the species remain extant. No species were assessed as Extinct in the Wild (EW).

Across all taxonomic groups, 202 species (13%) are assessed within the three threatened categories: Critically Endangered (CR) (50, 3%), Endangered (EN) (94, 6%) and Vulnerable (VU) (58, 4%) (Table 8.1, Figure 8.1). Some 82 species (5%) are assessed as DD. In order to estimate the true number and proportion of threatened species in each taxonomic group, we make three estimates;

- a) Assuming that all DD species are threatened with extinction
- b) Assuming that no DD species are threatened with extinction
- c) Assuming that the proportion of DD species threatened with extinction is equal to the proportion of non-DD species threatened with extinction.

Calculations a and b represent the upper and lower bounds for the number of threatened species, whereas calculation c represents the “best estimate”.

Considering the 82 (5%) DD species, the true number of threatened species native to the region is somewhere between 202 (13%) and 284 (19%), depending on whether none or all of the DD species are threatened. If the proportion of threatened species (13%) is the same for the 82 DD

Table 8.1 Number of freshwater species native to western Africa per Red List Category, by taxonomic group. Source: Compiled by the report authors using data from the IUCN Red List (2021).

Category	Fishes	Molluscs	Odonates	Decapods	Plants	All groups
EX	0	0	0	0	3	3
EW	0	0	0	0	0	0
CR	21	11	5	4	9	50
EN	66	9	7	7	5	94
VU	44	4	2	5	3	58
DD	36	8	10	13	15	82
NT	15	5	2	0	2	24
LC	373	63	281	25	449	1191
TOTAL	555	100	307	54	486	1502

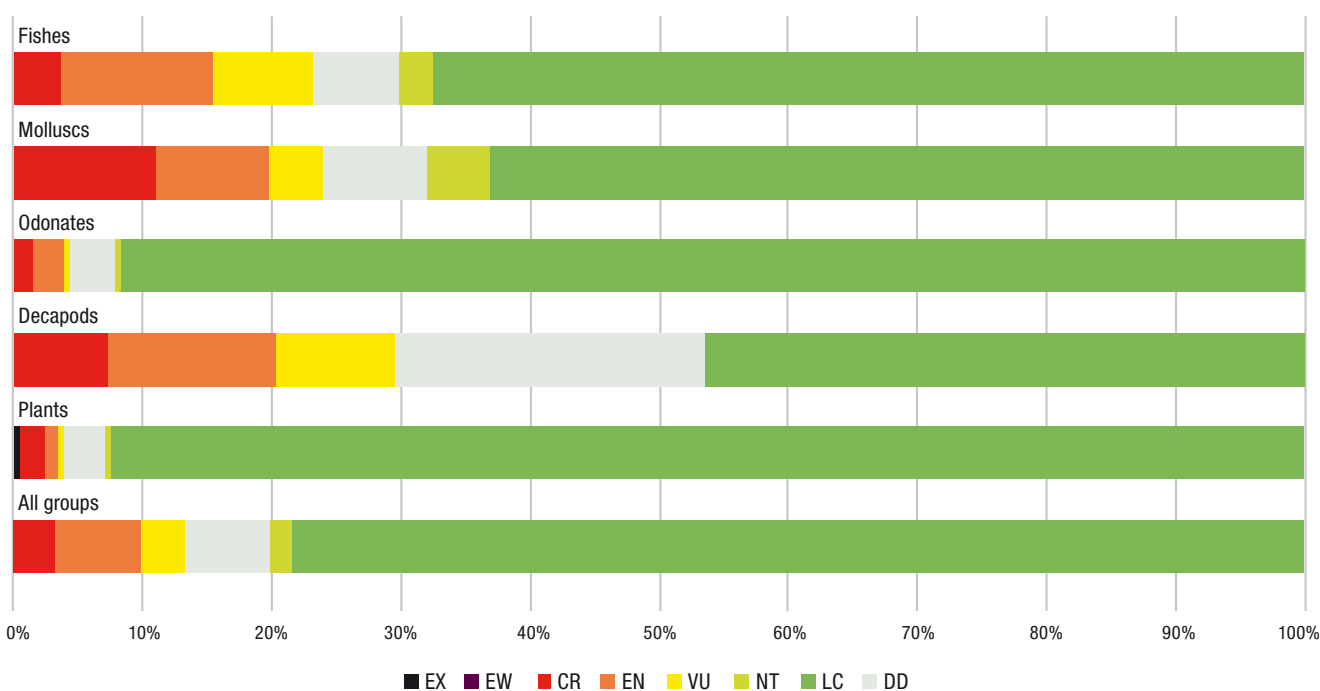


Figure 8.1 Percentage of freshwater species native to western Africa per Red List Category, by taxonomic group. Source: Compiled by the report authors using data from the IUCN Red List (2021).

species, then 11 DD species are likely to be threatened, bringing our best estimate for the number of threatened species to 213 (14%).

The majority of species native to the region are assessed as Least Concern, with 1,191 species (79%) placed in this category (Table 8.1, Figure 8.1), though there are some notable disparities between taxonomic groups, which are visible from Figure 8.1.

The fishes represent the largest freshwater taxonomic group of those considered, with some 555 native species. Of these, 131 species (24%) are globally threatened and a further 36 species (6%) are DD. The best estimate is therefore 140 globally threatened fish species (25%).

The freshwater molluscs are represented in western Africa by 100 species, of which 24 species (24%) are globally threatened and eight species (8%) are assessed as DD. The best estimate for the number of globally threatened species is 25 species (25%).

The odonates are represented by 307 native species. Of these, 14 species (5%) are assessed as globally threatened and a further 10 species (4%) are DD. The best estimate for the number of globally threatened odonate species is 15 species (5%).

The smallest taxonomic group assessed here is the freshwater decapods, represented by 54 species of freshwater crabs (26 species) and shrimps (28 species). Of these, 16 species (30%) are assessed as globally threatened and 13 species (24%) are DD. The best estimate for the

number of globally threatened decapods native to western Africa is 20 species (37%).

The aquatic plants are represented by 486 species. Of these, 17 species (3%) are assessed as globally threatened and a further 15 species are DD. The best estimate for the number of globally threatened plant species is therefore 18 species (4%).

8.3 Comparison against 2009 baseline

The previous assessment of western Africa’s freshwater biodiversity some 11 years ago (Smith et al., 2009) provides a baseline against which to compare the more recent assessments. Smith et al. (2009) assessed some 1,395 species of freshwater fishes, molluscs, odonates, decapods and selected aquatic plants using the Regional Red List categories and definitions. Of these species, 460 (33%) were considered endemic to western Africa, so that their regional Red List assessments were equivalent to global assessments representing the risk of global extinction for these species. They found that 14% of all native species were regionally threatened, but 34% of the regionally endemic species were regionally threatened, and hence globally threatened. Because we have here conducted global Red List assessments for all species native to the western Africa region, this does not provide a complete like-for-like comparison, but we are able to compare the past and present global assessments and to use these to calculate a Red List Index based on the available data for each taxonomic group (see Section 8.4). Previous global assessments were provided by Darwall et al. (2011).

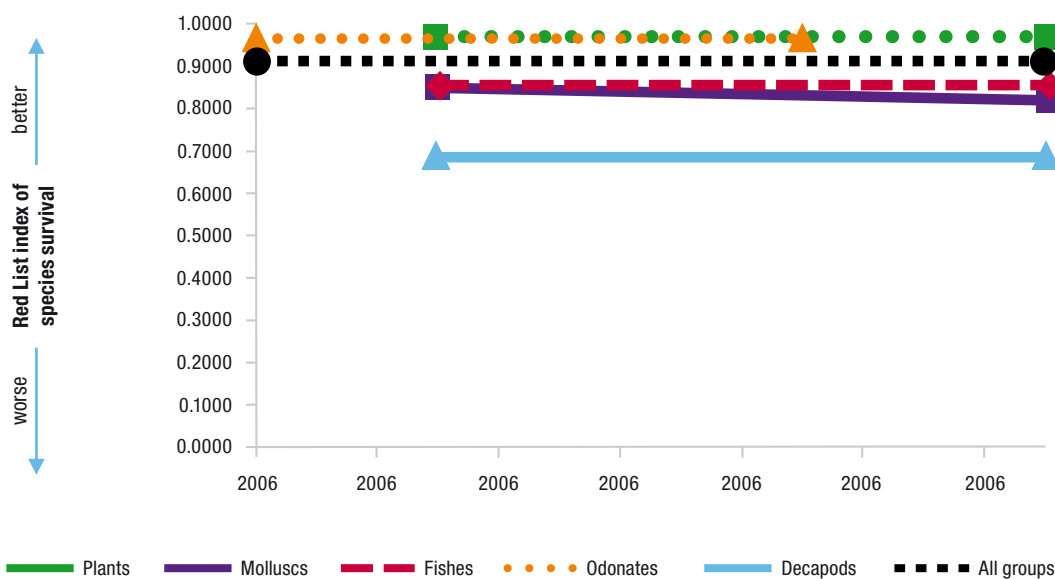


Figure 8.2 Red List Index for freshwater taxonomic groups in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

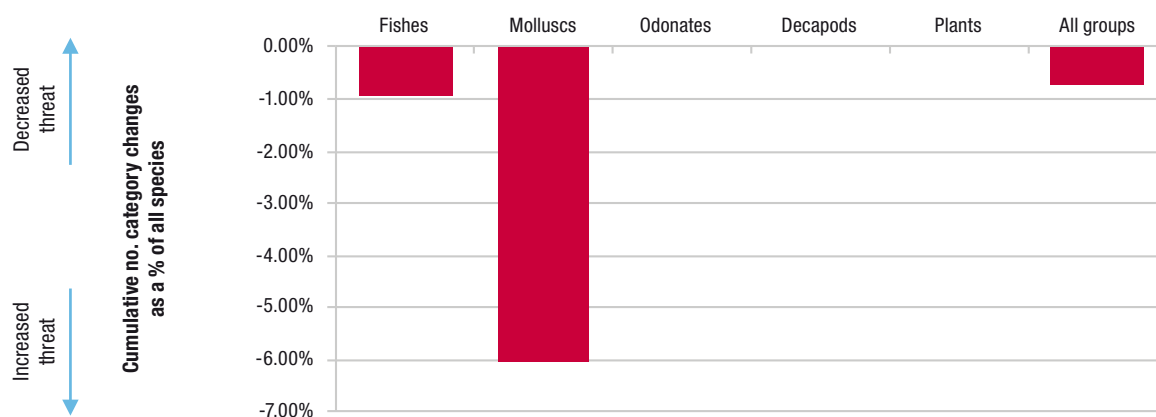


Figure 8.3 Cumulative proportion of species undergoing Red List category changes 2009–2019. Source: Compiled by the report authors using data from the IUCN Red List (2021).

8.4 Red List Index

The background and methods for calculating the Red List Index (RLI) are presented in Chapter 2.

The assessments presented in Darwall et al. (2011) were completed over a number of years (2003–2009) but all were reviewed in 2009. Therefore, 2009 was chosen as the previous time point for assessment. The new assessments presented here were completed in 2018–2019 and so 2019 was used as the second time point for the assessment. A number of species have been assessed at other times outside of these two periods. However, these assessments were not comprehensive for all species in the taxonomic group and so have not been included in the RLI calculations.

As described in Chapter 2, The RLI is calculated from the number of species in each Red List category and the number of species changing categories between assessments as a result of genuine improvement or deterioration in status (i.e. genuine changes). Changes in category resulting from improved knowledge or revised taxonomy (i.e. non-genuine changes) are excluded (Bubb et al., 2009).

8.4.1 Fishes

The Red List Index was calculated for 555 freshwater fish species between 2009 and 2019. During this time, five species (1%) experienced a genuine change (an increase) in their threat status (Figure 8.3). No species experienced a decrease in extinction threat. This caused a small decrease in the Red List Index of freshwater fishes from 0.8558 in 2009 to 0.8528 in 2019. The five species experiencing a genuine change in conservation status are listed below.

Arnoldichthys spilopterus (EN) has changed from VU to EN as result of increasing loss of habitat and quality due to oil exploration, urban development and deforestation within its range.

Brycinus caroliniae (EN) has been uplisted from VU to EN. Urbanisation is advancing quickly in this region and this has resulted in a reduction in the distribution area of this species.

Bryconaethiops quinquesquamae (EN) has been uplisted from LC to EN. It is mainly threatened in Nigeria by oil exploitation and pollution and potentially by dredging on the Cross River, which are leading to a continuing decline in habitat.

Micralestes eburneensis (EN) has an increasingly restricted range, and there are recent reports of threats from habitat loss and decline in quality across its range caused by ongoing gold mining activities in and around the Cavally River, and increasing fishing pressure from artisanal fisheries (Doffou et al., 2018). This species is therefore reassessed as EN from Near Threatened (NT).

Tetraodon pustulatus (EN) has been uplisted from VU to EN. Increasing human populations, oil exploration and urban and industrial development in the lower Cross River are threatening the habitat extent and quality of this species, and threats from deforestation and subsequent loss of habitat quality are predicted to occur in the upper Cross River in the near future.

Some 146 species had nongenuine changes in their conservation status since their previous 2009 assessments, including nine species being moved from non-threatened categories (LC or NT) into threatened categories, and an additional 15 species moved from DD into threatened categories. Conversely, 32 species were moved from threatened categories into non-threatened categories, and an additional 15 species moved from DD into non-threatened categories, reflecting new information on the ranges of these species. These nongenuine changes reflect new knowledge on existing threats rather than new or emerging threats since the previous assessment.

8.4.2 Molluscs

The Red List Index was calculated for 100 species of freshwater molluscs for which data were available between 2006 and 2019. Twelve species only had a single Red List assessment in 2019 and were therefore not included in the RLI. Of the remaining species with two assessments, six species (6%) underwent a genuine change in their conservation status. All six species moved into a higher threat category. This manifested as a decrease in the RLI from 0.8440 in 2006 to 0.8154 in 2019. This six species with a genuine change in conservation status are listed below.

Afropomus balanoidea (EN) was uplisted from NT to EN. Explosive human population growth and subsequent conversion of lowland swamps to rice fields and use of molluscicides for Bilharziosis control is suspected to have caused a 50% decline in the population of this species over the last 10 years, while a further 50% decline in population is suspected as these threats continue to intensify.

Mutela franci (EN) was moved from VU to EN. The area of occupancy and extent of occurrence of this species has continued to decline since the last assessment as VU in 2009. This is due to the increasing drought caused by climate change and water abstraction/damming upstream. The species' habitat quality and area have been decreasing, and can be inferred to decrease further over the next decade. For these reasons, the species is presently assessed as EN (EN) based on a predicted population decline of at least 50% over the next 10 years (2019–2029).

Potadoma bicarinata (CR) was uplisted from LC to CR. The habitat quality in the aquatic environments in the Oti River and Volta Basin for this restricted habitat specialist has changed drastically since the original assessment in 2006, and it is considered likely to meet the population decline thresholds for CR in the next 10 years, if not already extinct.

Potadoma freethi (NT) was moved from LC to NT. The rate of population decline for this species is suspected to be increasing as the threats of siltation, water abstraction and droughts intensify throughout its wide range, so the species is assessed as NT, reflecting a change from Least Concern in 2006.

Pseudocleopatra togoensis (CR) was moved from LC to CR. The locality Moheyenga, 'possibly on the Obi River' fide (Brown, 1994) could not be traced and has been omitted. The other localities either have been inundated by Lake Volta or are on river stretches that presently are polluted. It is assumed that the species has become locally extirpated in these areas and it has only been recently recorded from a single locality downstream the Akosombo Dam. Considering the highly limited EOO, AOO, number of localities and

the trend of increasing nutrient enrichment in the Lower Volta, which greatly reduced the EOO, the species is now considered CR, a change from Least Concern, which was based on an assumed previously larger range.

Sierraia expansilabrum (EN) was uplisted from VU to EN. The former assessment was based on data mainly of the pre-civil war situation in Sierra Leone. Since the conflict ended, the demographic, industrial (mining, logging,) and agricultural developments have significantly increased and this trend can be expected to continue in the next decade. The lack of efforts to counter the negative effects to the ecosystems, in particular the surface waters, is leading to a situation in which the drainage systems where many of the sensitive, rare aquatic species occur are becoming rapidly degraded.

8.4.3 Odonates

Of the 307 species of odonate considered here to be native to western Africa, some 204 species had two assessments in 2006 and 2015 on which to calculate the RLI. A further 21 species were assessed in 2016 (2015–2018) (18 LC and 3 DD) and these assessments were back-cast and included in the RLI, bringing the total species included in the RLI to 225.

Some 82 species have not been reassessed since their first global assessment in 2009 (34 LC and 2 DD) and these species were therefore not included in the RLI. There have been no genuine status changes in the odonates between 2009 and 2016, and the overall threat level for species in this taxonomic group is relatively low, resulting in a static RLI of 0.9699.

8.4.4 Decapods

The Red List Index was calculated for the 22 species of crabs between 2009 and 2019. The 28 species of freshwater shrimps native to western Africa have only undergone one global Red List assessment (of which 25 were assessed in 2013), so it was not possible to calculate a Red List Index for this group, which includes four threatened species and nine DD species.

There have been no genuine status changes to the freshwater crab species since 2009 and hence the Red List Index has remained stable at 0.67. However, several species have not been observed at all during this time and in reality, the stability of the Red List Index reflects a lack on new information on the status and distribution of these species, rather than a genuinely stable conservation status.

The Lobster Claw Crab *Liberonautes rubigimanus* (VU) has been downlisted from EN to VU due to new records showing the species to be more widespread than previously

thought. Conversely, Sachs' stream crab *Potamonemus sachsii* has been uplisted from VU to EN due to a reduction in the estimated Area of Occupancy and the number of threat based locations. These are non-genuine changes and hence do not affect the Red List Index for crabs. One additional species of freshwater crab, *Potamonautes lipkei*, was described in 2010 (Đuriš & Koch, 2010), and assessed as DD.

8.4.5 Plants

The Red List Index was calculated for 178 species of aquatic plants for which data were available between 2009 and 2019. Of these, no species underwent a genuine change in conservation status. This is reflected as a stable RLI of 0.9747 in 2009 and in 2019. Some 29 species underwent a nongenuine change in conservation status, primarily owing to new information becoming available on these species.

8.4.6 Discussion

The overall RLI for all freshwater biodiversity decreased from 0.9152 in 2009 to 0.9122 in 2019 (Figure 8.2). The RLI shows an increase in extinction risk for 1% for freshwater fishes (Section 8.4.1) and 6% of freshwater molluscs (Section 8.4.2), but no change was detected for the other taxonomic groups. This is despite clear evidence pointing to increased environmental degradation and human pressure in the region during the previous 10 years (see Chapter 1). For the decapods, only the 22 species of freshwater crabs had two assessments upon which to base an RLI, and for many of these species there were no new surveys since the previous assessment in 2009 (with some notable exceptions, see Chapter 6).

It is vital that conservation actions are implemented to halt and reverse the declines to freshwater biodiversity where possible and conservation actions are recommended for each taxonomic group in Chapters 3–7 and for freshwater biodiversity more generally in this chapter (Section 8.7). However, without monitoring systems in place to track changes to species' conservation status in response to emerging threats, it is difficult to prioritise conservation efforts and to track the impact and effectiveness of conservation interventions.

RLIs and the trends they depict are only as good as their data inputs. Red List assessments are considered scientifically robust because they follow a standardised method, are based on quantitative criteria, and use the best scientific data available. Red List assessments also undergo a thorough review process before publication. However, Red List assessments may be revised, for example as knowledge of species and their habitats increases, resulting in changes to the Red List categories assigned.

Additionally, the Red List categories are broad in nature with wide thresholds for moving between categories and, as a result, RLIs should be considered only a coarse measure of changes in the status of biodiversity over time. It should also be recognised that time lags often occur between changes in the real-life situation of a species, detection of these change, and incorporation of these changes into Red List assessments (Bubb et al., 2009). Finally, in the absence of regular monitoring, changes in threats to species are often hard to detect and their impacts hard to quantify over the periods used here to calculate RLIs.

We currently lack basic information on the distribution and population for most of the taxonomic groups considered here. Standardised regional surveys have not been conducted for many years, if at all, and there are no significant long-term programmes for monitoring the state of freshwater biodiversity throughout the region. There is much evidence for declines in water quality and loss of natural habitats through conversion to other land uses, but there are few data available to determine the impact of these environmental changes on the freshwater species themselves. Consequently, many of the Red List assessments are based on inferred declines in species populations or distributions, rather than robust scientific monitoring data. This lack of monitoring means that real time changes in the status of freshwater biodiversity are not being detected.

There is an urgent need, therefore, to instigate surveys of freshwater biodiversity in the region, combined with the establishment of long-term monitoring stations. Such surveys and monitoring programmes must be able to identify species accurately if we are to have sufficient information to manage and conserve the globally unique freshwater biodiversity in the region. It is also important to make the findings of all surveys which are conducted, often as environmental impact assessments, freely available as input to studies such as this one. The results of these surveys can be used to better inform Red List assessments, which can in turn be used to help track trends in the status of freshwater biodiversity in the western Africa region through use of tools such as the RLI.

8.5 Patterns of species richness

Patterns of species richness discussed in this section consider only the mapped (polygon) extant native ranges of assessed species where they are available. Species with only point localities and no mapped ranges were not included in the species richness maps, neither were parts of species ranges mapped as Possibly Extant, Possibly Extinct or Extinct.

8.5.1 Overall species richness

Species ranges from all taxonomic groups are combined in Figure 8.4 Figure 8.1 to highlight areas containing the highest numbers of freshwater species overall. Species richness maps for each of the five taxonomic groups (freshwater fishes, freshwater molluscs, odonates, freshwater decapods and aquatic plants) are presented in Chapters 3–7.

Freshwater species richness is highest in the coastal areas including the Niger Delta, the Bight Drainages, the coastal basins of the Upper Guinea ecoregions (Sierra Leone and Liberia), the lower sections of the Volta (Ghana), the entire Ashanti ecoregion (Ghana) and lower Eburneo (Côte d'Ivoire) with up to 387 species per subcatchment (Figure 8.4). Species richness generally declines towards the north, approaching the Dry Sahel ecoregion, with the notable exception of the Upper Niger and the Inner Niger Delta (Mali). Relatively high overall species richness can be found in the Gambia drainage (Gambia and Senegal) in the west and Lake Chad (Chad, Cameroon, Nigeria, Niger) in the east.

8.5.2 Threatened species richness

All known ranges for globally threatened freshwater species are mapped in Figure 8.5. Areas emerging as centres of threatened freshwater species richness include the Niger Delta (Nigeria), the upper Cavally/Cavalla River and Mount Nimba (Liberia, Guinea, Cote d'Ivoire), Fouta Djallon and Northern Upper Guinea (Guinea and Sierra Leone). Other areas with threatened freshwater biodiversity include Lake Chad, the Inner Niger Delta and several coastal drainages between Liberia and Nigeria. Many of these areas are also identified as potential Key Biodiversity Areas for freshwater species in Chapter 9.

8.5.3 Endemic species richness

Species with global ranges restricted to the western Africa region were mapped in Figure 8.6. Upper Guinea and the Niger Delta emerge as centres of endemic species richness, with up to 53 regionally endemic species per sub-catchment. Other areas of endemic richness include the Lower Niger, Upper Niger and Inner Niger Delta, the Ogun River (Nigeria) and Ouémé River (Benin) in the Bight Drainages, the lower Sassandra, Bandama and Komoé Rivers in Côte d'Ivoire and the Senegal and Gambia Rivers in the west.

8.5.4 Data Deficient species richness

Areas emerging as centres of DD species richness include the Lower Niger River, the Volta and the Inner Niger Delta (Figure 8.7).

Maps of DD species should be viewed with some caution as, by definition, they represent the known ranges of species about which we know relatively little and their mapped distributions are therefore putative. A number of DD species, for which we have no data on their distribution ranges, could not be mapped so are not represented here. This can therefore be viewed as a map of 'known unknowns', and may be useful to target future surveys, particularly to gather information on DD species.

8.6 Major threats

With a high population growth rate, western Africa is experiencing a regionally unprecedented increase in threats to biodiversity, including its freshwater biodiversity. By compiling threats identified by Red List assessors across taxonomic groups, we highlight some of the major threats faced by freshwater biodiversity in the region overall.

It should be noted that the threats listed on the global Red List assessments refer to species' global populations and are therefore not necessarily restricted to, or present within, the western Africa region. This makes it difficult to be spatially explicit about threats affecting species, unless locations are specified in the text accounts accompanying the Red List assessments or if the species is range restricted. However, the threats presented here are broadly representative of the threats known to be occurring within the region, and we refer to certain specific threat locations where these are well documented.

The major threats affecting freshwater species overall are ranked in Figure 8.8. Threats are listed by number of species affected, with breakdowns provided for each taxonomic group. This is not an exhaustive representation of threats facing freshwater species, but highlights the key threats frequently identified by Red List assessors. More details on the specific impacts of these threats to freshwater species are presented in Chapters 3–7.

8.6.1 Pollution

Pollution represents the highest threat to freshwater biodiversity in western Africa, alongside biological resource use. Three main pollution-related threats are commonly identified for freshwater species.

- *Agricultural & forestry effluents* are identified as a threat to some 208 freshwater species, including 139 fish species, 28 plant species and 28 species of mollusc.
- *Domestic & urban waste water* is a documented threat to 182 species, including 73 species of freshwater fishes,

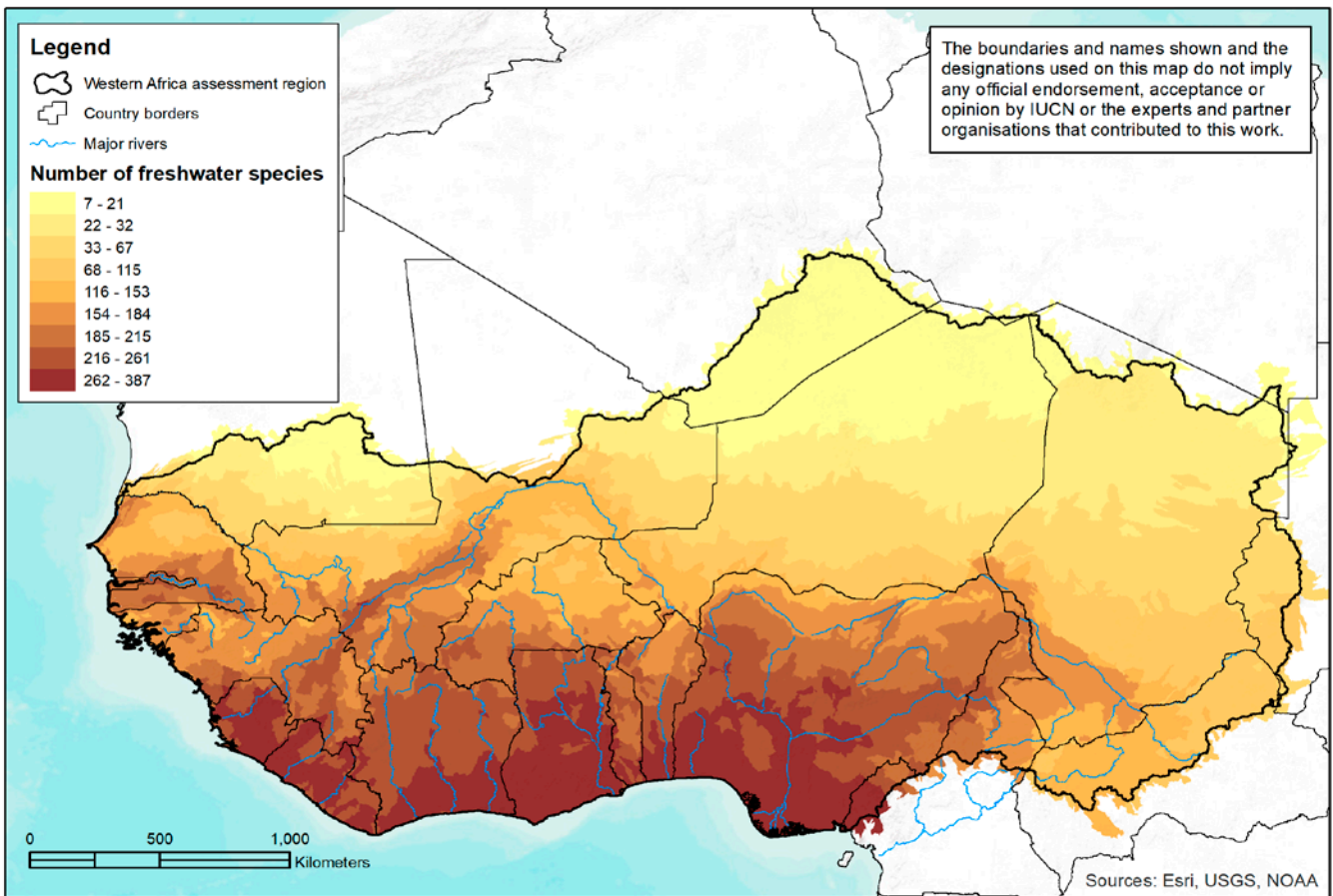


Figure 8.4 Freshwater species richness in the western Africa region. Source: Compiled by the report authors using data from the IUCN Red List (2021).

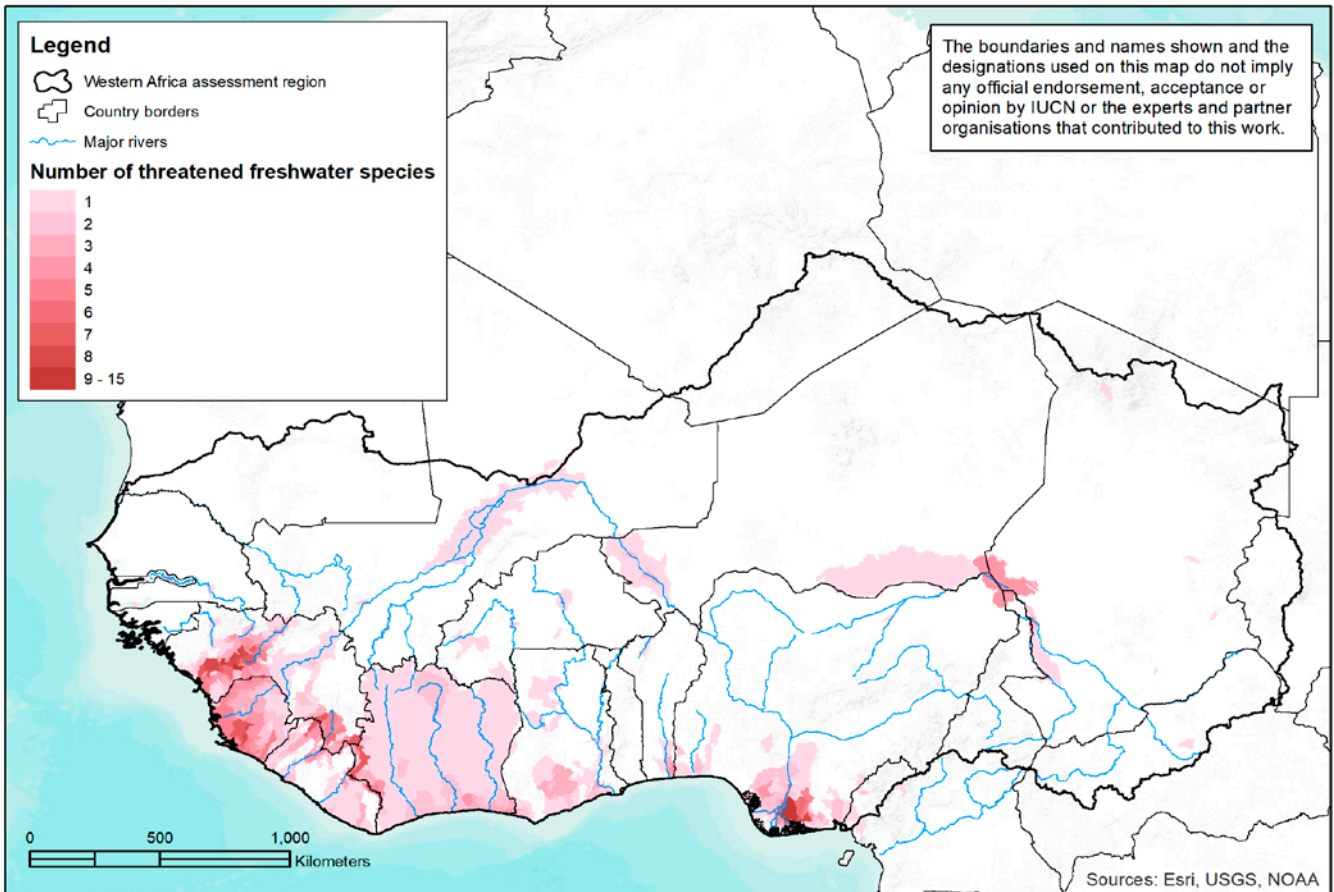


Figure 8.5 Freshwater threatened species richness in the western Africa region. Source: Compiled by the report authors using data from the IUCN Red List (2021).

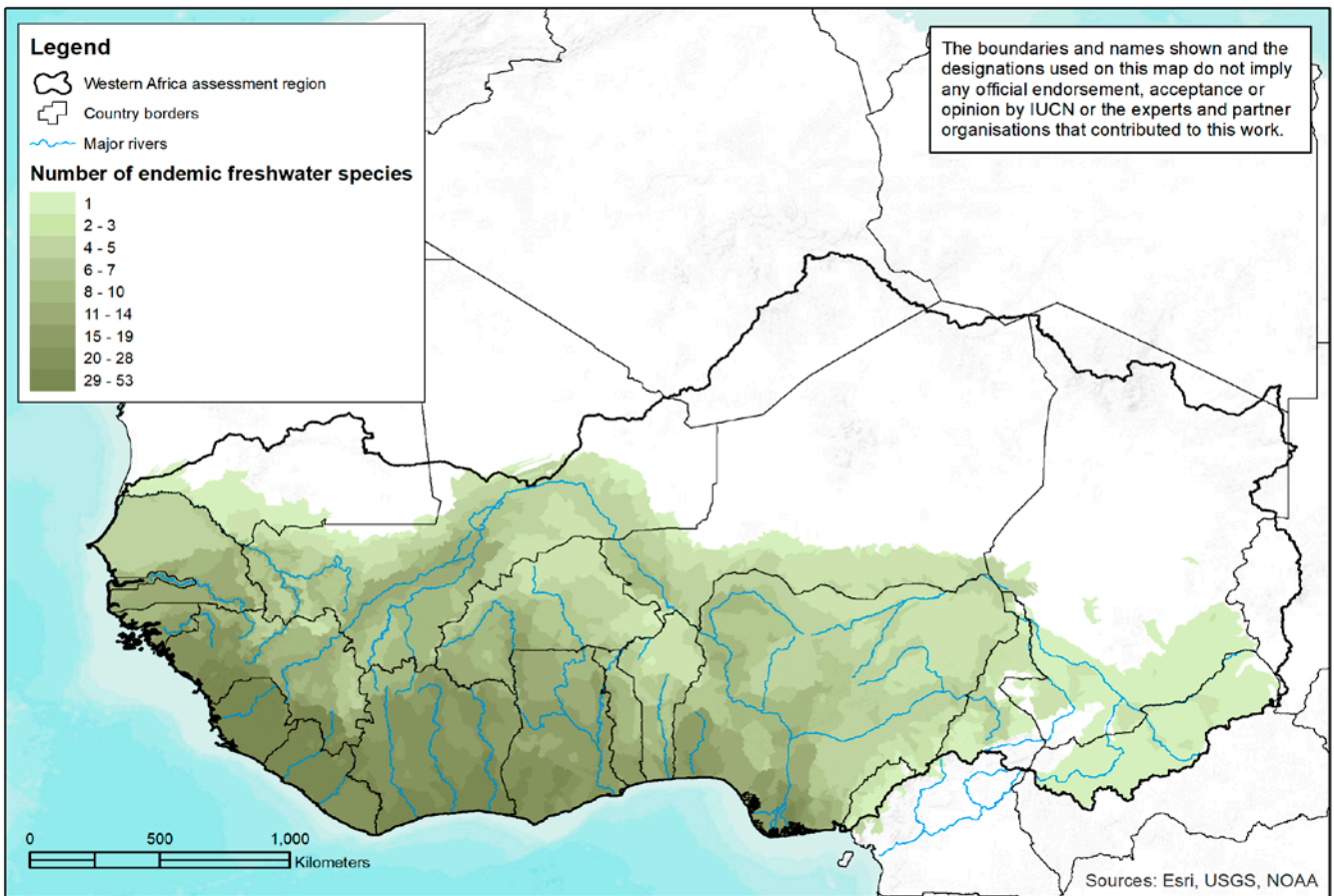


Figure 8.6 Regionally endemic freshwater species richness in the western Africa region. Source: Compiled by the report authors using data from the IUCN Red List (2021).

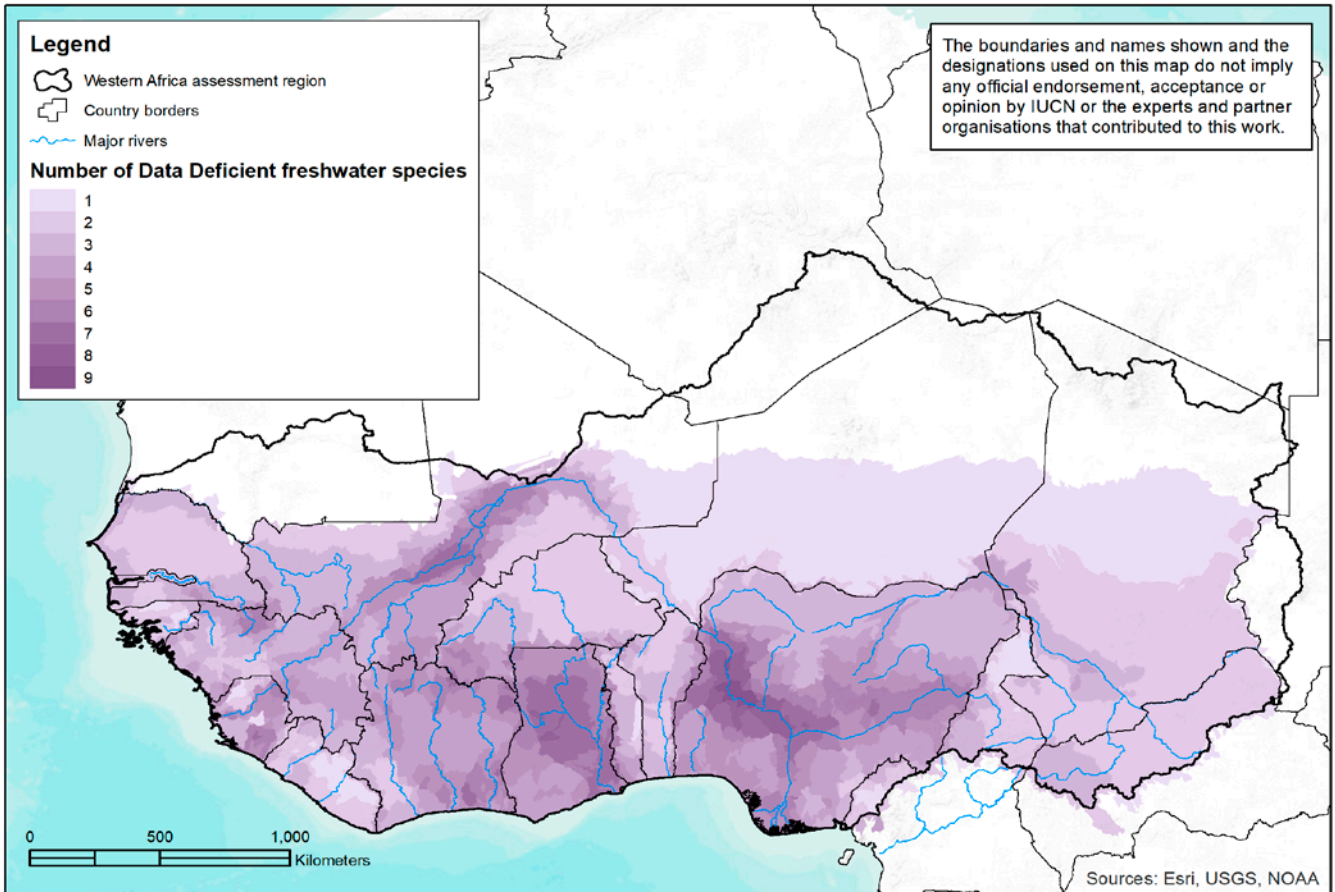


Figure 8.7 Freshwater Data Deficient species richness in the western Africa region. Source: Compiled by the report authors using data from the IUCN Red List (2021).

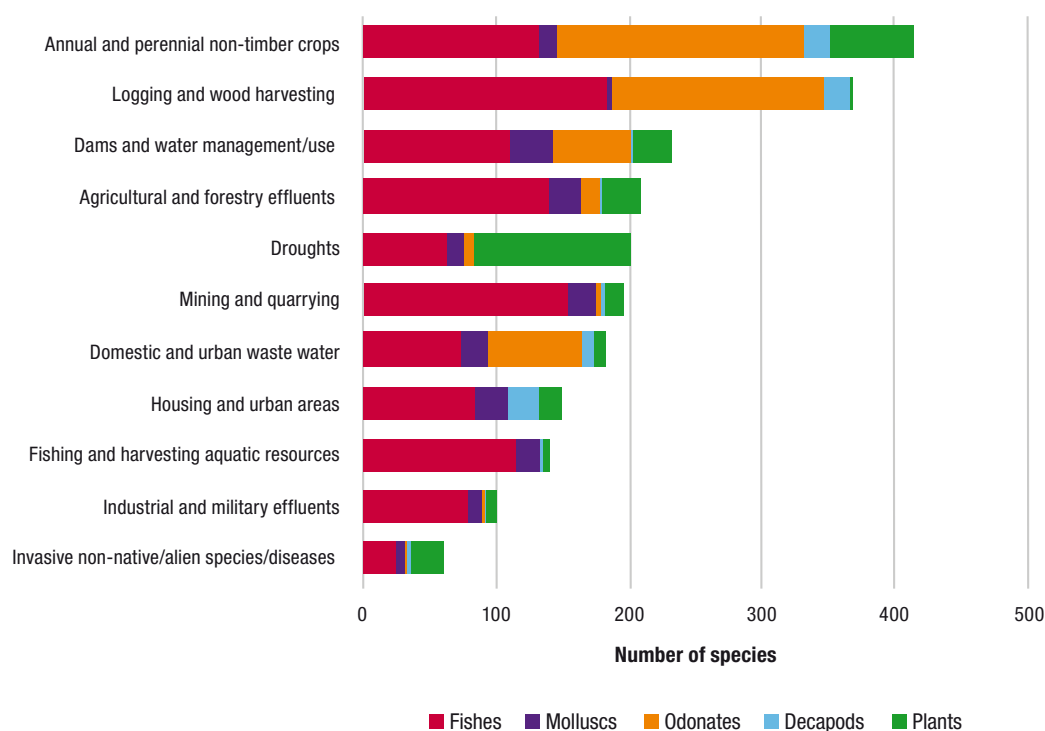


Figure 8.8 Major threats to freshwater biodiversity in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

71 species of odonates and 21 species of freshwater molluscs.

- *Industrial & military effluents* are a threat to 101 freshwater species, including 79 species of freshwater fishes and 10 freshwater mollusc species.

Water pollution presents a particularly pervasive threat to freshwater organisms, as threats are readily transported downstream, throughout lakes and into wider aquatic environment. Water pollution from agricultural fertilisers, heavy metals from mining and untreated waste water are prevalent in the region (Pare & Bonzi-Coulibaly, 2013). Artisanal, small-scale gold mining is a major source of pollution in Senegal-Gambia, Ghana and Nigeria (Global Alliance on Health and Pollution, 2021).

The Niger Delta is one of the most important wetland ecosystems in western Africa and yet it is also one of the most polluted ecosystems in the world (Kadafa, 2012). The IUCN Niger Delta Panel makes specific recommendations for bioremediation procedures in the Niger Delta (IUCN Niger-Delta Panel, 2013; Martin-Mehers, 2018). Recommendations included emphasising oil spill prevention, improving emergency response procedures and developing remediation standards. Lessons learned here can be applied in other parts of the region.

8.6.2 Biological resource use

Biological resource use, alongside to pollution, represents the most commonly identified threat to the freshwater species in this study. The two major threats in this grouping are logging & wood harvesting, and fishing & harvesting of aquatic resources.

- *Logging & wood harvesting* is documented as a threat to 368 species including 183 species of freshwater fishes, 159 species of odonates and 20 freshwater decapod species.
- *Fishing & harvesting of aquatic resources* threatens 140 species, primarily 115 species of freshwater fishes but also 18 freshwater mollusc species and 5 species of aquatic plants.

8.6.3 Agriculture and aquaculture

Annual & perennial non-timber crops affects 413 freshwater species, making it the single most commonly identified threat by Red List assessors. This threat impacts 185 species of odonates, 132 species of fishes and 62 species of plants, as well as 10 species of decapods and 14 species of molluscs. Other threats in this category include *livestock farming* (20 species), *freshwater aquaculture* (14 species) and *wood & pulp plantations* (9 species).

Land use change, driven by urban development combined with agriculture, logging and mining, leads to habitat loss and degradation. The freshwater ecoregions of western Africa have experienced some of the highest levels of land conversion globally, particularly in the Upper Guinean Forest, Upper Niger and Eburneo ecoregions. The Ashanti ecoregion has experienced upwards of 80% land conversion.

8.6.4 Natural systems modifications

Dams & water management/use, affects some 232 freshwater species. Dams pose a threat to 111 species of fishes, 59 species of odonates, 29 species of plants, 31 species of molluscs and 2 species of decapods according to Red List assessments. Dams such as the Manantali on the Bafing River in Mali, the Akosombo Main Dam on the Volta River in Ghana and the Mount Coffee Dam on the St Paul River in Liberia have large impacts on freshwater systems. Dams alter the hydrology of freshwater systems, present barriers to river system connectivity and, if not managed sensitively, can lead to reduced flows and droughts downstream. The large artificial reservoirs that the dams create replace freshwater habitats.

There are already over 150 dams in the region and another 91 planned or under construction, on every major river, according to the Future Hydropower Reservoirs and Dams (FHReD) dataset (Zarfl et al., 2015). Many of these future dams are within areas of high threatened species richness and 16 of them are within existing protected areas. The 128 MW Sambagalou hydroelectric dam on the Gambia River in Guinea has recently been approved. Baseline ecological data and a preliminary monitoring plan were established in 2009 (Ndiaye et al., 2009).

8.6.5 Climate change and severe weather

Droughts are identified as a threat to 201 freshwater species. Naturally, aquatic plants are particularly susceptible to drought, and drought is listed as a threat to 118 aquatic plant species. Some 63 species of fishes are also identified as being threatened by droughts. Temperature extremes are also identified as a threat to 27 freshwater species.

Western Africa is particularly vulnerable to climate change due to high climate variability and high reliance on rain-fed agriculture. An increase on extreme droughts is predicted for



Figure 8.9 An old iron mine at Blue Lake, Nimba County in Liberia, abandoned since the First Liberian Civil War in the late 1980s.
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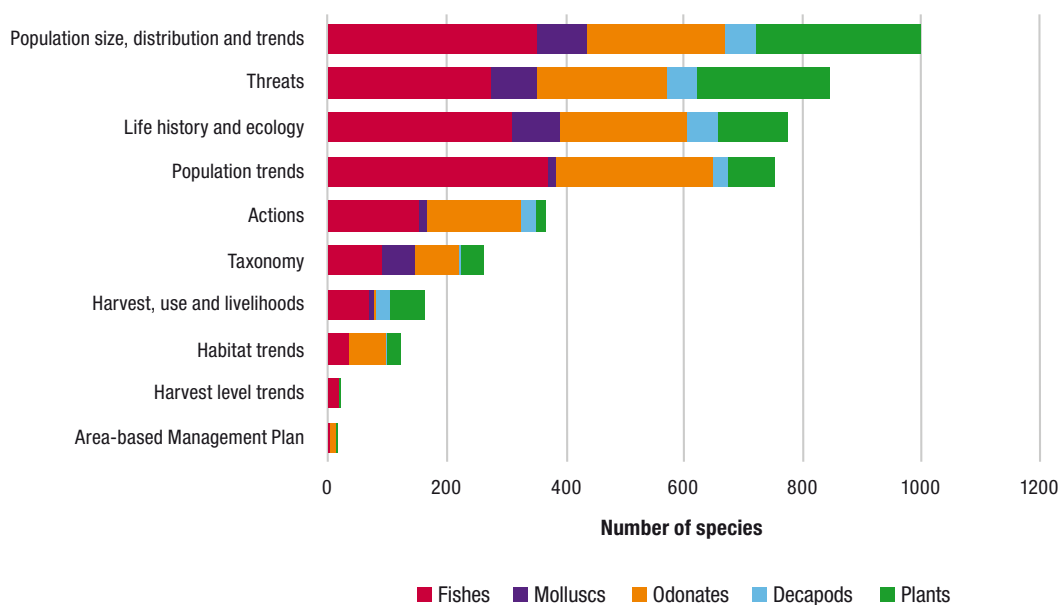


Figure 8.10 Recommended research priorities for freshwater biodiversity in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

coastal part of Liberia and Cameroon, Côte d'Ivoire, Nigeria and Cameroon (Quenum et al., 2019).

8.6.6 Energy production and mining

Mining & quarrying affects some 196 species, of which 154 are species of freshwater fishes. Sand mining, for example, poses a threat to inland freshwater ecosystems via habitat disturbance, alteration to riparian zones and changes to downstream sediment transport (Koehnken et al., 2020). Sand is the second most consumed natural resource after water (West Africa Coastal Areas Management Program, 2018), and sand mining is specifically listed as a threat to the Butterfish *Irvineia voltae* (EN) and Toothed carp *Epiplatys chaperi* (NT) in southwest Ghana, where sand mining is prolific (Jonah & Adu-Boahen, 2016). A factsheet on sand mining produced by the West Africa Coastal Areas Management Program of the World Bank Group (West Africa Coastal Areas Management Program, 2018) suggests that Benin has moved sand mining activities from coastal areas to inland lakes and rivers, perceiving the latter to carry fewer risks. Limited evidence suggests that rivers can sustain extraction if volumes are within the natural sediment load variability, but further research is needed (Koehnken et al., 2020). *Oil & gas drilling* also directly affects at least 21 species of freshwater fishes, according to species assessments.

8.6.7 Residential and commercial development

Housing & urban areas is listed as a threat to 149 species including 84 species of freshwater fishes, 25 species of molluscs, 17 species of plants, 16 species of decapods and

7 species of odonates. Other threats include commercial & industrial areas (26 species) and tourism & recreation areas (6 species). Western Africa has the second highest regional population in Africa with over 400 million inhabitants or 5% of the global population and it has the world's fastest growing population at c. 2.75% growth per year (United Nations, Department of Economic and Social Affairs & Population Division, 2019). Nigeria has by far the largest population in the region with over 200 million inhabitants and one of Africa's three 'megacities' Lagos in Nigeria. Lagos has close to 20 million inhabitants and its population is expected to continue growing at a rate of 3.5% or more per year (United Nations, Department of Economic and Social Affairs & Population Division, 2019). This is reflected in a wider pattern of urbanisation across the region, which will drive further land conversion for urban expansion.

8.6.8 Invasive non-native species

Invasive non-native species (INNS) are identified as a threat in 61 species assessments. The two taxonomic groups most commonly associated with this threat are the fishes and the aquatic plants, each with 25 species. In particular, water hyacinth is explicitly identified as a threat to several native species, such as the freshwater mollusc *Biomphalaria tchadiensis* (EN) in Lake Chad and the freshwater shrimp *Euryrhynchina edingtonae* (EN) in the Niger Delta. Because river systems cross many international boundaries in western Africa, this makes the invasive weed all the more difficult to control. Efforts to control the species in Ghana in the 1990s was hampered by influx from neighbouring Togo and Burkina Faso, which did not have similar programmes in place. In

addition to being a threat to aquatic wildlife, the large mats of water hyacinth, which form on rivers and lakes, also hamper fishers by blocking navigable channels.

8.7 Recommended research and conservation actions

Recommended research and conservation actions are identified as part of the Red List assessment process. Here we summarise the most frequently recommended research and conservation actions for freshwater species, as identified by Red List assessors, including a breakdown by taxonomic group.

Research is recommended on the *population size, distribution & trends* of 998 species, or 66% of species assessed (Figure 8.10). Other frequently recommended research areas include *threats* (843 species, 56%), *life history & ecology* (773 species, 51%) and *population trends* (752 species, 50%). *Taxonomic research* is far from complete, with 261 species (17%) requiring further study.

Most of these research recommendations can be addressed through field surveys to gather more information about species populations, threats and ecology. A focus for future survey and monitoring should be the sub-catchments with high numbers of DD species (Figure 8.7) and those with high numbers of threatened species highlighted (Figure 8.5).

The conservation actions recommended by Red List assessors broadly reflect those laid out in the Emergency Recovery Plan for freshwater biodiversity (Tickner et al., 2020). The most frequently recommended conservation action for freshwater biodiversity is site/area management, recommended for 734 species or 49% of species (Figure 8.11). By contrast, site/area protection is recommended for 177 species (8%) and resource & habitat protection for 171 species (11%). This suggests that sites need not necessarily be formally protected, so long as they are effectively managed for freshwater species conservation. This highlights the need to identify Key Biodiversity Areas (KBAs) for freshwater species. KBAs do not prescribe protected area designation, but represent potentially manageable areas of global importance for the persistence of biodiversity (IUCN, 2016) (Chapter 9). Further to this, a critical sites network for freshwater biodiversity is presented in Chapter 10.

Habitat & natural process restoration is the second most frequently cited area of conservation action required for freshwater species (Figure 8.11). Targeting freshwater systems as we enter the UN Decade on Ecosystem Restoration will have tangible benefits not only for western Africa's freshwater biodiversity, but for water security and myriad other ecosystem services. This will be of critical importance over the next decade as the region develops economically.

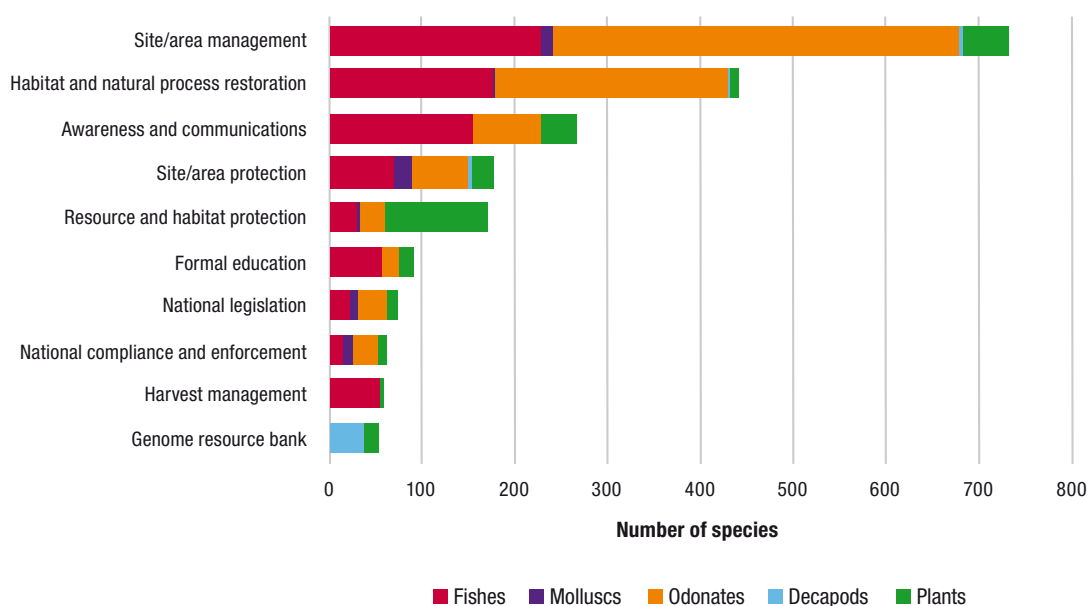


Figure 8.11 Conservation priority actions for freshwater biodiversity in western Africa. Source: Compiled by the report authors using data from the IUCN Red List (2021).

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Chapter 9

Key Biodiversity Areas

Starnes, T. ¹ Spiliopoulou, K. ^{2,3}

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9.1 Background

Over the last four decades, a number of organisations have invested in compiling information on the location of sites that are significant for biodiversity. Since the late 1970s, BirdLife International has developed criteria for the identification of Important Bird Areas (IBAs) and over 13,000 sites have been identified worldwide (BirdLife International, 2021). Building on this approach, other methodologies have been developed (for example, Important Plant Areas (IPAs), Alliance for Zero Extinction (AZE) sites and Prime Butterfly Areas, for multiple taxonomic groups in freshwater, terrestrial and marine environments. These approaches generally focus on one group of species or one biome, and use diverse assessment criteria, which has led to some confusion amongst decision-makers, as well as duplication of conservation efforts (Dudley et al., 2014).

As a consequence, during the World Conservation Congress held in Bangkok Thailand in 2004, IUCN members requested for IUCN “to convene a worldwide consultative process to agree a methodology to enable countries to identify Key Biodiversity Areas” (International Union for Conservation of Nature (IUCN), 2004). In response to this resolution (WCC 3.013), the IUCN Species Survival Commission (SSC) and the IUCN World Commission on Protected Areas (WCPA) established a Joint Task Force on Biodiversity and Protected Areas, which since 2012 has mobilised expert input from IUCN commissions, members, secretariat staff, conservation organisations, academics, decision-makers, donors and the private sector to consolidate globally-agreed scientific criteria and harmonise work for identifying KBAs. All these efforts have culminated in *A Global Standard for the Identification of KBAs* (IUCN, 2016), which can be applied robustly across taxonomic groups and all elements of biodiversity.

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KBAs are sites contributing significantly to the global persistence of biodiversity (IUCN, 2016). This does not imply that a specific site-based conservation action, such as protected area (PA) designation, is required. Such management decisions should be based on conservation priority-setting exercises, which combine data on biodiversity importance with the available information on site vulnerability and the management actions needed to safeguard the biodiversity for which the site is important. It is often desirable to incorporate other data into priority setting, such as conservation cost, opportunity for action, importance for conserving evolutionary history and connectivity. KBAs thus do not necessarily equate to conservation priorities but are invaluable for informing systematic conservation planning and priority setting, recognising that conservation priority actions may also be outside of KBAs (IUCN, 2016).

Data generated through application of the KBA standard are expected to have multiple uses (Dudley et al., 2014). KBAs can support the strategic expansion of PA networks by governments and civil society working towards the achievement of the Aichi Biodiversity Targets (in particular Targets 11 and 12), as established by the Convention on Biological Diversity (Butchart et al., 2012) (and successor targets in the post-2020 Global Biodiversity Framework). They serve to inform the description or identification of sites under international conventions (such as Wetlands of International Importance designated under the Ramsar Convention, natural World Heritage Sites, and Ecologically and Biologically Significant Areas (EBSAs) as described under the CBD). They contribute to development of other

effective area-based conservation measures (Jonas et al., 2014). They inform private sector safeguard policies, environmental standards and certification schemes. KBAs support conservation planning and priority setting at national and regional levels and provide local and indigenous communities with opportunities for employment, recognition, economic investment and societal mobilisation (IUCN, 2016).

9.2 Methodology

The methodology for identification and delineation of global freshwater KBAs in western Africa followed the new Global Standard for identification of Key Biodiversity Areas (IUCN, 2016). Here we briefly describe the KBA criteria and thresholds (section 9.2.1), and then go on to describe how these were applied to validate the CEPF freshwater KBAs in western Africa (section 9.2.2), first through desktop analysis (section 9.2.2.1) and then followed by stakeholder consultation workshops (section 9.2.2.2).

9.2.1 KBA criteria and thresholds

The criteria set out in the Global KBA Standard (IUCN, 2016) provide quantitative thresholds for identifying sites that contribute significantly to the global persistence of biodiversity (Table 9.1). The high level criteria are designed to capture sites of importance for: A) threatened biodiversity; B) geographically restricted biodiversity; C) ecological integrity; D) biological processes; and E) irreplaceability through quantitative analysis. Sites identified as potential KBAs should ideally be assessed against all criteria. Although not

Table 9.1 Summary of the KBA A and B criteria and thresholds, modified after IUCN (2016).

	KBA criterion	Biodiversity element at site	% global population. Size/extent	RU
A. Threatened biodiversity	A1. Threatened species	(a) CR or EN species	≥0.5%	≥5
		(b) VU species	≥1%	≥10
		(c) CR or EN species threatened only due to population size reduction in the past or present	≥0.1%	≥5
		(d) VU species threatened only due to population size reduction in the past or present	≥0.2%	≥10
		(e) CR or EN species	Entire global population size	
B. Geographically restricted biodiversity	B1. Individual geographically restricted species	Any species	≥10%	≥10
	B2. Co-occurring geographically restricted species	Restricted-range species: ≥2 species OR 0.02% of global number of species in the taxonomic group, whichever is larger	≥1%	–
	B3. Geographically restricted assemblages	(a) Within a taxonomic group, ≥5 ecoregion-restricted species OR 10% of the species restricted to the ecoregion, whichever is larger	≥0.5%	–
		(b) ≥5 bioregion-restricted species OR 30% of the bioregion-restricted species known from the country, whichever is larger, within a taxonomic group	–	–
	(c) Part of the globally most important 5% of occupied habitat of each of ≥5 species within a taxonomic group	–	–	

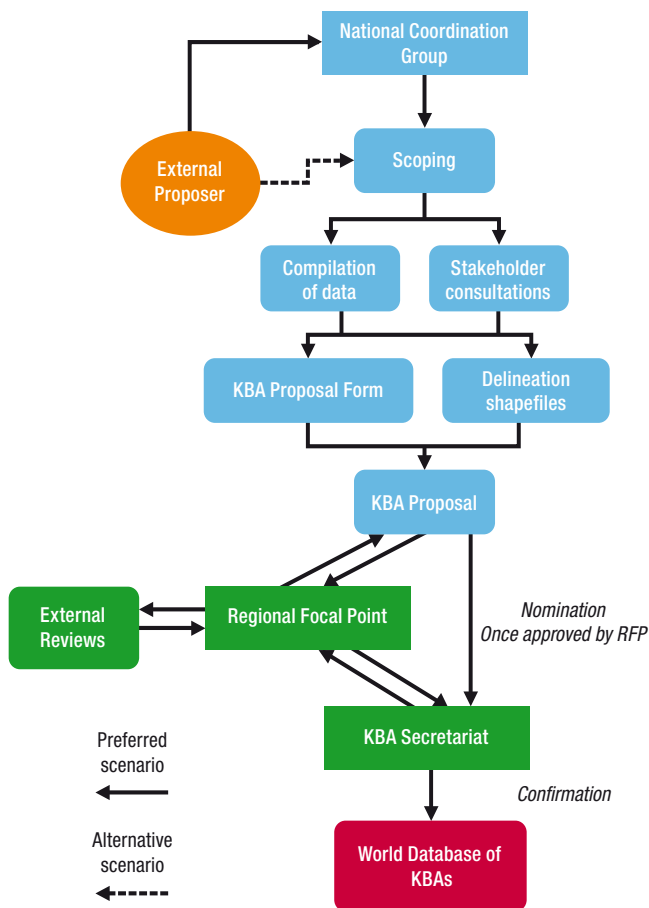


Figure 9.1 Schematic diagram of KBA Proposal process, modified after KBA Secretariat (2019).

all these criteria are applicable or relevant for the freshwater taxonomic groups considered at the workshop (e.g. not all taxonomic groups have species that aggregate), meeting any one of the criteria (or sub-criteria) is enough for a site to be considered for qualification as a KBA. Species meeting the KBA thresholds and criteria are defined as KBA trigger species. KBA criteria C, D and E were not utilised here due to a lack of suitable data. The criteria and thresholds employed in this project are summarised in Table 9.1.

In addition to these technical criteria and thresholds, the Global KBA Standard specifies that KBAs must be ‘potentially manageable’ units. They can be delineated so as to ‘adopt’ existing management units such as protected areas or community conserved areas, or else to take account of legal and customary land tenures. Furthermore, KBAs cannot overlap one another. When a new KBA is identified which would overlap with another existing KBA, the new KBA proposers have three options:

- a) Adopt the existing KBA boundary
- b) Propose an adjacent KBA which does not overlap the existing KBA
- c) Propose an extension to the existing KBA boundary, to incorporate the new biodiversity element

In all cases, it is recommended to inform the existing KBA proposers of the new biodiversity element, and consultation is required before making any modifications to existing KBA boundaries (option c).

9.2.2 Freshwater KBA validation

There are 13 freshwater KBAs proposed in the Guinean Forests of West Africa (GFWA) Ecosystem Profile (CEPF, 2015), spanning a range of countries in the Upper Guinean Forests and Lower Guinean Forests. These sites were identified through the Ecosystem Profile as being the most critical sites for freshwater biodiversity within the GFWA Biodiversity Hotspot. These sites were identified prior to publication of the KBA Global Standard (IUCN, 2016), delineated according to large river basins, and are not considered to be ‘manageable’ sites. Here we re-assess these sites against the KBA Global Standard. We first used the updated Red List assessments, discussed in Chapters 3–7, in a desktop analysis to screen the CEPF freshwater KBAs and other potential sites in western Africa against KBA criterion A on threatened biodiversity, and criterion B on geographically restricted biodiversity. We then convened stakeholder consultation workshops in six countries to assess the potential manageability and delineation of these sites with respect to local and national laws, jurisdictions and other designated areas such as existing protected areas and KBAs.

9.2.2.1 Desktop analysis

A desktop analysis was conducted using data collated through IUCN Red List assessments for the following freshwater taxonomic groups: i) fishes, ii) molluscs; iii) odonates (dragonflies and damselflies); iv) crabs and shrimps, and; v) aquatic plants (Chapters 3–7). The datasets collected include the required information on species ranges and their IUCN Red List Categories of extinction risk as published on the IUCN Red List. The steps in the analysis are as follows:

- a. Assemble spatial data sets of:
 - i) Species Red List distribution maps for freshwater fishes, molluscs, odonates, crabs and crayfish, and aquatic plants;
 - ii) Boundaries of existing KBAs and Protected Areas.

It should be noted that KBA delineation is an iterative process leading to revision and updating of existing KBAs as appropriate through use of better and more recent data, as they become available (IUCN, 2016). The species Red List Assessments employed here were completed in 2018–2020 through the first component of the project (see Chapters 2–7), to ensure that data are traceable to a reliable source and sufficiently recent (and updated) to give confidence for confirming whether biodiversity elements are still present at the sites.

b. Derive proposed site boundaries based on biological data. Using the species distribution maps assembled in Stage 1a above, all river/lake sub-catchments in western Africa that contain potential KBA trigger species were identified based on intersections of sub-catchments with species' mapped ranges. River/lake sub-catchments were delineated according to the spatial data layer called HydroBASINS (Lehner & Grill, 2013) (see Chapter 2). The resolution used for selecting sub-catchments holding KBA trigger species was HydroBASINS Level 8, which in western Africa delineates sub-catchments with a median area of 352 km², including lakes. In this way, maps were created to show the numbers of potential trigger species per sub-catchment. Lists of potential trigger species thought to be present in each sub-catchment were also compiled. This process was achieved through a screening of all sub-catchments against the full complement of species maps using an R script (R Core Team, 2020) developed by Konstantina Spiliopoulou (Spiliopoulou, 2021) to identify the trigger species present and the criteria triggered for each sub-catchment (Figure 9.2). During the analysis those sites that potentially qualified as AZE sites were also identified. AZEs sites are places that contain the last or only populations of globally Critically Endangered or Endangered species almost entirely restricted to that single remaining site (Ricketts et al.,

2005). The AZE map can be accessed at <https://www.zeroextinction.org/>.

9.2.2.2 Validation and delineation workshops

Workshops were convened to identify and delineate KBAs in each of the six countries containing freshwater KBAs in the CEPF GFWA Ecosystem Profile (CEPF, 2015). These workshops were convened by IUCN in the first quarter of 2021. Each of the workshops took place physically within each respective country, with the IUCN Global Species Programme providing KBA training via remote video link to avoid international travel during the global coronavirus pandemic. IUCN also presented the potential KBAs, as derived from the Stage 1 desktop analysis, for validation. The workshops in Sierra Leone, Liberia, Côte d'Ivoire, Ghana and Nigeria were facilitated by the BirdLife Partner in each country, respectively. In Cameroon, the workshop was facilitated by IUCN West and Central Africa Regional Office.

The workshops convened stakeholders from various sectors including local and national government, civil society and the private sector. The aim of the workshops was to validate the 13 freshwater KBAs presented in the CEPF Ecosystem Profile and to identify and validate any other potential KBAs emerging from the desktop analysis and to delineate site boundaries which are ecologically relevant and practical

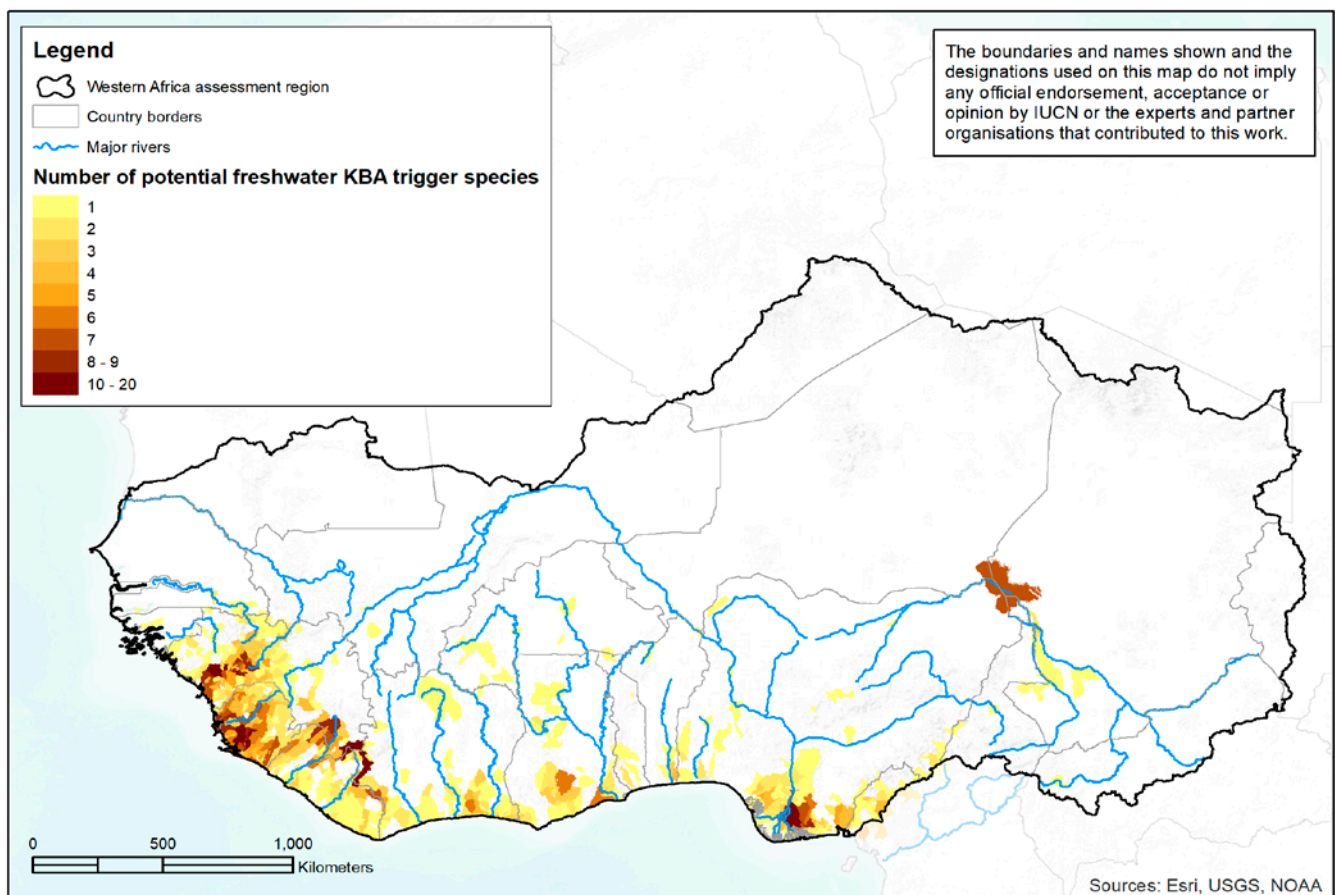


Figure 9.2 Number of potential KBA trigger species per sub-catchment, based on threat status, taxonomic classification and range intersection. Source: Compiled by the report authors using data from the IUCN Red List (2021).

for management (IUCN, 2016). Workshop participants were asked to delineate KBA boundaries according to the following procedure:

- a. Confirmation of KBA trigger species' presence within sub-catchments
- b. Delineation of potential new KBAs boundaries:
 - i. with respect to pre-existing KBAs
 - ii. with respect to Protected Areas
 - iii. for KBAs with no overlap with other KBAs or Protected Areas
- c. Complete the minimum documentation requirements for each KBA

A significant outcome of these workshops was to raise awareness about the most important sites for freshwater biodiversity in western Africa. Many of the workshop participants will be involved in national spatial conservation prioritisation and policy, as well as the re-assessment of existing KBAs and identification of new KBAs in western Africa.

9.3 Capacity building

The six national KBA training and validation workshops were held in Sierra Leone, Liberia, Cote d'Ivoire, Ghana, Nigeria

and Cameroon, delivering a significant boost to the capacity for identifying, proposing and conserving KBAs within the region, initiation of National KBA Coordination Groups (KBA NCGs), as well as linking to national policies. A total 120 people attended these workshops including participants from the conservation NGOs, Government Departments, such as for Protected Areas, the private sector and local community representatives (Figure 9.5). A list of KBA workshop participants is provided in Annex ii.

In Sierra Leone, Liberia, Côte d'Ivoire, Ghana and Nigeria, the IUCN Global Species Programme worked with the BirdLife Partner to convene workshops in each country. The reasons for this were twofold; i) the implementation team considered the BirdLife Partners well placed to convene the relevant stakeholders in their respective countries, and ii) the majority of existing KBAs in western Africa (and globally) are also Important Bird and Biodiversity Areas (IBAs), which are now recognised as KBAs. Most of the IBAs in western Africa are priorities for re-assessment against the Global KBA Standard, and the BirdLife Partners will be largely responsible for this undertaking, with support from BirdLife International and other KBA Partner organisations.

The IUCN Global Species Programme enlisted the help of BirdLife West Africa office in Ghana to deliver KBA training in Nigeria and Ghana. Staff from Missouri Botanical Garden

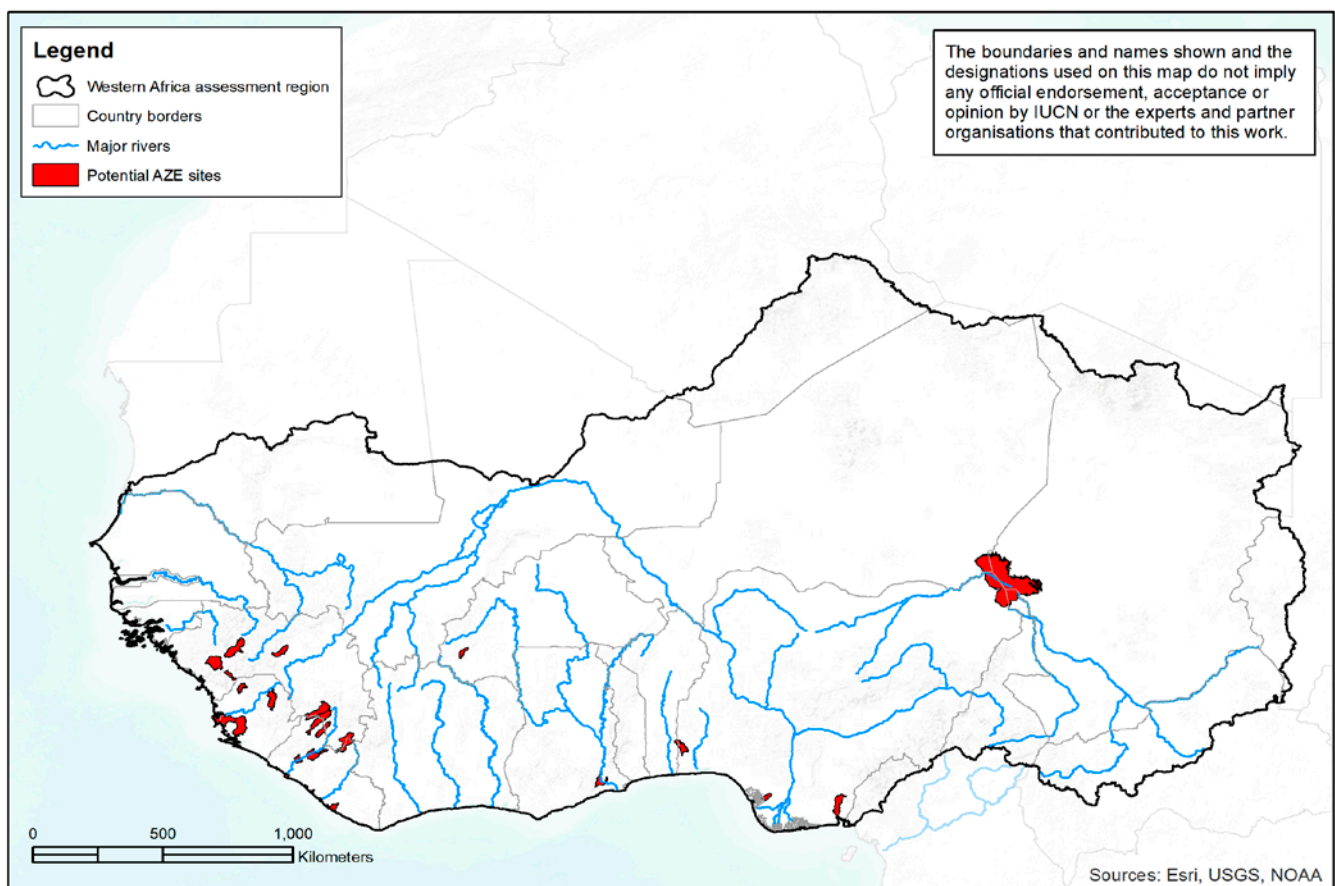


Figure 9.3 Sub-catchments potentially yielding AZE sites based on range intersection. Source: Compiled by the report authors using data from the IUCN Red List (2021).

and the French Institut de Recherche pour le Développement (IRD) were invited to receive two days' KBA training during the Ghana workshop. They were then able to deliver KBA training in French in Côte d'Ivoire and Cameroon. These two workshops represent the first KBA training delivered in French globally.

Several of the countries that received KBA training are subsequently working towards the establishment of NCGs, which will bring together the key stakeholders within the countries, to identify and safeguard KBAs nationally. The establishment of NCGs in each country is seen as a key step in the future identification and confirmation of the KBAs,

ensuring coordination of efforts to identify sites important for the full range of taxonomic groups and involvement of all relevant stakeholders. The KBA Secretariat as well as the KBA Regional Focal Point for southern and western Africa joined many of the training workshops remotely, helping to build momentum for national KBA identification initiatives and providing support for the emerging National Coordination Groups.

The training and capacity building undertaken within the region has elevated the policy awareness and technical capacity for KBA identification and re-assessment amongst

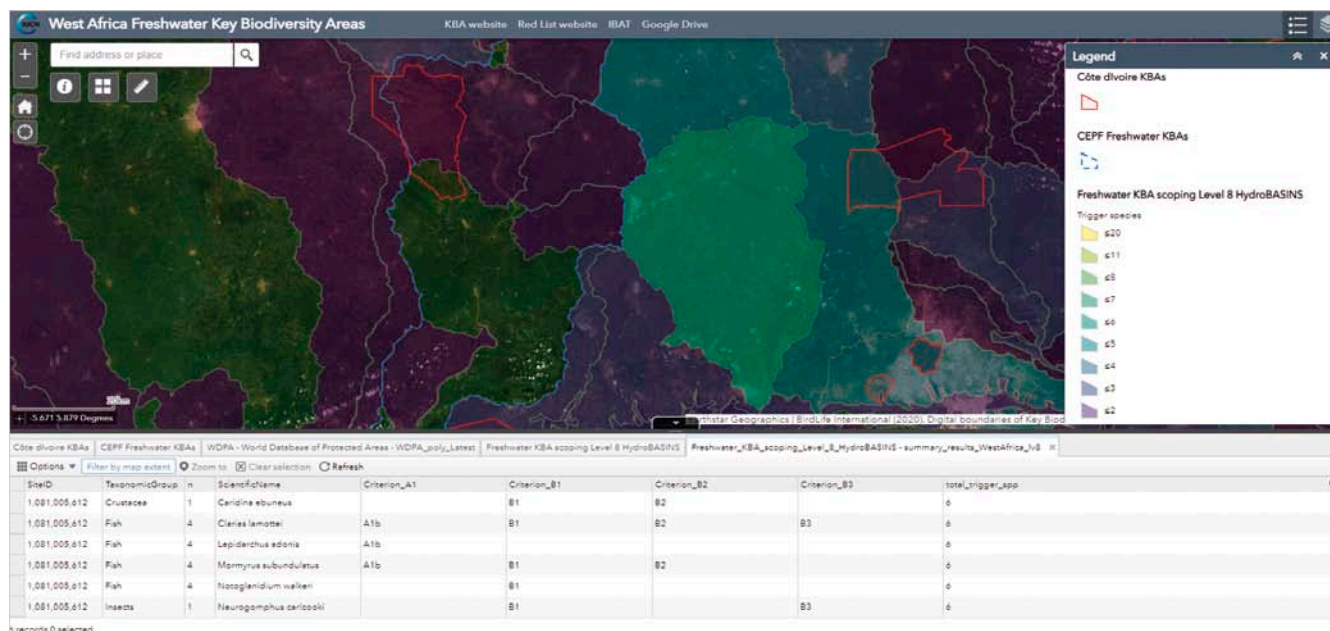


Figure 9.4 Online interactive map developed for identifying and delineating freshwater KBAs during workshops. Source: Compiled by the report authors.



Figure 9.5 Participants at the Liberia freshwater KBA training and validation workshop on 9–10 March 2021. © The Society for Conservation of Nature in Liberia

many of the key stakeholders who will take this forward over the coming years.

9.4 CEPF freshwater KBAs

The 13 CEPF freshwater KBAs (Figure 9.6) identified in the GFWA Ecosystem Profile (CEPF, 2015) are each addressed in this section. For each CEPF freshwater KBA, we summarise the results of the desktop analysis and the KBA workshops in each country. The potential KBA trigger species, based on desktop analysis using species ranges as described in section 9.2.2.1, are summarised in Annex i Table 9.3. The outcomes of the workshops are summarised for each KBA in the following sections, and the recommendations for taking forward each of the sites are summarised in Table 9.2.

9.4.1 Gbangbaia River Basin (fw1)

State of knowledge prior to re-assessment

“Gbangbaia River Basin (fw6), holds six globally threatened fish species and two threatened dragonflies. It is also believed to be the only remaining site for the very rare, relict species of mollusk *Pleiodon ovatus*, which is thought to be the ancestral species for the western Africa bivalves” (CEPF, 2015).

New knowledge and proposed actions

Covering some 2,665 km², the Gbangbaia River Basin is situated in Moyamba District, Sierra Leone. The catchment crosses two districts and several chiefdoms and, according to the KBA manageability criteria, is unlikely to constitute a manageable KBA in its previous delineation. However, the catchment contains several potential KBA trigger species, notably two potential AZE species *Ladigesia roloffi* (CR) and *Pleiodon ovatus* (CR).

Pleiodon ovatus (CR) is a western African bivalve mollusc previously recorded in Senegal, Gambia, Mali, Guinea and Guinea-Bissau. The species was not recorded since 1950 until 1986 when it was rediscovered in the Gbangbar River in Sierra Leone (Nagel 1990), where it was formerly unknown. It was recorded from Kwelu and Bundubu, 25 km north (8°18'26.3"N 12°19'07.9"W) and 10 km south (8°03'15.5"N 12°23'24.0"W) of Moyamba, respectively. The species was last seen in 1968 and so surveys are urgently needed to locate this CR species and to inform a suitable KBA proposal.

Ladigesia roloffi (CR) is a killifish species only known from one location, a small brook in Kasewe (Sierra Leone) according to Paugy et al. (2003) and possibly in a second locality in Du river drainage in Liberia (Van den Nieuwenhuisen 1972),

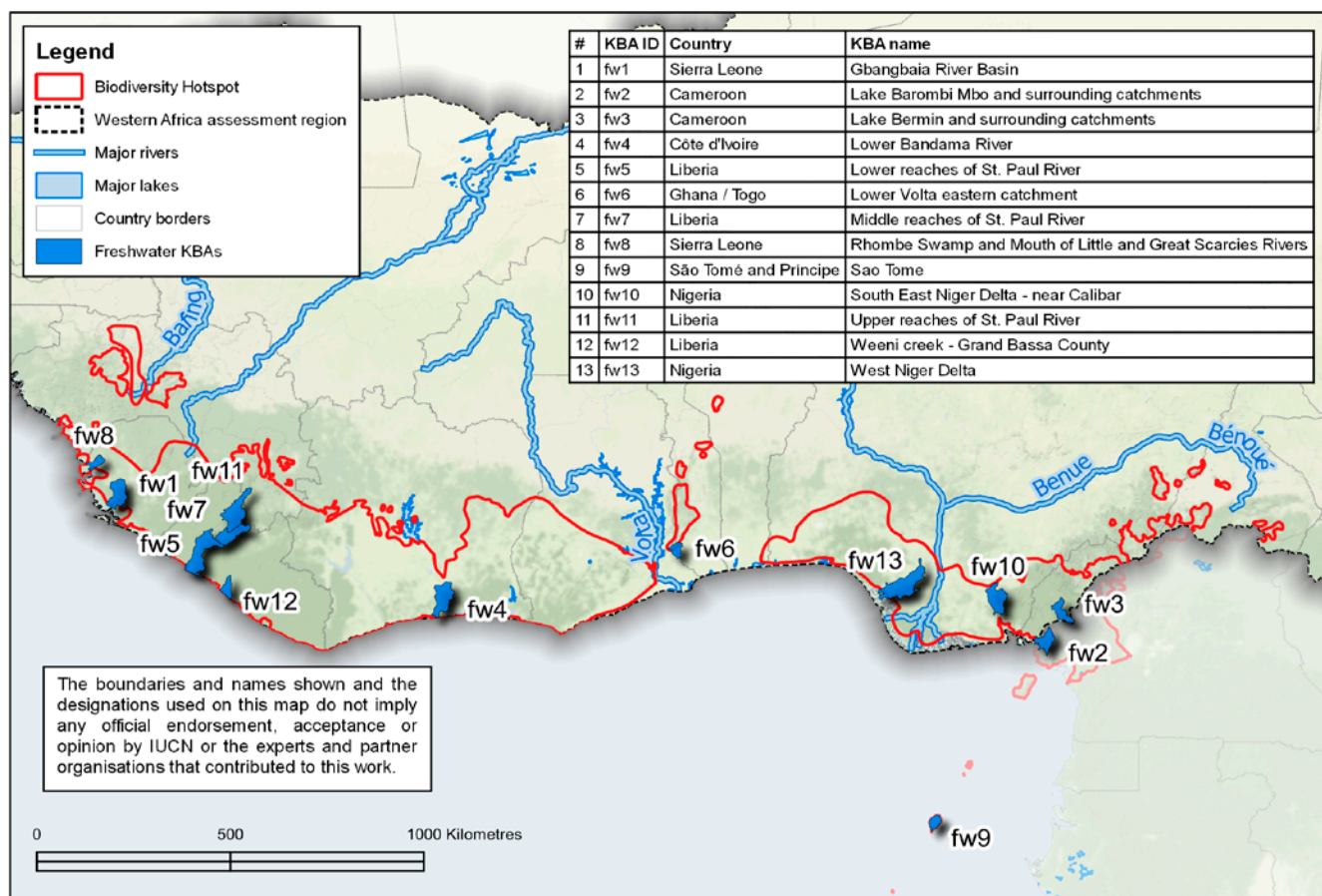


Figure 9.6 CEPF freshwater KBAs as presented in the Guinean Forests of West Africa Biodiversity Hotspot (2015). Source: Compiled by the report authors using data from CEPF (2015) and Myers et al. (2000).

Table 9.2 Next steps for CEPF freshwater KBAs in the Guinean Forests of West Africa. Source: Compiled by the report authors.

CEPF	Name	Country	Recommended next steps
Fw1	Gbangbaia River Basin	Sierra Leone	Confirmation of presence is needed for two AZE trigger species at two sites within the basin. An urgent survey is needed for the CR killifish <i>Ladigesia roloffi</i> , known only from the small Kasewe Forest Reserve.
Fw2	Lake Barombi Mbo and surrounding catchments	Cameroon	Delineate crater watershed as the KBA boundary, encapsulating the Ramsar site.
Fw3	Lake Bermin and surrounding catchments	Cameroon	Update the existing Bakossi mountains KBA with the nine cichlid A1e trigger species and submit the crater lake catchment as the biodiversity element boundary.
Fw4	Lower Bandama River	Côte d'Ivoire	Several smaller KBAs were proposed within this catchment by the workshop participants, taking account of the existing KBAs and protected areas and recent survey data. Some further surveys or assimilation of existing data are required, and a focal person has been appointed to coordinate this work.
Fw5	Lower reaches of St. Paul River	Liberia	This catchment includes the type localities for several CR species that have not since been recorded. Surveys are urgently needed to confirm the presence and whereabouts of this species on the river, so that appropriate KBA/s may be designated.
Fw6	Lower Volta eastern catchment	Ghana	A KBA was delineated during the workshop encompassing a stretch of the Volta and northern catchments which meets KBA criteria for several species. The proposal is being developed with stakeholders from BirdLife West Africa and University of Cape Coast, Ghana.
Fw7	Middle reaches of St. Paul River	Liberia	Liberian tree-hole crab <i>Globonantes macropus</i> (EN) was not recorded from 1898 until 1988. Awareness raising and identification guide to be disseminated through the Species Working Group to gather data on this potential KBA trigger species.
Fw8	Rhombe Swamp and Mouth of Little and Great Scarcies Rivers	Sierra Leone	The Rhombe Swamp has been identified for an irrigation project and the government is on the verge of establishing a large rice project there.
Fw9	São Tomé	São Tomé and Príncipe	Taxonomic work is needed on potential KBA trigger species, the freshwater shrimp <i>Atya intermedia</i> , before a KBA can be considered for this species.
Fw10	South East Niger Delta – near Calabar	Nigeria	Further monitoring is needed to refine focal areas for the potential KBA trigger species within this large catchment and the neighbouring Cross River National Park – Oban Division, particularly for <i>Fundulopanchax scheeli</i> (CR).
Fw11	Upper reaches of St. Paul River	Liberia	Surveys needed for two CR minnow species, <i>Enteromius carcharhinoides</i> and <i>E. melanotaenia</i> , known only from their type locality inside Wonegizi Mountains KBA.
Fw12	Weeni creek – Grand Bassa County	Liberia	The existing AZE boundary needs to be revisited with respect to the type locality for the KBA trigger species, the freshwater crab <i>Liberonantes grandbassa</i> (CR).
Fw13	West Niger Delta	Nigeria	Further surveys are needed to determine the presence of potential KBA trigger species within this catchment and surrounding areas, most notably <i>Parauchenoglanis buettikoferi</i> (CR) in the lower Warri River.

but this needs confirmation. The species is located within a protected area (Kasewe Forest Reserve), but this reserve is vulnerable to the impacts of climate change because of its small size, and deforestation from agricultural activity and logging which is thought to be causing ongoing declines in its habitat quality.

It is now proposed that field assessments be conducted to confirm presence of these two species in the Kasewe Forest Reserve, which could then be nominated as an AZE. Surveys should also be mounted to the previous two localities for *P. ovatus* on the Gbangbar River.

9.4.2 Lake Barombi Mbo and surrounding catchments (fw2)

State of knowledge prior to re-assessment

“Lake Barombi Mbo and surrounding catchments, to the northeast of Doula, partly overlaps with Mount Cameroon and Mokoko-Onge KBA. Thirty-seven species of freshwater

fishes, plants, dragonflies and shrimps trigger the KBA criteria in this site, including two species of fish (*Clarias maclareni* and *Sarotherodon lohbergeri*) and one plant (*Ledermannia batangensis*) that are Critically Endangered. The latter species has not been recorded since its original collection in 1908 and may be extinct. A most important focal area within this KBA is Lake Barombi Mbo, a crater lake of approximately 7 km² in area, with a high diversity of endemic freshwater species. The catfish, *C. maclareni*, is endemic to the lake along with 11 species of endemic cichlid fishes. The main threat to the lake is the expansion of oil palm plantations, proposed tourism development, water abstraction for Kumba town, and deforestation leading to increased sedimentation in the lake. The Sunda Gorge Dam on the lower Nyong River poses a potential threat to many riverine species should its construction be resumed” (CEPF, 2015).

New knowledge and proposed actions

While the CEPF KBA encompasses a 1,765 km² catchment,

the Lake Barombi Mbo volcanic crater lake itself measures just 7 km² and contains 11 species of threatened and endemic cichlid fishes, all of which qualify as AZE trigger species. At the KBA workshop in Cameroon on 7 April 2021, it was proposed to adopt the existing Barombi Mbo Crater Lake Ramsar Site for this species. However, the Ramsar delineation traces the lake shoreline whereas the main threats to the KBA trigger species are from slash and burn agriculture within the crater leading to sedimentation and pollution in the lake. The entire crater catchment of 12 km² was therefore recommended by IUCN as the ecologically appropriate and manageable delineation for a KBA. This is the crucial site within the catchment to be nominated as a KBA. The workshop participants shared a great deal of knowledge from stakeholders about the local policy context of the site. The trigger species have all recently been observed within the lake, confirming their presence (Musilova et al., 2019) and the proposal is being finalised in consultation with the key stakeholders for nomination as a KBA.

9.4.3 Lake Bermin and surrounding catchments (fw3)

State of knowledge prior to re-assessment

“The freshwater KBA, Lake Bermin and surrounding catchments (fw2) is located northwest of Ngongsamba, and partly overlaps with Bakossi Mountains KBA (CMR1) and Mont Manengouba KBA (CMR9), as well as overlapping more significantly with Banyang Mbo Wildlife Sanctuary KBA (CMR4) and largely overlapping Banyang Mbo Wildlife Sanctuary KBA (CMR4). Forty nine freshwater KBA trigger species are

present within the site including many fish, dragonfly, and plant species. Nine species of Critically Endangered cichlid fishes are endemic to another tiny crater lake, Lake Bermin, within this KBA, and two Critically Endangered species of odonata are found within the wider KBA” (CEPF, 2015).

New knowledge and proposed actions

Lake Bermin is another crater lake within Cameroon supporting nine endemic cichlid fish species (Martin et al., 2015). The lake falls just within the existing Bakossi Mountains KBA. In the short term, the crater catchment boundary will be submitted to the KBA Secretariat along with the list of additional trigger species within the existing KBA. In this case, the existing KBA would also qualify as an AZE under KBA criterion A1e. The Bakossi Mountains is a priority KBA for re-assessment against the Global KBA Standard. If the existing KBA boundaries were to be modified, then Lake Bermin would qualify as a KBA (AZE) in its own right.

9.4.4 Lower Bandama River (fw4)

State of knowledge prior to re-assessment

“The Lower Bandama River in Côte d’Ivoire is a Priority 2 freshwater KBA (fw3) holding an Endangered mollusk and a Vulnerable freshwater plant” (CEPF, 2015).

New knowledge and proposed actions

The Lower Bandama River catchment intersects several protected areas including the Azagny National Park and Ramsar site, a wetland situated between the mouth of the Bandama River to the west and the Ébrié Lagoon to the east.



Figure 9.7 Bandama River, Lamto Ecological Research Station KBA. © Benjamin Barca

Azagny National Park is also an existing KBA and another KBA, Mopri Forest Reserve, lies to the west of Tiassalé.

Two species of mammals and two species of fish reported in the Bandama River were identified as potential KBA trigger species. The African manatee *Trichechus senegalensis* (VU) and Pygmy hippopotamus *Choeropsis liberiensis* (EN) are reported in the Azagny National Park. The distribution of these species includes the Bandama river estuary Bandama, the mangroves and marshes of the Azagny National Park and the Azagny canal. *Epiplatys etzeli* (EN) and *E. chaperi*, two species of fish from the Notobranchiidae, are reported to be present in the main course of the Bandama river, outside of their documented Red List range (Aboua et al., 2010). These two species were captured during electric fishing between the lakes of Kossou and Taabo. *E. chaperi* was also detected downstream of the Taabo dam. With regard to this list of species, a KBA can potentially be delimited taking into account the Azagny National Park, the classified forest of Mopri and the area between the lakes of Taabo and Kossou. It was proposed during the workshop in Côte d'Ivoire to take three actions.

1. Adopt the existing Azagny National Park KBA, potentially including the estuary of the Bandama river, the Azagny canal, and parts of the lagoon near the park. This may require alignment with the Azagny National Park Ramsar site boundary.
2. Adopt the existing Mopri Forest Reserve KBA. This may require alignment with the Mopri classified forest.
3. A new KBA located between the Taabo and Kossou lakes.

Based on the desktop exercise these sites are likely to meet the KBA criteria, but will require surveys confirming presence and reproductive unit thresholds within the three sites. Dr Aristide Yao Konan from the University Félix Houphouët-Boigny in Abidjan was elected as the focal point for taking forward these KBA proposals.

9.4.5 Lower reaches of St. Paul River (fw5)

State of knowledge prior to re-assessment

This KBA is not discussed in the Ecosystem Profile, but is contiguous with the Middle reaches of St Paul River.

New knowledge and proposed actions

This catchment contains the only known localities for several CR species, potentially yielding several individual AZE sites. However, none of the potential KBA trigger species have been observed recently, some of them not for decades.

Bellamya liberiana (CR) is a gastropod mollusc species which has not been recorded since 1888 and the Mount Coffee

dam has been constructed on the type locality. It may now be extinct, but surveys are required to confirm this conclusively. *Coptodon coffea* (CR), a cichlid fish species, is only known from, and is probably endemic to, the St. Paul River, Liberia. It has been reported from above the Mount Coffee Dam in 1970. *Callopanchax monroviae* (CR) is an African rivuline fish endemic to Liberia, where it is known from only one location in the lower Saint Paul River near Monrovia, recorded in the 1970s.

Field surveys are urgently needed to confirm the continued presence of these species at their type localities and further afield. If their presence is confirmed then the site can be nominated as a KBA, or potentially as several AZEs.

9.4.6 Lower Volta eastern catchment (fw6)

State of knowledge prior to re-assessment

"A single transboundary freshwater KBA in the Lower Volta eastern catchment (fw5) has a number of restricted range freshwater fish and mollusks, including the Endangered butterflyfish (*Irvineia voltae*) which is only known from the lower Volta river basin" (CEPF, 2015).

New knowledge and proposed actions

The KBA trigger species associated with the Lower Volta eastern catchment freshwater KBA were found to have undergone range shifts and contractions in the latest Red List assessments. On this basis, an area of the North Tongu District on the Lower Volta, encompassing approximately half of the range of *Irvineia voltae* and including the only recent known observation of the species was identified during the freshwater KBA workshop in Ghana. The site is also considered to be of global importance for the persistence of three threatened freshwater mollusc species; *Pseudocleopatra voltana* (EN), *Pseudocleopatra togoensis* (CR) and *Potadoma togoensis* (CR).

Pseudocleopatra voltana (EN) has experienced a substantial range contraction since the 1970s. This species is endemic to Ghana, where its range formerly included the stretch of the Volta now inundated by Lake Volta and a stretch of the White Volta (Nakembe) near Daboya. The species is now thought only to occur in the Lower Volta below Lake Volta, where it remains abundant (Akpabey et al. in Ntiemoa-Baidu et al., 2017). This species was observed at several locations along the Lower Volta River, several of which are encompassed by the North Tongu KBA.

Pseudocleopatra togoensis (CR) has also experienced a range contraction associated with the inundation of Lake Volta and increasing pollution stress across its range. In the case of the localities that have been flooded by Lake Volta, it is expected that they have not survived the intense

molluscicide campaigns to destroy the intermediate hosts (Van Damme, 2020). The species' entire global range is encompassed by the North Tongu KBA, although recent confirmation of presence is needed.

Potadoma togoensis (CR) is threatened by habitat loss and degradation, including through eutrophication and pollution by urban and agricultural developments, stream velocity regulation and other effects of hydroelectric power dams, and droughts. Upstream of Lake Volta, the species was previously reported from the Oti River, near the border of Togo, but it is unlikely that it still occurs there considering the levels of water pollution. A recent survey over the length of the river downstream of the Akosombo Hydroelectric Dam only recovered the species (1 specimen) from the Adomi Bridge sampling site, and this single locality is captured within the proposed KBA boundary.

The site is in a Tropical Savannah Grassland zone, representing a portion of the Lower Volta drainage with tributaries emptying from the north into the Volta River. The site is situated between the Kalakpa resource reserve and Keta Lagoon Ramsar complex. Biodiversity features include a combination of species associated with Guinea savannah, woodland savannah, grassland and wetland. There are established communities within this proposed KBA especially the district very recent and there might be plans for expansion into natural habitats; currently there is a heavier population towards the south. The nearby population is <100,000 people, predominantly farmers, charcoal producers, fisherfolks, hunters and traders. There is fishing, especially for clams, as well as arable and cattle farming practised within the site. The site also contains sacred groves.

Further consultation on the KBA boundary delineation is required with several stakeholders, including Chiefs of communities in the area, local government and data holders at the University of Ghana.

9.4.7 Middle reaches of St. Paul River (fw7)

State of knowledge prior to re-assessment

This KBA is not discussed in the Ecosystem Profile, but is contiguous with the Upper and Lower reaches of the St Paul River.

New knowledge and proposed actions

Globonantes macropus, the Liberian tree-hole crab (EN) was originally known from only a single specimen collected in Liberia in 1898, and was not collected again for 90 years until it was rediscovered in 1988. This species is still known from only a few specimens from fewer than ten sites. The only existing protected area covering part of this species' range

is the Lake Piso Multiple Sustainable Use Reserve. The Lake Piso KBA may also harbour this species. Urgent surveys are needed to confirm the species' presence at these two sites and elsewhere within its range in the Lower and Middle St Paul River catchment.

9.4.8 Rhombe Swamp and Mouth of Little and Great Scarcies Rivers (fw8)

State of knowledge prior to re-assessment

"Rhombe Swamp and Mouth of Little and Great Scarcies Rivers (fw8) holds three globally threatened species of freshwater fish, one threatened mollusk and two threatened odonates" (CEPF, 2015).

New knowledge and proposed actions

An irrigation feasibility study was completed by the Ministry of Agriculture in 2009, funded by the African Development Bank (AfDB) (Namara & Sally, 2014). The Rhombe Swamps and Rolako Area Irrigation project would irrigate some 4,600 ha of swampland, pumping water from the Little Scarcies River to feed the project. The AfDB did not consider the project financially feasible at the time, but according to workshop participants, the government may be moving to resurrect these plans.

An endemic fish *Scriptaphyosemion etzeli* (CR) is known from brooks and marshes of the savannah northwest of Loko Port towards the mouth of Little Scarcies River. This species would qualify an AZE on the mouth of the Little Scarcies River, in Mambolo Chiefdom, Kambia District, if a recent confirmation of presence could be provided in a KBA proposal. Two other species, a catfish *Clarias laeviceps* (VU) and a cyprinid fish *Enteromius teugelsi* (VU) might also qualify a KBA if they occur in sufficient numbers at the site (≥ 10 reproductive units). Two freshwater mollusc species, *Afropomus balanoidea* (EN) and *Saulea vitrea* (VU) may also qualify under criteria A1a and A1b, respectively. Ground surveys are needed to confirm the presence of *S. etzeli* (CR) and to confirm the minimum reproductive units for the other species at the site.

9.4.9 São Tomé (fw9)

State of knowledge prior to re-assessment

This KBA, encompassing the entire island of São Tomé, is not discussed in the Ecosystem Profile.

New knowledge and proposed actions

São Tomé was recognised as a freshwater KBA in the CEPF Ecosystem Profile for the EN freshwater shrimp species *Atya intermedia* (EN), known only from the islands of São Tomé and Annobón in Equatorial Guinea. Recent communication with the Red List assessor indicated that there is taxonomic

uncertainty around this species (c.f. *A. innocous*) and the species should be considered DD. Therefore, this KBA was not taken forward, pending taxonomic work on this species. Everything that is known about this genus can be found in Hobbs and Hart (1982).

9.4.10 South East Niger Delta – near Calabar (fw10)

State of knowledge prior to re-assessment

“South East Niger Delta near Calabar KBA (fw10) is located in the eastern side of the delta at the lower reaches of the Cross River. This KBA has a small number of threatened and restricted range fishes and plants and one species of freshwater crab. An Endangered species of killifish, *Fundulopanchax scheeli*, is entirely restricted to this KBA. The Vulnerable crab, *Potamonautes reidi*, which has a global range restricted to the Niger Delta, is also present at the site” (CEPF, 2015).

New knowledge and proposed actions

The freshwater crab *Potamonautes reidi* (VU) is a potential KBA trigger species under criteria A1b and B1. In order to propose a KBA for this species under criterion A1b, the site must contain $\geq 1\%$ of the global population size, e.g. inferred through range, and ≥ 10 reproductive units of the species. These criteria might be met within the existing Cross River National Park, and given that this is a well-established KBA and protected area, it may be considered a priority to conduct surveys within the park. WCS Nigeria was present at the workshop for this species. Other forest reserves around the Cross River basin may be found to qualify as KBAs for some freshwater species, but they may not be effectively conserved.

The Scheeli killifish *Fundulopanchax scheeli* (CR) is a rare fish species that has been recorded from two localities, its type locality, Akamkpa, and at Okporo, in very close proximity to each other in the lower Cross River basin, on the Calabar River (Stiassny, Teugels & Hopkins, 2007). Therefore, its entire range lies directly in the gap between the Cross River National Park and Uwet Odot Forest Reserve, receiving no protected area coverage. A survey is urgently needed to confirm the presence of this species and to enable a KBA proposal to be drafted for this potential AXE site.

9.4.11 Upper reaches of St. Paul River (fw11)

State of knowledge prior to re-assessment

“A KBA in the Upper reaches of St Paul River (fw11) is important for the high concentration of globally threatened freshwater species including eight fish species and also the Endangered treehole crab, *Globonautes macropus*. *Barbus carcharhinoides* and *B. melanotaenia* are both Critically

Endangered fish species thought to be globally restricted to this upper section of the river. The Critically Endangered gastropod mollusk, *Bellamya liberiana*, is also potentially found in this part of the river and could benefit from additional survey effort” (CEPF, 2015).

New knowledge and proposed actions

Two CR species of minnows are only known from their type localities on the Via River. *Enteromius carcharhinoides* (CR) and *E. melanotaenia* (CR) and currently only known from their type locality (8°08'N, 9°28'W) on the Via River, Saint Paul's river drainage, Liberia (Stiassny, 1991; Paugy, Lévêque & Teugels, 2003). These species may occur in other parts of the upper Via River, an area that has not yet been thoroughly explored (R. Schmidt pers. comm. 2020). The locality lies just inside of the border with Guinea, within the Wonegizi Mountains KBA and the Wonegizi Nature Reserve. These potential KBA trigger species should be added as species of interest to the existing KBA, and an effort made to relocate them as a matter of urgency.

9.4.12 Weeni creek – Grand Bassa County (fw12)

State of knowledge prior to re-assessment

“Another high relative biological priority in Liberia is a cluster of subcatchments around Weeni Creek in Grand Bassa County (fw12), where a Critically Endangered crab, *Liberonautes grandbassa*, and three threatened fish species are found. This freshwater crab's entire known global distribution is within Weeni Creek where it is currently unprotected and subject to the impacts of ongoing deforestation” (CEPF, 2015).

New knowledge and proposed actions

The Grandbassa River Crab *Liberonautes grandbassa* (CR) is known only from two specimens collected in 1988 from a single locality. The previous Red List assessment mapped the species' range to the wider catchment (1,047 km²) but this was refined in the latest assessment to a smaller sub-catchment (121 km²) containing the type locality and Trade Town, southwest of the Libbing Company Palm Oil Plantation, since the species has not been recorded from the wider catchment. However, a KBA (AZE) was designated in 2018 for the neighbouring sub-catchment containing Newcess and Harmonville to the west. This delineation needs to be revisited in light of the information presented here (Neil Cumberlidge, pers. comm.).

The KBA scoping analysis found that the Weeni Creek catchment did not meet the population thresholds to qualify for additional freshwater KBA trigger species at this site. However, based on analysis by the KBA Secretariat, the broader 1,047 km² catchment delineated in the Ecosystem

Profile (CEPF, 2015) did potentially qualify under criteria A1c and A1d for Diana monkey, *Cercopithecus diana* (EN) and for four bird species (*Ceratogymna elata* (VU), *Criniger olivaceus* (VU), *Lobotos lobatus* (VU) and *Psittacus timneh* (EN)).

9.4.13 West Niger Delta (fw13)

State of knowledge prior to re-assessment

“West Niger Delta KBA (fw13), in the part of the delta southwest of Benin City, has two Endangered freshwater shrimps: *Desmocarlis bislineata* and *Euryrhynchina edingtonae*. The former species has its known global range restricted to the KBA” (CEPF, 2015).

New knowledge and proposed actions

The freshwater shrimp *Desmocarlis bislineata* (EN) is only known from three sites in the West Niger Delta (Powell, 1977). This species may qualify for an AZE, but there have been no recent records of the species and its habitat has been extensively degraded by repeated oil spills, loss of mangroves and the impact of extensive water hyacinth populations, which are degrading the species’ quality of habitat.

Two threatened species of killifish in the genus *Fundulopanchax* potentially meet KBA criterion A1a and another may meet criterion B1. The CEPF KBA boundary includes part of the range of *Fundulopanchax sjostedti* (EN) which is present along the coast, including Uremure Yokri and Olague Forest Reserves.

The type locality for the Critically Endangered catfish *Parauchenoglanis buettikoferi* (CR) lies just outside of the CEPF KBA boundary, to the south. The species has not been observed since the type specimen was collected in 1913.

9.5 Other potential freshwater KBAs

Many other potential freshwater KBA sites were identified through the desktop scoping analysis (Figure 9.2) and subsequent workshops, for example Mount Nimba and the Cavally/Cavalla River on the Liberia/Côte d’Ivoire and Guinea borders. Urgent surveys are required to relocate the Streamertail dragonfly, *Zygonychidium gracile* (CR), which has only been observed from the Korhogo area in northern Cote d’Ivoire but has not since been observed for many years. The species’ range includes several classified forest reserves, but surveys are first required to understand the species’ distribution.

Possibly the last remaining populations of the Endangered *Limbochromis robertsi* lie just between Atewa Forest KBA in Ghana and Apedwa Forest in Ghana (Lamboj et al., 2020).

Participants from the Ghana workshop including from A Rocha will be looking out for this species in the monitoring that is currently being undertaken across the Atewa range. Further targeted surveys may be required to detect whether the species is present in the neighbouring Adepwa Forest.

There is an urgent need to confirm KBAs for freshwater species in the Niger Delta, particularly in the Rivers and Imo states north of Port Harcourt. This area is exceptionally rich in freshwater biodiversity but is also amongst the most environmentally degraded areas in western Africa. These species are severely threatened by the pressures associated with a booming population and frequent oil spills.

The common theme is that the sites will require recent confirmation of presence and data to confirm minimum thresholds for reproductive units before they can be proposed as Global KBAs. It is hoped that the scoping analysis will serve as a guide to target future surveys. However, there is also huge potential in collating data, particularly from both targeted and untargeted environmental DNA (eDNA) surveys.

A site in Liberia was identified as a potential KBA for the Critically Endangered killifish *Scriptaphyosemion schmitti* based on the desktop scoping analysis. However, there were no recent data to confirm the persistence of the species at the site. By chance, a contact at Fauna and Flora International (FFI) shared the results of an eDNA survey for pygmy hippo on the Dugbe and Dubo Rivers, which revealed several detections of the species – the first for many years. These data can be used to revise the Red List range and subsequently to propose a KBA for the species. This is an example of the potential benefits of sharing eDNA survey data from the private and non-profit sectors, which may otherwise go unused.

9.6 Recommendations and next steps

The 13 CEPF freshwater KBAs have been refined and validated against the KBA Global Standard based on new information collated through the Red List re-assessments and the input of stakeholders at the KBA workshops. However, it is now clear that most of these sites are lacking sufficiently recent data (within the past 12 years) to confirm the presence of the species within these sites, or to confirm that the reproductive unit thresholds are met for some of the KBA criteria. Despite the new information collated, most of the refined boundaries for potential freshwater KBAs could not be formally proposed at this stage due to a paucity of recent data on the trigger species.

There is little evidence for tangible efforts to conserve the freshwater biodiversity elements within these sites to date. Furthermore, the proposed trigger species have often not

been observed, let alone monitored, since the sites were identified. By undertaking this revision and compiling a shortlist of potential KBA freshwater trigger species and sites using the KBA Global Standard, we have identified the key priorities for surveys and monitoring in the region. Such surveys, in many cases, would be all that is now required to take forward formal KBA proposals for these sites, giving them the international recognition and additional funding opportunities that Global KBA status confers.

Those sites with greatest potential to yield freshwater KBA have been identified and refined through stakeholder consultation workshops, and communicated to wider audiences. Where there is supporting field data e.g. for Lake Barombi Mbo crater lake in Cameroon, and North Tongu on the Lower Volta River in Ghana, KBA proposals are being taken forward by the relevant local stakeholders with support from IUCN. In Liberia, it was resolved to develop a 'field guide to the potential freshwater KBA trigger species of Liberia', for dissemination by the Species Working Group of Liberia. Many members of the group, which was established in 2016 to convene stakeholders working on conservation, are conducting regular surveys within potential freshwater KBA sites, but have not historically been aware of these rare and threatened freshwater species.

Even within conservation organisations, many relevant data may already exist but not be mobilised, and there is a need to develop and leverage existing data curation and data sharing infrastructure to unlock the potential of these data for conservation, including for the identification and delineation of KBAs. This must also include ways for the private sector to share data and incentives for doing so.

The private sector can use KBAs as a means to manage biodiversity risk associated with projects and investments. Information about KBAs is provided to companies, banks and multilateral financing institutions through the Integrated Biodiversity Assessment Tool (IBAT, 2021), and the *Guidelines on business and KBAs* (IUCN, 2018) provide a roadmap for companies operating in or near KBAs. However, as it stands, most of these freshwater KBAs cannot be confirmed without further data. Employing the precautionary principle, the sites identified here should be recognised as potential KBAs for the species indicated, until the recommended field surveys are conducted to confirm presence or absence of the potential KBA trigger species.

There is a great as-yet untapped potential for eDNA monitoring to play a key role in contributing to the identification, confirmation and monitoring of KBAs and the Red List assessments that underpin them. In the Lower Bandama River, for example, NatureMetrics are leading a project funded by CEPF, which is using eDNA to understand

the state of freshwater systems in the Lower Bandama freshwater KBA in Côte d'Ivoire. This project represents a direct investment in freshwater KBAs in the region. Working closely with the Université Nangui Abrogua in Abidjan and other conservation, government and private sector partners, this project is contributing to the validation and monitoring of this freshwater KBA.

The six national KBA training and validation workshops held in Sierra Leone, Liberia, Côte d'Ivoire, Ghana, Nigeria and Cameroon have delivered a significant boost to the capacity for identifying, proposing and safeguarding KBAs within the region, as well as linking to national policies. Several of these countries are working towards the establishment of KBA National Coordination Groups, which will bring together the key stakeholders within these countries to take forward KBAs nationally.

Most of the existing KBAs in western Africa (and globally) are Important Bird and Biodiversity Areas (IBAs) which were adopted as Global KBAs in 2016. Many of these sites require re-assessment against the KBA Global Standard (IUCN, 2016) and this process will often be driven by the BirdLife partners. By working with the BirdLife Partners in each of the countries containing CEPF freshwater KBAs, as well as building links with BirdLife International in West Africa, the freshwater biodiversity elements and potential trigger species have been brought into focus within the region. Where there has been a lack of field data to support formal KBA proposals for freshwater species at this stage, these sites are now flagged for consideration as KBAs and, where appropriate, incorporation into existing KBAs.

The outcomes of this work will be communicated to decision makers across the western Africa region by the IUCN PACO West and Central Africa office. In particular, efforts will be made to improve recognition of these important sites for freshwater species through KBA nomination, increased representation of freshwater biodiversity in protected area networks, and incorporation of freshwater biodiversity into protected area management and monitoring plans.

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Annex i – Potential freshwater KBA trigger species

Table 9.3 lists the potential KBA trigger species identified through a KBA desktop scoping analysis for each CEPF freshwater KBA per the Ecosystem Profile (CEPF, 2015). These sites are wide catchments and are not considered manageable units per the Global KBA Standard (IUCN, 2016). Therefore, this list was used in conjunction with corresponding maps as a scoping tool to guide KBA validation workshops with input from various stakeholders on species' distributions and ecology, as well as site manageability and delineation with respect to existing designations and land management boundaries. These site boundaries were refined to achieve ecologically relevant and

potentially manageable units. Because the analysis is based on range data, the inclusion of species on this list does not guarantee the presence of the species within the catchment. However, because freshwater species ranges on the Red List are mapped to sub-catchments, the species are considered present by the Red List assessors.

Species listed as meeting criteria B2 and B3 do not necessarily meet the minimum number of species required to trigger the criteria at a given site. E.g., in order to trigger B3a, there must be at least 5 ecoregion-restricted species at the site, depending on the taxonomic group.

Table 9.3 Potential KBA trigger species identified for the CEPF freshwater KBAs. Source: Compiled by the report authors using data from Spiliopoulou (2021)

KBA name	Group	Species	Criterion A1	Criterion B1	Criterion B2	Criterion B3
Gbangbaia River Basin (fw1)	Fishes	<i>Malapterurus leonensis</i>				B3
	Fishes	<i>Parailia spiniserrata</i>				B3
	Fishes	<i>Scriptaphyosemion geryi</i>				B3
	Fishes	<i>Callopanchax occidentalis</i>		B1		B3
	Fishes	<i>Ladigesia roloffii</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Clarias laeviceps</i>	A1b			
	Fishes	<i>Notoglanidium thomasi</i>	A1b	B1		B3
	Fishes	<i>Notoglanidium maculatum</i>	A1b	B1	B2	B3
	Molluscs	<i>Sierraia leonensis</i>				B3
	Molluscs	<i>Sierraia whitei</i>				B3
	Molluscs	<i>Afropomus balanoidea</i>	A1a			B3
	Molluscs	<i>Saulea vitrea</i>	A1b	B1		B3
	Molluscs	<i>Pleiodon ovatus</i>	A1c,A1e	B1	B2	B3
	Plants	<i>Eriocaulon deightonii</i>				B3
	Plants	<i>Fimbristylis aphylla</i>				B3
Lake Barombi Mbo and surrounding catchments (fw2)	Fishes	<i>Konia eisentrauti</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Konia dikume</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Myaka myaka</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Pungu maclareni</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Sarotherodon steinbachi</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Sarotherodon lohbergeri</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Sarotherodon linnellii</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Sarotherodon caroli</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Stomatepia mariae</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Stomatepia pindu</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Stomatepia mongo</i>	A1a,A1e	B1	B2	B3
	Crustacea	<i>Caridina sodenensis</i>	A1b	B1	B2	
	Insects	<i>Allocnemis eisentrauti</i>		B1	B2	
	Insects	<i>Microgomphus camerunensis</i>		B1	B2	
	Molluscs	<i>Neritilia manoeli</i>		B1	B2	

Annex i – Potential freshwater KBA trigger species, cont'd

KBA name	Group	Species	Criterion A1	Criterion B1	Criterion B2	Criterion B3
Lake Bermin and surrounding catchments (fw3)	Fishes	<i>Coptodon bakossiorum</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Coptodon bemini</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Coptodon bythobates</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Coptodon flava</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Coptodon gutturosa</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Coptodon imbrifera</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Coptodon snyderae</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Coptodon spongotroktis</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Coptodon thysi</i>	A1a,A1e	B1	B2	B3
Lower Bandama River (fw4)	Fishes	<i>Citharinus eburneensis</i>				B3
	Fishes	<i>Enteromius trispilos</i>				B3
	Fishes	<i>Fundulopanchax walkeri</i>				B3
	Fishes	<i>Marcusenius furcidens</i>				B3
	Fishes	<i>Parasicydium bandama</i>				B3
	Fishes	<i>Poropanchax rancureli</i>				B3
	Fishes	<i>Synodontis bastiani</i>				B3
	Fishes	<i>Synodontis punctifer</i>				B3
	Fishes	<i>Lepidarchus adonis</i>	A1b			B3
	Fishes	<i>Mormyrus subundulatus</i>	A1b	B1	B2	B3
	Molluscs	<i>Aspatharia droueti</i>				B3
	Molluscs	<i>Pettancylus eburnensis</i>				B3
Lower reaches of St. Paul River (fw5)	Crustacea	<i>Liberonautes paludicolis</i>		B1		B3
	Crustacea	<i>Globonantes macropus</i>	A1a	B1	B2	B3
	Crustacea	<i>Liberonautes nanoides</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Doumea chappuisi</i>				B3
	Fishes	<i>Epiplatys lamottei</i>				B3
	Fishes	<i>Scriptaphyosemion liberiense</i>				B3
	Fishes	<i>Monopterus boueti</i>		B1	B2	B3
	Fishes	<i>Paramphilius firestonei</i>	A1a	B1	B2	B3
	Fishes	<i>Callopanchax monroviae</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Coptodon coffea</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Clarias laeviceps</i>	A1b			
	Molluscs	<i>Bellamyia liberiana</i>	A1a,A1e	B1	B2	B3
Middle reaches of St. Paul River (fw6)	Crustacea	<i>Globonantes macropus</i>	A1a	B1	B2	B3
	Fishes	<i>Doumea chappuisi</i>				B3
	Fishes	<i>Epiplatys lamottei</i>				B3
	Fishes	<i>Scriptaphyosemion liberiense</i>				B3
	Fishes	<i>Nimbapanchax viridis</i>			B2	B3
	Fishes	<i>Epiplatys coccinatus</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Enteromius aliciae</i>	A1b			B3
	Fishes	<i>Enteromius huguenyi</i>	A1b			B3

Annex i – Potential freshwater KBA trigger species, cont'd

KBA name	Group	Species	Criterion A1	Criterion B1	Criterion B2	Criterion B3
Lower Volta eastern catchment (fw7)	N/A	N/A	N/A	N/A	N/A	N/A
Rhombe Swamp and Mouth of Little and Great Scarces Rivers (fw8)	Fishes	<i>Enteromius salessei</i>				B3
	Fishes	<i>Enteromius tiekoroi</i>				B3
	Fishes	<i>Malapterurus leonensis</i>				B3
	Fishes	<i>Paramphilius teugelsi</i>				B3
	Fishes	<i>Paramphilius trichomycteroides</i>				B3
	Fishes	<i>Scriptaphyosemion geryi</i>				B3
	Fishes	<i>Scriptaphyosemion etzeli</i>	A1a	B1	B2	B3
	Fishes	<i>Clarias laeviceps</i>	A1b			
	Fishes	<i>Enteromius teugelsi</i>	A1b			B3
	Molluscs	<i>Sierraia leonensis</i>				B3
	Molluscs	<i>Sierraia whitei</i>				B3
	Molluscs	<i>Afropomus balanoidea</i>	A1a			B3
	Molluscs	<i>Saulea vitrea</i>	A1b			B3
São Tomé (fw9)	Molluscs	<i>Neritilia manoeli</i>		B1	B2	
South East Niger Delta – near Calabar (fw10)	Crustacea	<i>Potamonautes reidi</i>	A1b	B1		B3
	Fishes	<i>Labeobarbus progenys</i>				B3
	Fishes	<i>Synodontis robbianus</i>		B1	B2	B3
Upper reaches of St. Paul River (fw11)	Fishes	<i>Doumea chappuisi</i>				B3
	Fishes	<i>Epiplatys lamottei</i>				B3
	Fishes	<i>Scriptaphyosemion liberiense</i>				B3
	Fishes	<i>Nimbapanchax viridis</i>		B1	B2	B3
	Fishes	<i>Epiplatys roloffii</i>	A1a	B1	B2	B3
	Fishes	<i>Enteromius melanotaenia</i>	A1a,A1e	B1	B2	B3
	Fishes	<i>Enteromius aliciae</i>	A1b			B3
	Fishes	<i>Nimbapanchax jeanpoli</i>	A1b		B2	B3
	Fishes	<i>Enteromius huguenyi</i>	A1b	B1		B3
Weeni creek – Grand Bassa County (fw12)	Crustacea	<i>Liberonautes grandbassa</i>	A1a,A1e	B1	B2	B3
West Niger Delta (fw13)	Crustacea	<i>Desmocarid bislineata</i>	A1a,A1e	B1	B2	
	Fishes	<i>Fundulopanchax deltaense</i>		B1	B2	
	Fishes	<i>Fundulopanchax sjostedti</i>	A1a		B2	
	Fishes	<i>Alestopetersius smykalai</i>	A1a	B1		
	Fishes	<i>Arnoldichthys spilopterus</i>	A1a	B1		
	Fishes	<i>Fundulopanchax gularis</i>	A1a	B1	B2	

Annex ii – KBA workshop participant

Table 9.4 List of organisations represented at each of the KBA training and validation workshops in western Africa. Source: Compiled by the report authors.

Country	Organisation
Nigeria	Nigerian Conservation Foundation (NCF)
	A.P. Leventis Ornithological Research Institute
	Michael Okpara University of Agriculture
	Wildlife Conservation Society (WCS)
	National Parks Service
	Federal Ministry of Environment
	University of Uyo
	Federal University, Dutse
	Wildlife Society of Nigeria (WISON)
	Federal Ministry of Environment – AEWA Focal Point
	Nigerian Institute for Oceanography and Marine Research
	University of Benin
	Rivers State University of Technology
	University of Lagos
	National Environmental Standards and Regulation Enforcement Agency
	Forestry Research Institute of Nigeria
	Nigerian Freshwater Fisheries Research Institute New Bussa
	Lake Chad Research Institute
	Nigerian Environmental Study/ Action team (NEST) – IUCN Member
	Obafemi Awolowo University, Ile Ife
	National Centre for Genetic Resources & Biotechnology (NACGRAB) – GBIF Coordination in Nigeria
	Nigerian Institute of Pharmaceutical Research & Development (NIPRD)
	Centre for Drylands Agriculture, Bayero University Kano
Ghana Wildlife Division	
Wildlife Conservation Society Nigeria	
Ghana	University of Ghana
	Resource Management Support Centre, Forestry Commission, Ksi
	Kwame Nkrumah University of Science and Technology
	CSIR, Box 38 Achimota, Ghana
	Botany Department, University of Cape Coast, Ghana
	University of Development Studies, Tamale Ghana
	University of Cape Coast
	Environmental Protection Agency
	GBIF
	Water Research Institute
	Fisheries Commission
	National Biosafety Authority
	Ghana Wildlife Society
	BirdLife
	CEPF
	A Rocha Ghana
	IUCN
	HerpGhana
	Save the Frogs
	Conservation Alliance
	Aqualife Conservancy
	Conservation International, Accra Ghana
	BirdLife West Africa
WAPCA	
Parliamentary Committee on Environment	

Annex ii – KBA workshop participant, cont'd

Country	Organisation
Sierra Leone	Sierra Leone Maritime Administration
	Sustainable Growth Cluster, United Nations Development Programme
	Water Resource Management Agency
	General National Mineral Agency (NMA)
	Environmental Protection Agency
	Ministry of Environment
	Ministry of Agriculture and Forestry
	Ministry of Water resources
	National Protected Area Authority (NPAA)
	Freetown City Council
	Western Area Rural District Council
	Institute of Marine Biology and Oceanography
	Forestry Department
	Office of the National Security (ONS-SL)
	Marine Police
	Ministry of fisheries and Marine Resources
	Conservation Society of Sierra Leone
	Planning Green Futures
	Environmental Foundation for Africa
	West Africa Fisheries Programme
	Biological Science Department, FBC
	Centre for Climate Change & Development
	FBC
	Natural Habitats Group
	Reptiles and Amphibian Programme, Sierra Leone
	The Headman, Tombo
	Wetlands International Africa
	Responsible Agricultural Investment, FAO/UN
	NPAA
	Ministry of Lands and Country Planning
National Fishery and Aquaculture Authority	
Liberia	Environmental protection Agency
	Forestry Development Authority
	Ministry of Agriculture
	Conservation International
	Wild Chimpanzee Foundation
	Fauna and Flora
	College of Agriculture and Forestry, University of Liberia
	Farmer Association to Conserve the Environment
	Mines and Energy
	Society for the conservation of Nature of Liberia
	Society for Ecosystem Conservation
	European Union
	United Nation Development Programme
	Friend of the Ecosystem and Environmental
	GEF (Point focal opérationnel)

Annex ii – KBA workshop participant, cont'd

Country	Organisation
Côte d'Ivoire	Rainforest Alliance
	Conservation Alliance
	Birdlife International/RSPB (SOS-Forêts)
	Eaux et forêts
	Environnement et Développement Durable
	Associations Villageoises
	UFEMCI
	OI-REN
	FEREADD
	OIPR
	SODEFOR
	Université Félix Houphouët – Boigny (Ichtyologie & Plancton & Macro-invertébrés)
	Université Nandjou Abrogoua (Ichtyologie & Herpétologie)
	Université Jean Lorougnon Guédé (Ornithologie)
	Centre de Recherche Ecologie
Ministry of Environment, Nature Protection & Sustainable Development (MINEPDED)	
Cameroon	Ministry of Forestry and Wildlife (MINFOF)
	Cameroon Wildlife Conservation Society(CWCS)
	African Marine Mammal Conservation Organization (AMMCO)
	Watershed Task Group (WTG)
	SUFACHAC
	Bivalves/Shrimp harvester & farmer
	Green Technologies Company (GRETECO)
	l'Université de Douala à Yabassi
	University of Buea
	Institut des Sciences Halieutiques
	Institut des Sciences Halieutiques de l'Université de Douala à Yabassi
	University Dschang

Chapter 10

A critical sites network for freshwater biodiversity in western Africa

Starnes, T. ¹

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10.1 Introduction

10.1.1 Systematic conservation planning

Since site-based conservation often competes with other human interests (Margules, Pressey & Williams, 2002) and funds for conservation are limited, it is not feasible to conserve all areas that contribute towards biodiversity. Spatial prioritisation can be used to identify areas where it is best to allocate these limited resources to receive the greatest conservation benefits (Knight et al., 2007), for example through designation of reserves (Hermoso et al., 2016), although these reserves should be considered in the wider context of the landscape (Irvine, 2015). The two objectives of reserve design are: i) representativeness – the adequate representation of the target conservation features (e.g. species, habitat types); and ii) persistence – the long-term survival of these conservation features through maintenance of natural processes and viable populations, and the exclusion or management of threats (Margules & Pressey, 2000). Historically, the selection of areas for reserves has often not been systematic. In some cases, areas that were remote or unproductive, and therefore not deemed to be of commercial importance, have been designated as reserves regardless of their biodiversity

value (Margules & Pressey, 2000). This often led to reserves that did not meet their objectives (Hermoso et al., 2011). In the 1980s, systematic conservation planning emerged in response to this problem (Nel et al., 2009).

Systematic conservation planning aims to identify an optimum network of areas in which explicit targets for conservation features are met, taking the cost of areas and other aspects of reserve design (e.g. individual reserve size, fragmentation) into consideration. Systematic conservation planning methods now generally use complementarity-based algorithms, where complementarity is the increase in representativeness of the network when a new area is added (Possingham, Ball & Andelman, 2000). This approach has been shown to result in solutions that are more efficient in terms of both cost and the representation of conservation features than alternative methods, such as ad hoc, scoring or ranking strategies (Margules, Pressey & Williams, 2002; Pressey & Nicholls, 1989; Pressey & Tully, 1994).

Although systematic conservation planning has been used extensively in the terrestrial realm, it has only more recently emerged in freshwater systems, with some alterations to consider the unique characteristics of these systems (e.g. hydrological connectivity) (Beger et al., 20w10; Dunn, 2003;

¹ Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

Equation 10.1 Marxan objective function equation

$$\text{objective function} = \sum_{\text{Planning Units}} \text{planning unit costs} + \sum_{\text{Conservation features}} (\text{SPF} \times \text{representation penalty})$$

Where BLM = boundary length modifier;

SPF = species penalty factor

Hermoso et al., 2011). Adoption of systematic conservation planning is vital for reserve design in the freshwater realm as at present protected areas (PAs) are rarely designated specifically for the conservation of freshwater biodiversity (Juffe-Bignoli et al., 2016), and existing PAs are largely ineffective for freshwater species and habitats (Abell, Allan & Lehner, 2007; Hermoso et al., 2016; Leal et al., 2020). Conversely, designing protected area networks for freshwater systems has been shown to be effective at also meeting terrestrial conservation goals (Leal et al., 2020).

We used the systematic conservation planning software Marxan (Ball, Possingham & Watts, 2009) to identify networks of sites within western Africa for the conservation of freshwater biodiversity, using existing Key Biodiversity Areas (KBAs) and PAs as a starting point. We identified networks for the conservation of freshwater species native to western Africa region. Here, we combine these to present an overall network considered optimal for the conservation of freshwater biodiversity. We highlight sites in the region which were identified by the systematic conservation planning analysis but which fall outside of the current network of KBAs and PAs.

We recognise that many other factors, such as land use, will also need to be considered in order to create an optimal conservation network representing freshwater biodiversity across the region. The objective here is to demonstrate the potential value of this approach now that we have a robust spatially resolved baseline for the region's freshwater species. We encourage environmental planners to develop this approach further, employing these additional data layers.

10.2 Methods

10.2.1 Marxan

We used the conservation planning software Marxan (Ball, Possingham & Watts, 2009) to identify networks meeting targets for the conservation of freshwater biodiversity. Marxan uses simulated annealing (a heuristic algorithm) to identify a near-optimal network of sites that meets

user-defined biodiversity targets at the lowest cost (see 10.2.3.1 Cost). Marxan compares potential networks of sites using the objective function (Equation 10.1), with a lower objective function value indicating a more efficient network in terms of meeting the biodiversity targets for the lowest cost. The first term in the general objective function is the sum of the costs of each planning unit (site) in the network. The second term is the sum of the boundary lengths of each planning unit, multiplied by a modifier that allows the degree of fragmentation of the network (i.e. whether planning units are clustered or dispersed) to be controlled. The third term is the penalty applied if conservation features are not represented at their target levels. The final term penalises the network if it passes a set cost threshold. The first and third terms are required, whereas the second and fourth are optional (Game & Grantham, 2008) and were not applied in this case.

10.2.2 Conservation features

Conservation features are the elements of biodiversity that are the focus of the network. The conservation features for this analysis were freshwater species native to western Africa in the following taxonomic groups: decapods (crabs and shrimps), fishes, molluscs, odonates (dragonflies and damselflies) and aquatic plants (see Chapter 2).

10.2.3 Planning units

We selected all level 8 HydroBASINS draining into the western Africa region. This comprised 10,137 level 8 HydroBASINS covering an area of 6,580,930 km². The median area per HydroBASIN was 443 km², including 232 lakes and lagoons ranging from 10 km² to 23,000 km² (median 23 km²).

10.2.3.1 Cost

When running Marxan, a cost needs to be specified for each planning unit, which is the value added to the objective function when the planning unit is included in a network. Estimates of the financial cost of each planning unit were not available for this study. Instead, we used the area of and the degree of anthropogenic impact within planning units.

In the first scenario (Scenario A), planning units were assigned no cost. This scenario represents a ‘blank slate’ network of the minimum number of planning units required to conserve threatened freshwater biodiversity regardless of costs related to the size of planning units or the level of anthropogenic impact therein.

The remaining scenarios used a cost index based on the planning unit area and the degree of anthropogenic impact within them. The Global terrestrial Human Footprint (HFP) is a global 1 km² resolution map of human pressure on the environment including built environments, population density, electric infrastructure, crop and pasture lands, communications infrastructure (Venter et al., 2016). As the name suggests, the HFP is based on terrestrial pressures and may not account for some of the major threats to freshwater species such as aquatic pollution, invasive non-native species and drought caused by climate change. The HFP is calculated for 1993 and 2009. We used the 2009 HFP which is still commonly in use (Jones et al., 2018; Linke et al., 2019; Venter et al., 2016), recognising that this is now quite out of date, particularly in a rapidly developing region such as western Africa. Given that there are multiple 1 km² HFP values in each planning unit, the mean HFP value was calculated for each planning unit.

The HFP dataset is based primarily on terrestrial data layers. Parts of some lakes e.g. Lake Volta have a HFP score of zero, but this does not necessarily mean that there is no anthropogenic impact there. Many of these lakes are themselves artificial reservoirs and so by definition they are the result of anthropogenic pressures. Lake Chad also has a large area of no data. In both cases, there are at least some HFP data points within each lake and so it was still possible to calculate a mean HFP score based on the available data points.

The mean HFP value relative to the maximum mean HFP value in western Africa was then calculated per planning unit to produce an index ranging from 0 to 1. Similarly, the area of each planning unit relative to the maximum area of planning units (Lake Chad, 23,006 km²) was calculated to produce an index from 0 to 1. The mean of these two indices was then calculated to produce the planning unit cost (Figure 10.1). Thus, planning unit area and HFP are weighted equally. Use of this planning unit cost shifts the focus to finding a network with the lowest levels of anthropogenic impact and the smallest area. This is a proxy for the ‘cost’ of conserving these areas. Conversely, another approach might be to target areas of high anthropogenic impact for ecosystem restoration.

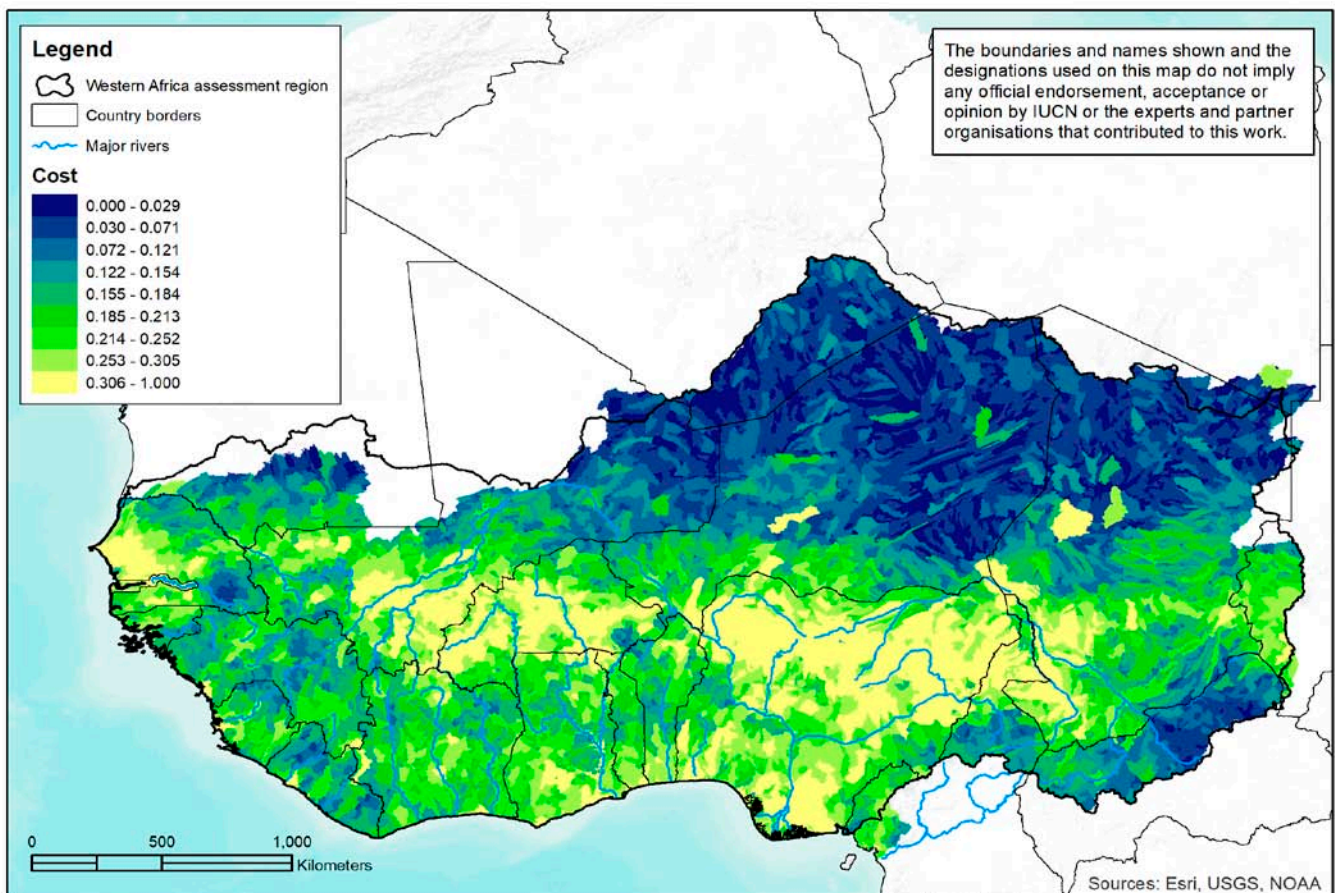


Figure 10.1 Planning unit cost – relative Human Footprint Index x relative area in km². Source: Compiled by the report authors using data from Lehner & Grill (2013) and Venter et al. (2006).

Equation 10.2 Equation for cost of planning units following method B

$$\text{cost } B = \text{relative area of planning unit (km}^2\text{)} \times \text{relative Human Footprint (HFP) score}$$

10.2.3.2 Locking in existing management units

When using Marxan it is possible to lock particular planning units in or out of the final network, meaning that the planning units are fixed into or excluded from, respectively, the final network. In some scenarios, we locked in planning units representing different combinations of existing management units, again in order to compare results between ‘blank slate’ networks (i.e. with no locked in planning units), those including areas currently identified as important for freshwater biodiversity (i.e. locked in freshwater KBAs) and those including areas currently identified as important for other biodiversity (i.e. locked in existing KBAs and PAs). This also allowed us to identify any additional planning units required to meet targets. These additional planning units represent gaps in the current network of existing management units and so represent priority sites to include in the network if the targets for conservation of freshwater biodiversity are to be met.

As discussed, level 8 HydroBASINS were used as planning units in this analysis. However, in general, KBAs and PAs are not delineated to HydroBASINS or grid cells and therefore, we were required to select planning units that represented these management units when there was not a one-to-one match. Note that freshwater KBAs are often delineated to HydroBASINS but generally at a higher resolution (e.g. level 10 or level 12 HydroBASINS) in order to focus actions on site based priorities.

We classed a planning unit (HydroBASIN) as being an existing management unit if over 50% of the area of the planning unit was covered by an existing management unit. This classification was done separately for:

- Protected areas – 1,486 planning units were selected covering 852,607 km² or 13% of the region.
- KBAs – 854 planning units were selected covering 483,619 km² or 7% of the region. Of these, 630 planning units were both protected areas and KBAs.
- All management unit types (all of the above) – 1,710 planning units were selected covering 973,780 km² or 15% of the region (Figure 10.2).

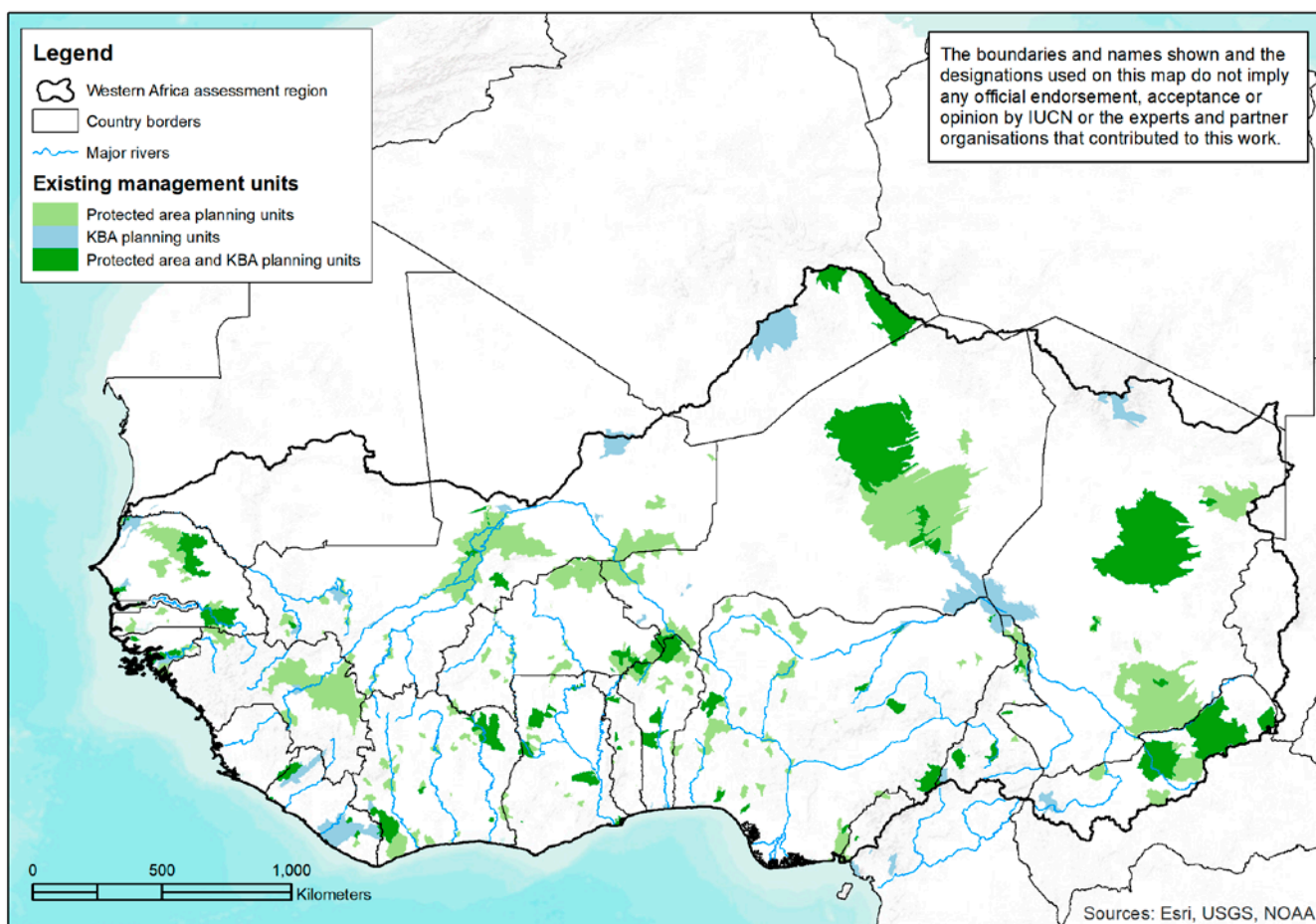


Figure 10.2 Existing management units assigned to planning units. Source: Compiled by the report authors using data from BirdLife International (2021), Lehner & Grill, 2013) and UNEP-WCMC (2021).

Due to the 50% threshold for area of overlap for locking in planning units, many of the smaller existing management units (e.g. Forest Reserves) are not represented by corresponding planning units. However, this threshold was found to be the best trade-off between including existing management units and not locking in planning units of which only a small area was covered by management units.

The 13 CEPF freshwater KBAs were not 'locked in' to the site network as they are not confirmed KBAs, most require boundary modifications pending further ecological surveys. However, we do report in the results which of the CEPF freshwater KBAs are identified in the final planning scenario, in effect 'backing up' their importance for inclusion in protected and conserved area networks. Those sites which are potentially AZE sites (containing the entire global population of an EN or CR species) are included as irreplaceable sites in the analysis by definition of the target for inclusion of at least one planning unit per threatened species.

10.2.4 Conservation features versus planning units

10.2.4.1 Current species distributions

We used the spatial data produced through the Red List assessment process (see Chapters 3–7) to map freshwater species distributions to planning units. Spatial data coded as Presence 1 (Extant) and Origin 1 (Native) or Origin 2 (Reintroduced) (see Chapter 2) were included in the analysis. Because freshwater species distributions are mapped to HydroBASINS, the Red List spatial range data are already made available as HydroBASIN tables. All planning units where any given species occurred were given an abundance value of one for that species.

10.2.5 Marxan configuration

10.2.5.1 General settings

As recommended in Game and Grantham (2008), we ran Marxan using simulated annealing followed by two-step iterative improvement, with the main parameters of the algorithm set at their default values. We ran each scenario 1,000 times and used the selection frequency of each planning unit as a measure of its irreplaceability in the network. Planning units that were selected in over 990 runs (over 99%) were considered irreplaceable because their inclusion was required in all networks for which the targets are met at a low cost.

10.2.5.2 Species penalty factor

The Species Penalty Factor (SPF) influences how high a penalty is applied to the network if conservation feature targets are not met. The SPF was set at the high value of 100 to ensure that conservation feature targets were always met.

An alternative approach would be to adjust the SPF to allow a compromise between meeting the conservation feature targets and the overall network cost.

10.2.5.3 Scenarios

Three different scenarios were run using different input parameters:

- A. 'Blank slate' networks using no planning unit cost and no locked in planning units.
- B. Networks using cost A (Equation 10.2, Figure 10.1) and no locked in planning units.
- C. Networks using cost A (Equation 10.2, Figure 10.1) with 1,486 planning units representing protected areas locked in.
- D. Networks using cost A (Equation 10.2, Figure 10.1) with 1,710 planning units representing protected areas and KBAs locked in.

10.3 Results

For each scenario, maps displaying the network meeting the biodiversity targets for the least cost (i.e. the run with the lowest objective function value) were produced.

Within this chapter, we discuss the network resulting from the best runs using the input parameters for each scenario to consider current land use and potential management and to demonstrate how we might use the biodiversity data generated through this project to identify an optimal site network for conservation of freshwater species. As noted above, when applying this method in practice it will be important to include other data sets, such as existing land management, legal and customary ownership and tenure, concessions and national spatial planning strategies, to come up with an optimal network employing the systematic conservation planning approach demonstrated here.

First, let us consider Scenario A, in which no planning unit cost was specified. Some 122 planning units were identified as being the minimum set of planning units required to meet the species targets (Table 10.1). This scenario does not account for the area or the human footprint within those planning units. The total area required by these planning units was 125,958 km² and the nominal cost was 4.9 (Table 10.1). Scenario B accounted for the area and human footprint within the planning units by using a planning unit cost (Equation 10.2, Figure 10.1). In this scenario, 65 planning units were retained from Scenario A; including 30 'irreplaceable' planning units that were required in each instance to meet the targets (see section 10.3.1). Some 57 planning units from Scenario A were 'dropped' and 64 planning units were added in. This resulted in a network which meets the species

Table 10.1 Results of Marxan analysis for scenarios A–D. Source: Compiled by the report authors.

Scenario	Cost Type	Locked in PUs	Number of locked in PUs	Number of species adequately represented by locked in PUs	Number of PUs in solution	Number of additional PUs	Locked in cost	Total cost	Additional cost incurred	Locked in area (km ²)	Total area in solution (km ²)	Additional area required (km ²)
A	None	None	0	0	122	122	0	4.9	4.9	0	125,958	125,958
B	A	None	0	0	129	129	0	3.3	3.3	0	87,254	87,254
C	A	PAs	1,486	41	1,582	96	16.9	19.9	3.0	852,607	931,217	78,610
D	A	PAs and KBAs	1,710	67	1,797	87	19.6	21.6	2.0	973,780	1,027,141	53,361

targets but which covers a smaller area of 87,254 km² and a lower cost of 3.3 (Table 10.1). By selecting slightly more planning units with a lower total area and human footprint (i.e. a lower cost), Scenario B represents a more efficient network for including the targets for representation of threatened freshwater species in western Africa.

Next, we consider scenarios C and D, in which planning units with existing management are ‘locked in’. Scenario C used the same parameters as for Scenario B, except that 1,486 planning units representing protected areas were ‘locked in’ to the network. These planning units covered an area of 852,607 km² and the targets for 41 of the 194 freshwater species were already met within these planning units (Table 10.1). The best solution for Scenario C resulted in an additional 96 planning units being selected in the optimal sites network, covering an area of 78,610 km² and at a cost of 3.0, in order to meet all species targets.

Scenario D used the same parameters as for Scenario C, except that an additional 224 planning units representing KBAs were locked in to the network. These combined 1,710 planning units covered 973,780 km² and the targets for 67 of the 194 freshwater species were already met within these planning units (Table 10.1). The best solution for Scenario D resulted in an additional 87 planning units being selected in the optimal sites network, covering an area of 53,361 km² and at a cost of 2.0, in order to meet all species targets. Several of these planning units included eight of the 13 CEPF freshwater KBAs discussed in Chapter 9 (excluding Rhombe Swamp, Upper St Paul River, Lower Volta Eastern Catchment, South East Niger Delta and São Tomé), as well as other potential freshwater KBAs and including all of those planning units containing potential AZE sites (which are irreplaceable sites in these scenarios).

10.3.1 Irreplaceability

The target for each species was presence in at least two planning units, except for 37 species occurring only in a single planning unit, for which the target was presence in one

planning unit. These 37 species were distributed between 22 planning units, and these planning units were effectively ‘locked in’ by definition of the target requiring their inclusion in any given solution (Figure 10.5). Most of these planning units represent the only known locality for these 37 species globally, of which 35 species are assessed as EN or CR, and therefore by definition have potential to yield AZE sites (meeting KBA criterion A1e). Confirmation of AZE sites in these planning units will require field surveys to confirm species’ presence (see Chapter 9).

An additional 12 species each occurred in only two planning units. Therefore, there was also only one option to meet these species’ targets i.e. inclusion of both of the planning units for each of these species. This resulted in an additional eight planning units being implicitly locked in to the network. Ultimately, 30 ‘irreplaceable’ planning units representing 49 restricted range species occur in every network where the targets are met.

10.3.2 Gaps in the current network

Based on Scenario D, the target of one or two planning units per threatened freshwater species was already met by the existing protected area and KBA networks for 67 of 194 species. The presence and importance of any freshwater species known to occur at these sites should be communicated to the site managers, and management strategies aimed at these freshwater biodiversity elements should be developed and implemented. An additional 87 planning units (with a combined area of 78,610 km²) are outside of the KBA and PA networks (Figure 10.4), and these sites represent the most important gaps, with respect to the conservation of threatened freshwater species, in the current network of sites. We advise that this network of gap sites be used in conjunction with other KBA scoping methods (Spiliopoulou, 2021) as a scientific basis for the development and expansion of the existing KBA and protected and conserved area network, including OECMs, in order to ensure that freshwater biodiversity is better represented and protected.

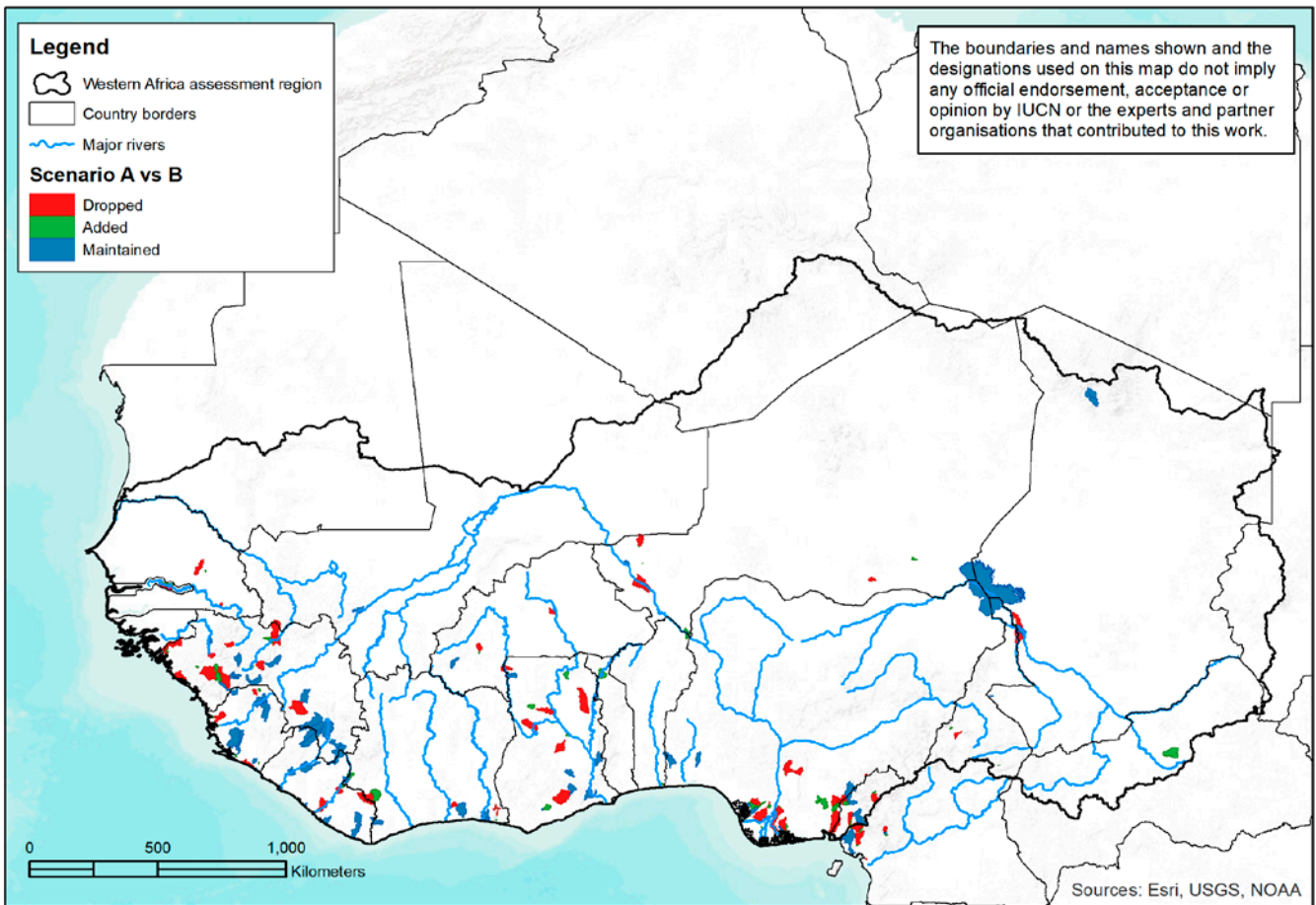


Figure 10.3 Scenario A vs Scenario B spatial conservation prioritisation networks. Source: Compiled by the report authors.

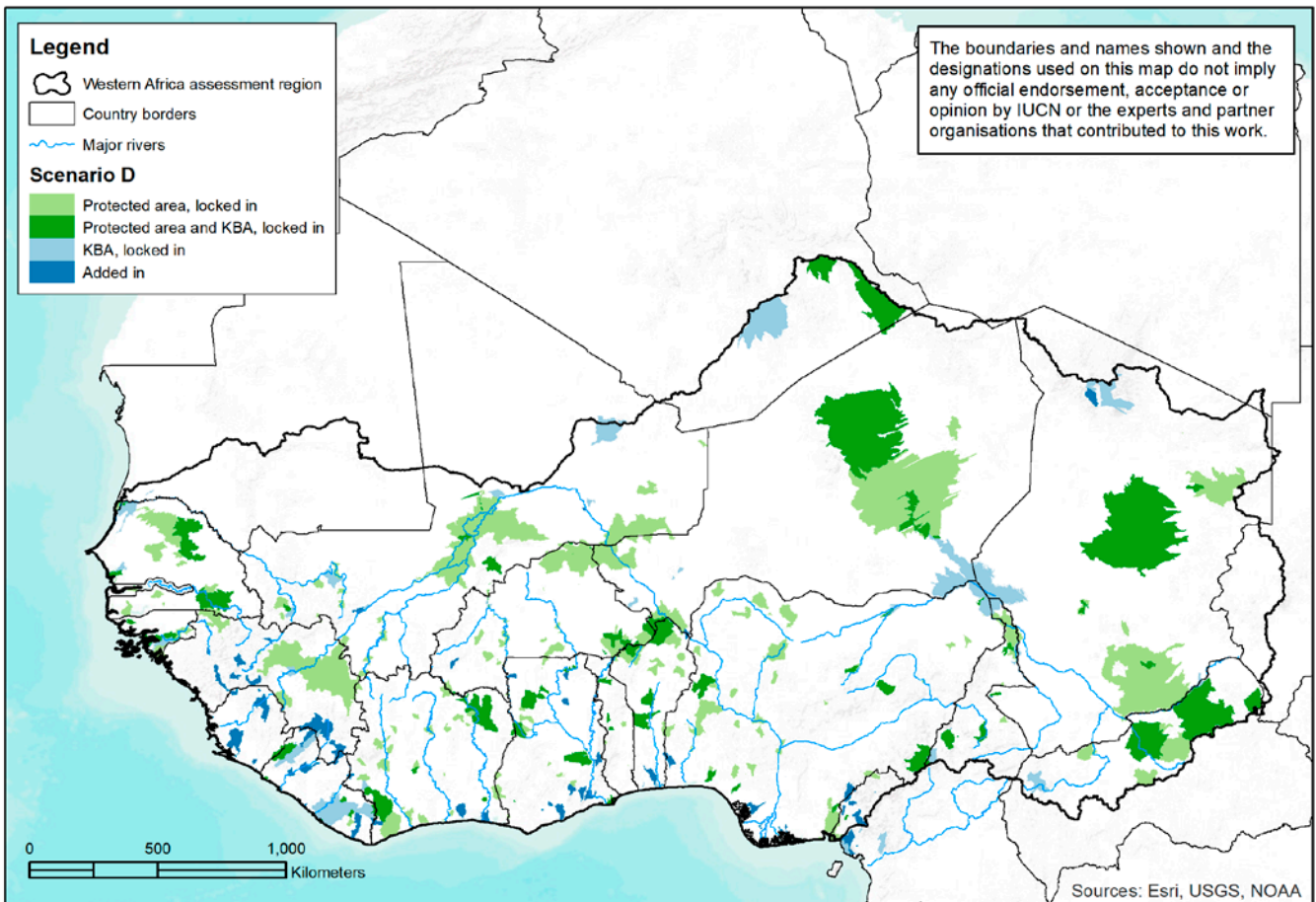


Figure 10.4 Scenario D spatial conservation prioritisation network. Source: Compiled by the report authors.

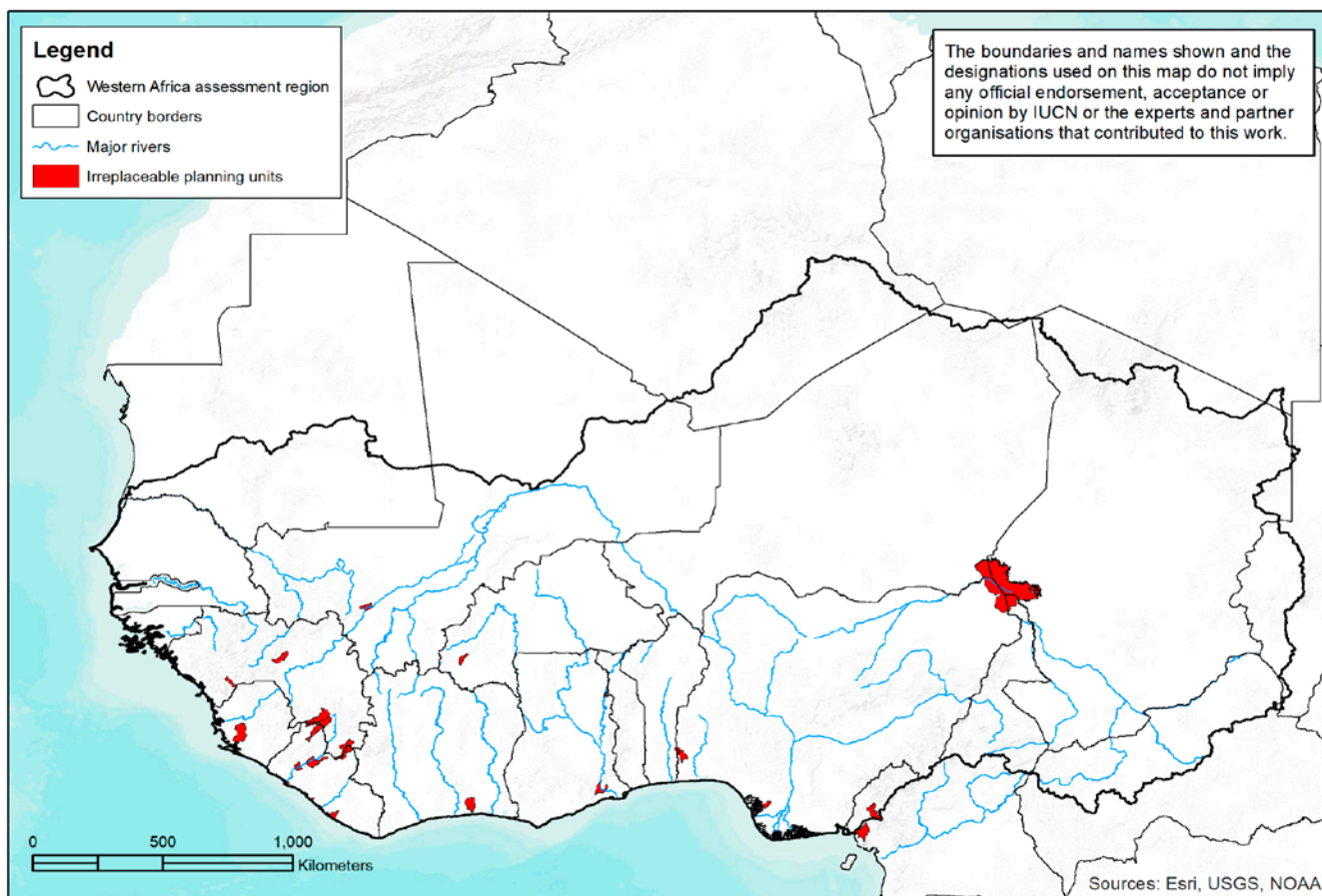


Figure 10.5 Planning units representing the only known localities for 37 freshwater species in western Africa. Source: Compiled by the report authors.

10.4 Caveats

In this analysis, species were considered equally abundant across all planning units where indicated to be present, although this is probably an incorrect assumption based on the species-area relationship. This assumption was followed because the IUCN Red List spatial data used to inform whether species were present in planning units only indicate presence and not the species' distribution within a spatial unit. Population abundance data are lacking for the majority of freshwater species and this is an area requiring further research.

Because of the way in which planning units were categorised as representing KBAs and protected areas (i.e. if $\geq 50\%$ of the planning unit was covered by a KBA or protected area), the presence of protected areas and Key Biodiversity Areas within planning units does not guarantee that they coincide with the freshwater biodiversity elements. Furthermore, the presence of threatened freshwater species within KBAs and protected areas does not guarantee their survival in those localities. In addition to identifying gaps in the protected area network for freshwater species, it will be of vital importance to ensure the inclusion of freshwater biodiversity elements in protected area management plans and in KBA factsheets.

The management category or effectiveness of protected areas was not taken into account in this analysis. Of the 2,266 protected areas in the region, just 18% had an IUCN protected area management category assigned. Some designations such as Forest Reserves are likely not to be effectively conserving freshwater biodiversity in those areas, but these areas were implicitly not included in planning unit designation on the basis of their small size not amounting to 50% coverage within planning units.

We did not promote spatial clustering of the site network by use of a Boundary Length Modifier (BLM) as is sometimes used in Marxan analyses, nor did we use a Connectivity Strength Modifier (CSM) (Hermoso et al., 2011; Maíz-Tomé, Sayer & Darwall, 2018; Sayer, Maíz-Tomé & Darwall, 2018). We would encourage these parameters be considered in any attempt at a systematic spatial conservation prioritisation which builds on what we have demonstrated here.

10.5 Conclusions

Through this analysis, we have demonstrated how data from the Red List assessments presented in Chapters 3–7 can be used in conjunction with other spatial data to identify

optimal networks of sites for the conservation of threatened freshwater biodiversity within western Africa, according to a number of different criteria whilst building on the existing KBA and PA network. We emphasise that this exercise serves as a demonstration of the use of Red List and other datasets to identify gaps in the current protected area network for freshwater species and that further work building on this approach would be required to inform policy decisions.

We have identified 87 planning units representing gaps in the current network of KBAs and protected areas, and 30 irreplaceable sites for threatened freshwater species conservation. We note that, in addition to formal protected areas, Other Effective Area-based Conservation Measures (OECMs) may be an effective means of conserving freshwater biodiversity at some of the sites identified here, and these will play an increasingly important role over the next decade (Alves-Pinto et al., 2021; Donald et al., 2019). We hope that this exercise serves as a useful demonstration to be used as a basis for a more inclusive application of the systematic conservation planning approach to help inform future development and expansion of the existing KBA and protected area networks for freshwater biodiversity throughout the region.

This report will be disseminated, together with a policy brief, to relevant stakeholders across the region by the IUCN PACO Central and West Africa Office, as well as to the 120 KBA workshop participants and their institutions.

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