

Article

Fishes of the Lower Lulua River (Kasai Basin, Central Africa): A Continental Hotspot of Ichthyofaunal Diversity under Threat

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Abstract: The ichthyofauna of the Lulua River, a large right bank tributary of the Kasai River in central Africa, is among the most poorly documented in the Kasai ecoregion. To remedy this lack of knowledge, sampling was carried out between 2007 and 2014 along the main channel and in many tributaries. A total of 201 species distributed in 81 genera, 24 families, and 12 orders are reported from the lower reaches of the Lulua. The species richness reported in this study represents a substantially improved documentation of the Lulua ichthyofauna (historically estimated at only 79 species). Here, 129 species are recorded for the first time, bringing the total number of known species to 208. Among these, five have recently been described: *Raiamas brachyrhabdotos* Katemo Manda, Snoeks, Choca Manda, and Vreven 2018, *Distichodus kasaiensis* Moelants, Snoeks, and Vreven, 2018, *Distichodus polli* Abwe, Snoeks, Choca Manda, and Vreven 2019, *Epiplatys attractus* Van Der Zee, Mbimbi, and Sonnenberg 2013, and *Hypsopanchax stiassnyae* Van Der Zee, Sonnenberg, and Mbimbi 2015; numerous additional taxa are currently under investigation. Recognized here as a continental hotspot of ichthyofaunal diversity, the Lulua is under extreme threat from exploitation of forest products for building materials, deforestation for shifting agriculture and charcoal exploitation, destructive fishing practices, and mining, all of which are rapidly increasing in the watershed. The present study provides baseline documentation for use in conservation planning and future developmental projects in the Kasai ecoregion in general and Lulua River basin in particular.

Keywords: fish diversity; Congo Basin; Kasai River; biogeography; taxonomy; threatened species

Citation: Mbimbi Mayi Munene, J.J.; Stiassny, M.L.J.; Monsembula Iyaba, R.J.C.; Liyandja, T.L.D. Fishes of the Lower Lulua River (Kasai Basin, Central Africa): A Continental Hotspot of Ichthyofaunal Diversity under Threat. *Diversity* **2021**, *13*, 341. <https://doi.org/10.3390/d13080341>

Academic Editor: Simon Blanchet

Received: 3 July 2021

Accepted: 22 July 2021

Published: 26 July 2021

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1. Introduction

The Congo Basin (CB) comprises an immense hydrographic network with a wide variety of habitats hosting an extremely diverse fish community currently estimated at 1270 species, of which over 75% are considered basin endemics [1–3]. Second only to the Amazon in terms of volume, the CB drains an area of about 3.7 million km² of Central Africa [4,5], and its location on both sides of the Equator results in the Congo River (CR) discharging an almost constant volume of 1308 km³ [6] of freshwater into the Atlantic Ocean (AO). From its source in the savanna highlands of the Lualaba and Haut-Katanga provinces in southeastern Democratic Republic of the Congo (DRC) to its mouth in the western Kongo Central province, the main channel of the CR flows through 4374 km [5] generating a high diversity of macro- and microhabitats including falls, rapids, swamps, pools, floodplains, flooded forests, lakes, deep rocky substrates, and a short estuarine

reach. Along its journey to the AO, in the western basin, the CR is joined by large tributaries such as the Lulonga, Ruki, Ubangi, Sangha, Alima, Lefini, Kwa-Kasai, N'sele, and Inkisi that greatly increase its hydrographic and habitat complexity. The alternation of macro- and microhabitats creates perfect conditions for isolation of fish populations that may accelerate the processes of speciation even at remarkably small geographic scales [7,8]. Despite such high levels of species richness and endemism, it is recognized that several areas of the CB remain underexplored [9], and their respective ichthyofauna are poorly documented [10]. Therefore, the number of fish species currently reported from the CB is certainly underestimated and fails to capture the true ichthyofaunal diversity in the basin.

Historically, ichthyological exploration of the CB dates to the late 19th century [11] but is characterized by unequal sampling across the basin [12]. Paugy [11] reported that one of the earliest fish collecting efforts in the CB was that of N.E. Ballay between 1882 and 1885. Later numerous expeditions, such as those of P.S. de Brazza (1883–1886), M.A. Greshoff and M.P. Delhez (1899), and H. Lang and J.P. Chapin (1907–1915), have contributed to large collections of specimens housed in the Muséum National d'Histoire Naturelle (MNHN), Paris, the Africa Museum (MRAC), Tervuren, the American Museum of Natural History (AMNH), New York, and the Natural History Museum (NHMUK), London. Many of those collections formed the basis for G.A. Boulenger's influential work on the fish fauna of the CB [13]. From 1929 through the early 1980s, several other studies (e.g., [14–22]) further documented the ichthyofauna of the CB. However, most collecting efforts were undertaken in the CR main channel, some associated lakes, and a few easily accessible tributaries, leaving several major tributaries and sub-tributaries virtually unexplored. This situation has made it very difficult for the scientific community to estimate with precision the true ichthyofaunal diversity of the CB. To improve this situation, the last decade has seen increasing efforts to explore and document under-sampled affluent tributaries of the CR (e.g., [23–31]). However, parts of the CB, particularly those of the Kasai ecoregion, in addition to being seriously impacted by ongoing deforestation and mining activities, remain poorly known [10].

The Kasai ecoregion [32], composed of the Kasai River (KR) and its main tributaries (Kwango, Kwilu, Loange, Lulua, and Sankuru), is one of the largest ecoregions of the CB and, likely due to the presence of numerous rapids and falls that restrict fish movement, is estimated to have a high level of endemism [3]. However, as already noted, this ecoregion remains underexplored, and the occurrence and distribution of many fish species remain uncertain. The lack of documentation for many tributaries and sub-tributaries of the KR constitutes a major deficit in our knowledge of fish biodiversity of CB.

An accurate accounting of species diversity is, therefore, of central importance for data-based conservation and sustainable development efforts. As such, species discovery and description remain fundamental tasks for advancing biodiversity studies in poorly documented regions such as the central CB where considerable diversity remains to be documented [33,34]. This study was carried out as part of the Congo Project initiated by the American Museum of Natural History (AMNH), in partnership with the University of Kinshasa (Democratic Republic of Congo) and the University of Marien Ngouabi (Republic of Congo), to assess ichthyofaunal diversity in the middle and lower reaches of the CRiver. Here, we provide an inventory of fish species of the lower reaches of the LR, the distributions of these species across that portion of the river and the KR, and the anthropogenic activities that constitute the main threats to that ichthyofauna and the ecological integrity of the basin.

2. Materials and Methods

2.1. Study Area

The LR catchment covers a surface area of about ca. 71,400 km² and extends between 4.764° and 11.111° S and between 21.111° and 24.119° E. The river originates in the Lualaba Province in the southeast of the Democratic Republic of Congo near the Angolan border at an elevation of about 1200 m asl [35], and it gradually descends the Katanga plateau (a northward extension of the Kalahari plateau) crossing the Central Kasai Province to merge with the main channel of the Kasai River at about 58 km downstream of the city of Luebo in the Kasai Province. From its headwaters, near the boundaries of the Upper Zambezi and Lualaba ecoregions (Figure 1), to its confluence (at about 386 m asl) with the KR, the Lulua flows over a distance of 1256 km, characterized by high geomorphological complexity [36], resulting in extensive habitat heterogeneity along its main channel including numerous rapids, pools, small and large tributaries, large floodplains, and perennial and permanent swamps [37,38]. The numerous rapids divide the main channel of the LR into several alternating sections of low (muddy and deep) and fast current (rocky and shallow).

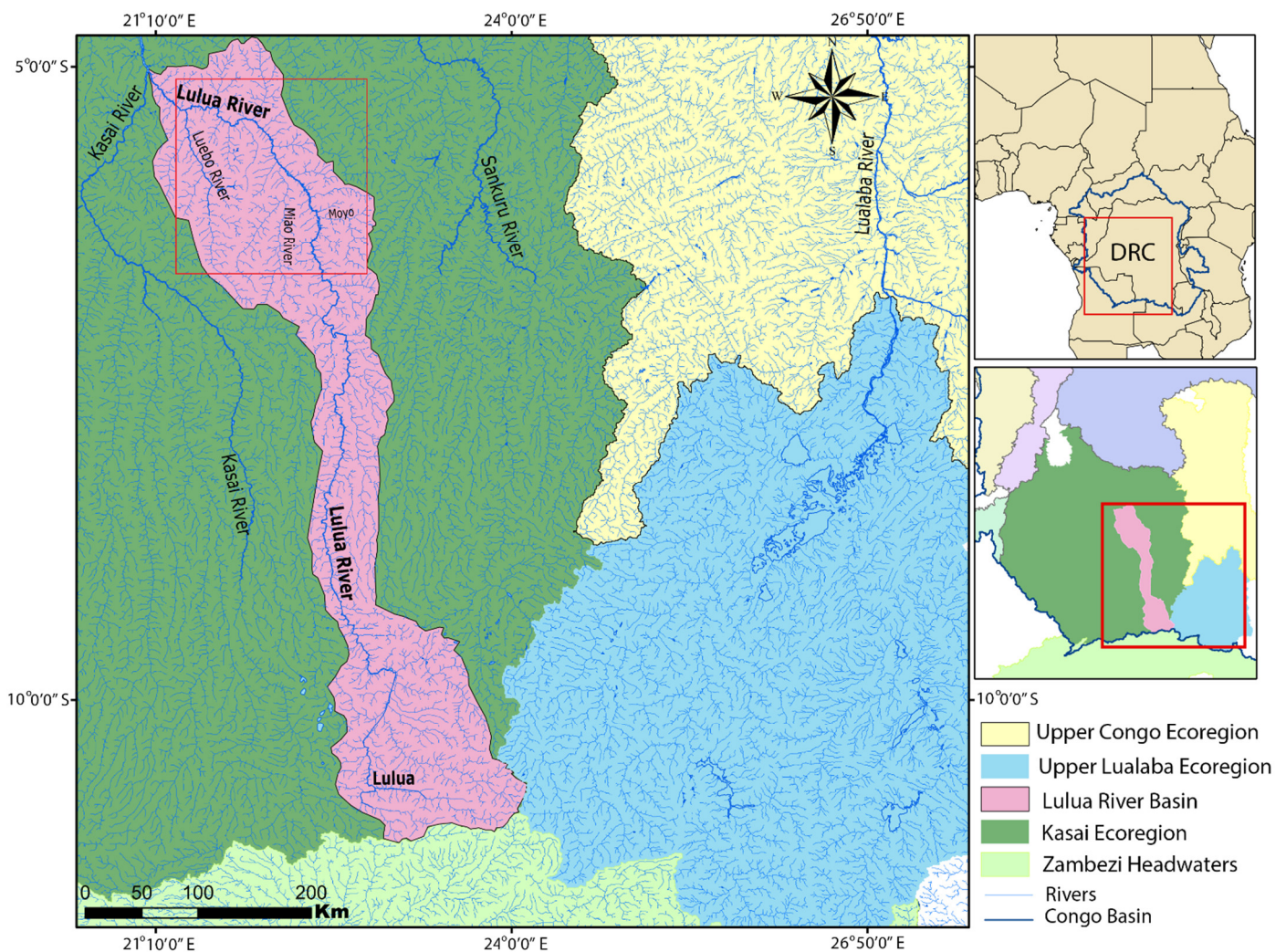


Figure 1. Map of the Lulua River showing the location of the Lulua catchment in the Kasai ecoregion of the Congo Basin and neighboring ecoregions. The red rectangle indicates the part of the lower LR where this study was conducted.

The LR is under a tropical savanna climate characterized by two main seasons: a longer wet season (from October to early May) and a shorter dry season from (mid-May

to mid-September). The basin receives an annual rainfall that varies between 1259 and 1750 mm [39].

On the basis of its elevation profile, we divided the LR into three sections: Upper, Middle, and Lower Lulua (Figure 2). The Upper Lulua is about 260 km long, flowing from its source near the Angolan border to Kusununu, about 160 km upstream of the city of Sandoa (Sanduwa), where a significant expansion, from about 200 m to over 1000 m, of the river's floodplain is noted. Following the classification of McManamay and Derolph [40], that section of the river has a low stream gradient with an average of 2.19 m/km (0.22%). With a length of about 660 km, the Middle Lulua is the longest section of the river and stretches from that first expansion of the floodplain to the Mbumba rapids (just upstream of Mwana Nanga at about 336 km from the Lulua outflow into the Kasai) marking the beginning of a long series of rapids. The Middle Lulua is characterized by a very low stream gradient with an average of 0.215 m/km (0.022%). From the Mbumba rapids, the river flows again in a low-gradient zone, marking the beginning of the Lower Lulua, before flowing through a very low stream gradient as it joins the Kasai. That stretch of the river is about 336 km long and can be divided into two subsections. The first subsection is about 200 km long starting from the Mbumba rapids to the vicinity of Muebela and has an average stream gradient of 1.62 m/km (0.162%), with several rapids and localized braiding of the channel. The last 136 km of the LR, which constitutes the second subsection of the Lower Lulua and its estuary, is characterized by a flattening of stream gradient with an average of 0.188 m/km (0.0188%). In this stretch, the LR is joined by its largest and longest tributary, the Kaluebo or Luebo River.

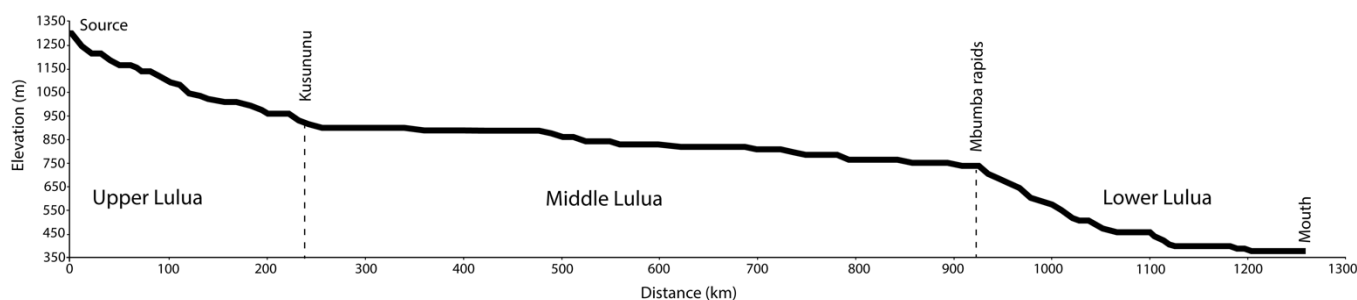


Figure 2. Longitudinal profile of the Lulua River and its subdivision into three sections based on the channel slope gradient.

Notes on Collection Sites

A total of 43 sites were sampled along the lower reaches of the LR including 13 main channel sites, 20 tributaries, and 10 sub-tributaries, as reported in Table A1 and Figure 3. Most main channel sites are in areas of river braiding and rapids (Figure A1), except sites 1 (Luebo), 3 (Nsanga Nyembo), and 9 (Ntumba). Typically, the sampled sites are characterized by shallow habitats with a rocky substrate and fringing sandy beaches. The river flow in these sections is very rapid, generating numerous cascades, rapids, and waterfalls, and vegetal cover is predominately forest islands and woody riparian savannas. Water pH is slightly acidic with an average of 6.65 but can drop to 5.5 (at Dijiba, Site 6). However, a basic pH of 8 was recorded at Site 12 (Kabeya Nsaka) during the dry season. Collecting sites located on tributaries and sub-tributaries are more diverse, ranging from large channels of 35–63 m width (Kaluebo, Miao, and Moyo Rivers) to small creeks of less than 5 m width (Kasonga, Nkalala, and Tukomba Creeks). The pH in these tributaries is generally slightly acidic but varies from 5.5 (Luyenga River) to 7.1 (Kapelekese River). The substrate is also highly diverse, alternating among rocky, muddy, sandy, and leaf covered depending on location along channels (Figure A2).

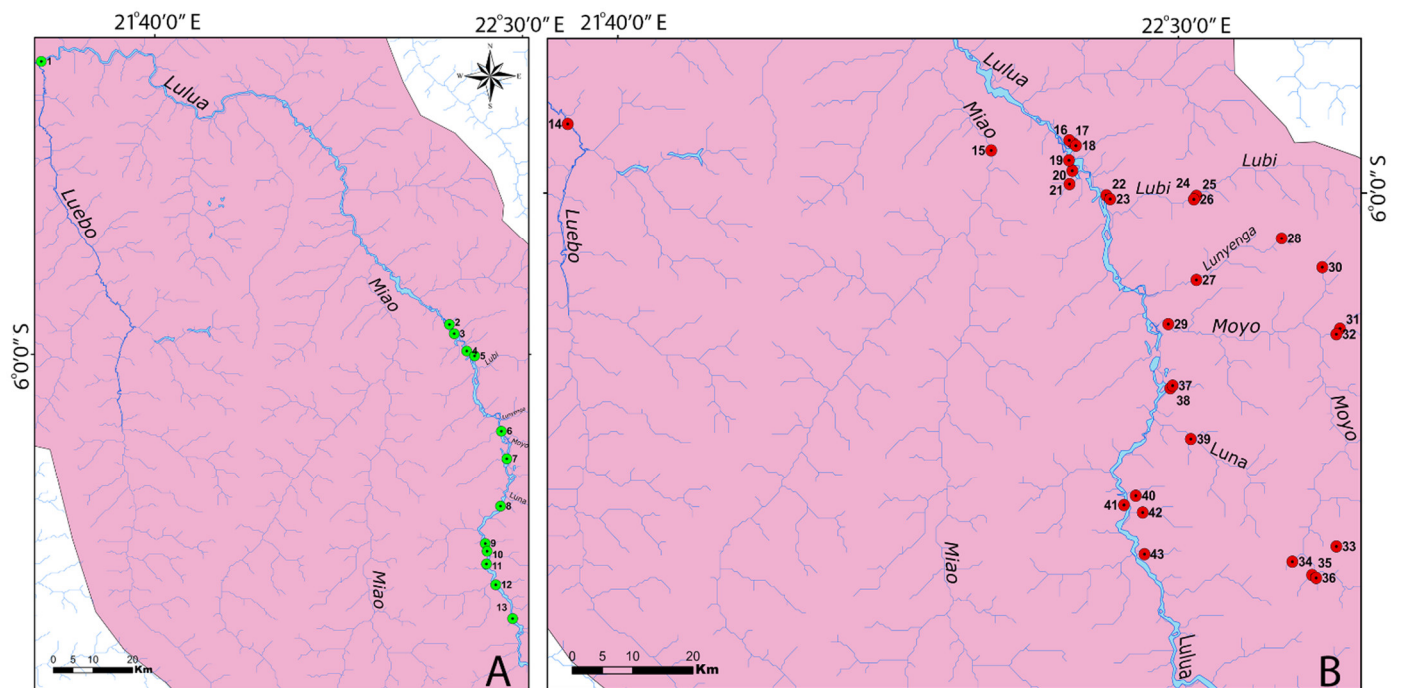


Figure 3. Map of the LR sampling sites: (A) green circles, main channel sites; (B) red circles, tributary and sub-tributary sites.

2.2. Ichthyofauna Sampling

A total of six field expeditions, each a month long, were undertaken between 2007 and 2014: the first, during the rainy season in December 2007; the second, at the beginning of the dry season in June 2008; the third, during the rainy season in February 2010; the fourth, during the dry season in July 2010; the fifth, at the end of the dry and the beginning of rainy season in September 2011; the sixth, in September 2014. At each site, a stretch of 100 m was defined, and standard fishing techniques were employed [41]. Depending on habitat and conditions, these techniques included dip nets, cast nets, monofilament gill nets, seine nets, and some local fishing gears (Figure A3). In isolated stretches of the main channel and some tributaries, with permission, the controlled use of the isoflavone ichthyocide rotenone, was employed to sample species not readily captured using other methods [42]. Fishes were euthanized, with MS222, prior to tissue sampling and body preservation in accordance with recommended guidelines for the use of fishes in research [43,44].

Most voucher specimens are housed in the Department of Ichthyology at the American Museum of Natural History (AMNH), and associated data are accessible at <https://emu-prod.amnh.org/db/emuwebamnh/index.php>. Additional specimens are housed in the Department of Biology at the University of Kinshasa where they serve as teaching materials. Taxonomic nomenclature follows Fricke et al. [45]. In the absence of a comprehensive taxonomic key for the CB ichthyofauna, identification of specimens was determined on the basis of available publications on the ichthyofauna of the Congo provinces and surrounding regions. In addition to Boulenger's catalog of fishes in the British Museum (Natural History) [46], we consulted several other documents [47–60], and the following internet resources <http://www.poissons-afrique.ird.fr/drupal/faunafri>, <http://www.mormyrids.myspecies.info/en>, and <https://research.amnh.org/vz/ichthyology/congo/taxoindex.html> (all accessed on 1 June 2020).

2.3. Anthropogenic Activities

Anthropogenic activities were surveyed along the LR during our sampling trips. We recorded human activities, both in and outside collecting sites, that likely had direct or indirect impacts on land cover, water quality, fish populations, and hydrology of LR and its tributaries.

3. Results

3.1. Fish Diversity

A total of 3825 individuals were collected between 2007 and 2014. Examination of these specimens resulted in the identification of 201 species, belonging to 24 families and 12 orders with their distribution among the main channel and tributaries indicated in columns 1–21 (Table A2). The distribution of species among all sites is provided in Supplementary Table S1. The order Siluriformes, with 49 species, is the most dominant and represents about 24% of all identified species (Figure 4). It is followed by Cypriniformes (20%), Characiformes (19%), Osteoglossiformes (18%), and Cichliformes (6%). These five orders together represent 87% (177 species) of the species diversity currently known from the LR basin.

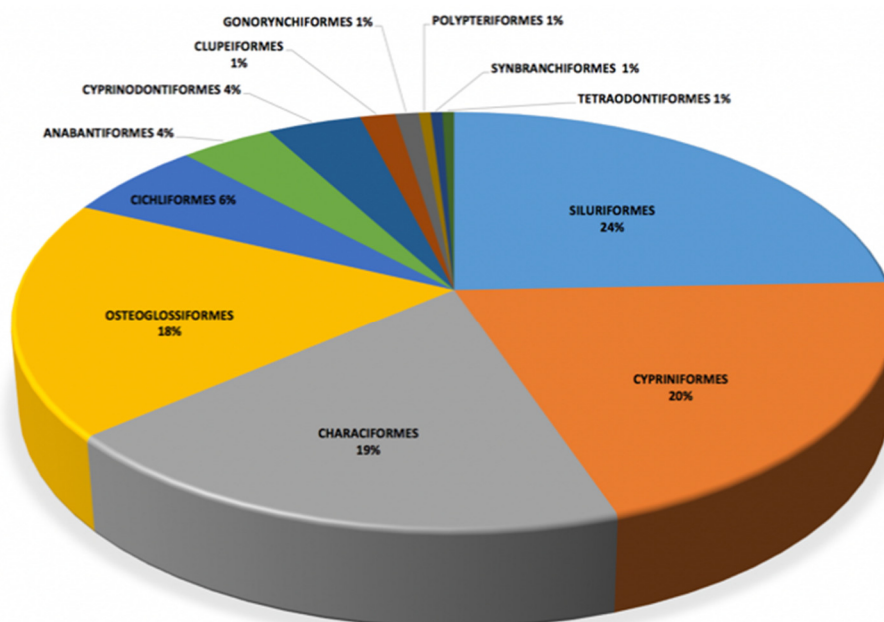


Figure 4. Relative representation of each order in the lower Lulua River.

At the family level, the ichthyofauna of the LR is predominated by Cyprinidae, which is the most speciose family with 41 species (20%), followed by Mormyridae with 35 species (17%), Distichodontidae with 19 species (9%), Alestidae with 18 species (8.9%), Mochokidae with 17 species (8%), and Cichlidae with 12 species (6%). The remaining families are less abundant, each with less than 5% (Figure 5). Overall, Cyprinidae, Mormyridae, Distichodontidae, Alestidae, Mochokidae, and Cichlidae account for about 70% of the ichthyofaunal diversity in the lower LR.

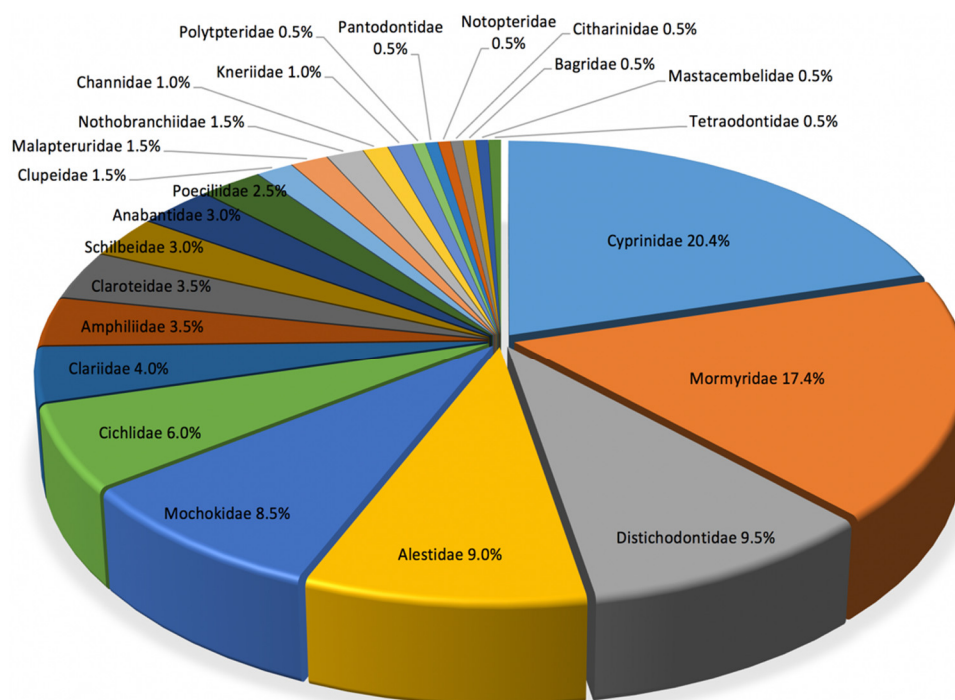


Figure 5. Relative representation of each family in the lower Lulua River.

3.2. Anthropogenic Activities

Overall, the economic situation of people in the LR basin is cause for considerable concern. Economic activity is almost entirely based on unsustainable exploitation of natural resources and minerals, and this, along with rapid demographic growth, is placing increasing pressure on ecosystems throughout the LR valley. During our sampling trips, we identified four main categories of human activity with direct or indirect impact on fish communities in LR: (1) activities affecting land cover, (2) water quality, (3) river hydrology, and (4) fish populations (Table 1). The first three categories contribute to habitat loss and degradation, which are the greatest threats to fish communities in central Africa [10], whereas the last category affects fish population equilibrium and contributes to population fragmentation and decline.

Table 1. Human activities identified in the LR valley grouped in categories following their impact on the system.

Category	(1) Land Cover	(2) Water Quality	(3) Hydrology	(4) Fish Populations
Activities	<ul style="list-style-type: none"> Shifting agriculture Settlement Forest exploitation for building materials and charcoal Diamond mining 	<ul style="list-style-type: none"> Diamond mining Clay mining 	<ul style="list-style-type: none"> Large- and small-scale damming Diamond mining 	<ul style="list-style-type: none"> Fisheries Dams

Shifting agriculture (Figures A7A,B) is consistently observed along the LR valley (Figure A8) and is a primary source of income and food for numerous households in the area. This activity is the major cause of deforestation and land-cover alteration throughout the valley. Additionally, settlement into the region is very active and characterized by the rapid expansion of preexisting towns and villages, as well as the creation of new villages and camps. In the absence of electricity, most households rely on charcoal and firewood for cooking and lighting, further contributing to deforestation.

Artisanal alluvial diamond mining (Figures A7E,F) is widespread (Figure A8) and remains the most lucrative activity for local populations throughout the valley. Mines are

mostly located along riverbanks, and sometimes whole tributaries are dammed or diverted to mine their beds. Mined materials are directly sifted or washed in the river, releasing large amounts of clay, silt, sand, and gravels. Clay mines (Figure A7C) are generally smaller and provide clay for brick fabrication (Figure A7D) destined for local construction.

Currently, the only major hydroelectric project in the LR valley is the Grand Katende hydroelectric dam, with a planned capacity of 64 MW, which is in an advanced planning stage.

Fishes play a central role in the regional food supply and are often the only source of animal protein. Fishing activities in the LR are extensive and practiced by men, women, and children primarily for subsistence. Many fishing techniques are used including netting, trapping, damming and dewatering (Figure A7G), long lines, hook and line, and a locally produced vegetal ichthyocide (Figure A7H). Fishing practices are generally unregulated and often destructive, utilizing extremely small mesh-sized nets targeting small fish, as the larger fish are becoming increasingly scarce.

4. Discussion

The dominance of Siluriformes, Cypriniformes, Characiformes, Osteoglossiformes, and Cichliformes in the LR reflects a similar composition as found in the entire CB [12,61]. At the family level, the CB ichthyofauna is dominated by Cyprinidae, Mormyridae, Cichlidae, Mochokidae, Alestidae, Distichodontidae, Amphiliidae, and Nothobranchiidae, accounting for 73% of basin-wide diversity [62]. A similar family composition is also found in the LR. We note that the apparent shift in taxonomic dominance in the lower LR is likely due to the fact that representatives of the Siluriformes are distributed among seven families, while Cypriniformes are represented by members of a single family. When compared to the family composition of the northeastern tributaries of the CR in the Cuvette Centrale ecoregion [26], we noticed the dominance of the same families in both systems. However, the most speciose family is no longer the Cyprinidae but the Mormyridae. Such a shift in dominance suggests that a difference of dominant habitats available in these river networks may be the cause. The rivers of the Cuvette Centrale ecoregion flow through dense tropical forests, with numerous blackwater swamps and small forested streams, likely offering more suitable habitats for mormyrid species than for most cyprinids. While the Mormyridae is also predominant in another river in the Kasai ecoregion, the Kwilu [27], as well as in proximate ecoregions [28,34,63], the dominance of Cyprinidae in the lower Lulua is noteworthy and likely reflects the influence of surrounding savannah and grasslands, and a riparian vegetation restricted in width along its course. Additionally, historical connections between the Upper Lulua with the headwaters of the Upper Zambezi ecoregion (see below), with its high number of cyprinid species, may contribute to the large number of cyprinids collected in the present study. These factors, combined with the presence of some characteristic and endemic species, suggest that the LR basin may represent a distinctive ecoregion within the CB; however, additional collecting within the basin is needed before definitive conclusions can be reached.

While the family composition of the LR is similar to that of the CB as a whole, species composition indicates some affinities with the Upper Zambezi ecoregion to the south of the basin (Figure 1). Indeed, species such as *Pollimyrus castelnaui* (Boulenger 1911) (Figure A4E), *Enteromius brevidorsalis* Boulenger 1915 (Figure A5D), *Enteromius thamalakanensis* Fowler 1935 (Figure A4B), *Enteromius radiatus* Peters 1853, *Clypeobarbus bellcrossi* (Jubb 1965), *Parauchenoglanis ngamensis* (Boulenger 1911), *Hypsopanchax jubbi* Poll and Lambert 1965 (Figure A5H), *Coptodon rendalli* (Boulenger 1897) (Figure A5A), *Tilapia sparrmanii* Smith 1840, *Pseudocrenilabrus philander* (Weber 1897) (Figure A5B), *Pharyngochromis acuticeps* (Steindachner 1866), and *Ctenopoma multispine* Peters 1844, present in the LR, have also been reported from the Upper Zambezi system [25,50,62]. Such affinities with the Upper Zambezi can be explained by the existence of intermittent connections between the

headwaters of the two systems during their geological evolution and currently in times of extreme humidity [25,64–67].

From a taxonomic point of view, the lower LR is characterized by a remarkably rich and diversified ichthyofauna. In addition to the 201 fish species inventoried in this study, seven species reported by [14,47,68–70], but not observed during our study, need to be added to the list. These species are *Petrocephalus simus* Sauvage 1879, *Brachypetersius cadwaladeri* (Fowler 1930), *Clarias dumerilii* Steindachner 1866, *Synodontis depauwi* Boulenger 1899, *Tetracamphilius pectinatus* Roberts 2003, *Trachyglanis intermedius* Pellegrin 1912, and *Lacustricola katangae* (Boulenger 1912). It is likely that these species are rare, are very localized, or occupy specialized habitats and were able to escape capture during our campaigns. Adding these seven species, the total number of species known from the LR basin reaches 208 species. This number will very likely be exceeded in the coming years as we intensively sample more habitats in unexplored areas of the basin, particularly the Middle and the Upper LR. Indeed, of the 1256 km of the main channel, only a 200 km stretch was intensively prospected within the framework of this study. Thus, the present results suggest that the Lulua catchment harbors an extraordinarily high number of fish species in comparison to other CR tributaries, such as the Inkisi River basin where 61 fish species have been reported [31], the Lefini River basin where 140 fish species have been inventoried [30], the N'sele River with 148 fish species [28], the Kwilu River with 150 species [27], the Luilaka and Salonga Rivers, both tributaries of the Ruki River, in the Salonga National Park where 152 species have been inventoried [29], and the Lindi River where 187 fish species have been reported [26]. Overall, only the Itimbiri (232 species) and Aruwimi (246 species) Rivers, in the Cuvette Centrale ecoregion, have been reported to harbor a higher number of species [26] than that reported in the present study. These differences could, of course, be due to many factors including the size of each river catchment, the diversity of habitats, and their respective productivity, to which we can add sampling techniques, effort, and gear used in different studies. Furthermore, according to Worm and Duffy [71], there is a reciprocal influence among the productivity of an ecosystem, its stability, and its biodiversity; thus, the most productive ecosystems would have high diversities.

It should be noted that about 14.4% (29 species) of the species reported in the lower LR were exclusively collected in tributaries and have yet to be found in the main channel (species in bold type in Table A2). Tributaries share an additional 83 species with the main channel bringing the total number of species collected in tributaries to 112 (55.7% of the lower LR fish diversity). This suggests that the LR tributaries harbor a significant proportion of species in the system. It is likely that the real proportion of species finding shelter in tributaries is considerably higher as our investigation was halted due to insecurity in the Kasai provinces, and we undoubtedly did not capture the entire species richness of certain tributaries and sub-tributaries since only a single campaign was undertaken in localities outside of the main channel. Furthermore, several tributaries of the lower LR were not surveyed at all. Nonetheless, the main channel harbors the highest number of species and provides shelter to about 85% (172 species) of the basin's ichthyofauna.

Among species reported in this study, five (*Epiplatys atractus* Van Der Zee, Mbimbi, and Sonnenberg 2013 (Figure A6E), *Hypsopanchax stiassnyae* Van Der Zee, Sonnenberg, and Mbimbi 2015 (Figure A6G), *Distichodus kasaiensis* Moelants, Snoeks, and Vreven, 2018, *Raiamas brachyrhabdotos* Katemo Manda, Snoeks, Choca Manda, and Vreven 2018, and *Distichodus polli* Abwe, Snoeks, Choca Manda, and Vreven 2019 (Figure A6H)) have recently been described. The first two are endemic to the Lulua basin while the remainder are more widely distributed. Furthermore, eight putatively new species have been identified, namely, *Chiloglanis* sp. "Lulua", *Tetracamphilus* sp. "Lulua", *Epiplatys* sp. "pale" Van Der Zee, Mbimbi, and Sonnenberg (in prep) (Figure A6C), *Lacustricola* sp., *Micropanchax* sp. (Figure A6H), *Enteromius* sp. "purple stripe" (Figure A4C), *Labeo* cf. *lukuluae* "Lulua" Liyandja (in prep), and *Labeo* sp. nov. Liyandja (in prep). The descriptions of some of these are currently underway while others need more investigation to be confirmed as new. In

addition, some taxa, such as *Chelaethiops luluae*, *Chrysichthys cf. duttoni*, *Garra cf. congoensis*, and *Ctenochromis luluae* (Figure A6B), require further taxonomic attention.

The species richness reported in this study represents a substantial improvement over the documentation of the LR ichthyofauna historically estimated at 79 species [14,47,68–70]. In columns 22 and 23 of Table A2, distribution data culled from published IUNC assessment of the status and distribution of central African fishes [72], the Kwilu River [27,73], the freshwater fishes of Angola [25,49], and FishBase [62] were used to investigate which of the species reported in this study have previously been recorded as present in the LR basin and/or the Kasai ecoregion as a whole. We found that 129 of the species reported here have not previously been recorded in the LR (Table A2, column 22). Representatives of families such as Malapteruridae, Tetraodontidae, Bagridae, Kneriidae, Clupeidae, Pantodontidae, and Notopteridae have not previously been reported from the LR, and 32 species reported here were previously unrecorded from the Kasai ecoregion (Table A2, column 23). Adding these species to the list of 367 species compiled from existing publications and databases [25,27,60,62,72–75] brings the total number of species currently known from the Kasai ecoregion to 399. On the basis of this assessment, the Kasai ecoregion occupies the first position, in terms of species richness, in the entire CB (exclusive of Lake Tanganyika). It is followed by the Cuvette Centrale ecoregion with 360 species [26,29], the Lower Congo rapids and Lower Congo ecoregions with a combined 328 species [76], and Pool Malebo estimated at 316 species [3]. However, a total of 399 species for the Kasai ecoregion needs further investigation as some of the species in these lists, such as *Labeo ansorgii*, *Labeo cylindricus*, and *Labeo annectens*, may have far more restricted distributions than currently indicated, and it is highly likely that additional species will be documented in the Middle and Upper Lulua (personal observation). Additionally, it has become clear that molecular analyses are needed throughout the entire basin to ensure that species are not under-split due to rampant cryptic speciation [77–79] or over-split due to morphological plasticity (Liyandja, in prep.).

The highly diversified ichthyofauna of the lower LR and that of the entire basin is threatened by a combination of exploitation of forest products for building materials, deforestation for shifting agriculture and charcoal production, destructive fishing practices, and mining (particularly for diamonds), as presented in the results. According to Nguimalet [80], alluvial diamond mining is responsible for regressive and lateral erosion resulting in a complete restructuring of river geomorphology in the Central African Republic. Such changes lead to significant habitat loss and, consequently, to fish population fragmentation and/or decline. In addition to geomorphological modifications, water quality is impacted by clay, silt, and other materials released into the water, by sifting or washing operations during diamond mining, which further increase turbidity and conductivity. Soil erosion caused by deforestation and increase in runoff also contribute to the modification of water quality by carrying more materials (sediment runoff) into the water. This excess of particulate matter in suspension affects fish physiology in numerous ways, including suffocation by clogging their gills [81]. As human populations increase, each of these activities will continue to intensify, and threats are expected to worsen throughout the region. Additionally, intensification of mining and dam construction projected to support the planned Congolese Government developmental programs is underway. A prime example is the Grand Katende hydroelectric dam which is now in an advanced planning stage (<https://www.afrik21.africa/en/drc-kinshasa-to-restart-work-on-the-katende-hydroelectric-dam-64-mw>; accessed on 20 June 2021). If completed, the Katende dam will inundate the lower LR where the present study has been carried out, and it will undoubtedly lead to major habitat degradation and likely the extirpation of many fish species [82], numerous of which are of central importance to the fisheries of the region. Subsistence fisheries in the LR valley are not monitored, and no data on the number of fish produced from these activities are available to allow an accurate assessment of their impact on the fish communities. However, according to observations made on the field and the types of fishing gear and techniques used by fishers, we can hypothesize that fish resources in the LR

valley are under very high pressure and possibly already overexploited. Some of these techniques affect movements of migratory species (*Labeo* spp., *Labeobarbus* spp.) and have an impact on their reproduction cycle. Additionally, the repetitive use of locally produced organic ichthyocides, such as *Tephrosia* spp., have a drastic impact on fish communities. They are already known to be responsible for the decline in species richness and abundance in tropical streams [83].

Among identified species, only one, *Teleogramma monogramma*, has been evaluated as vulnerable by the IUCN Red list of threatened species [84] in Central Africa. According to Stiassny et al. [10], a congener, *Teleogramma brichardi*, is critically endangered because of urbanization around its restricted range near Kinshasa. The populations of *T. monogramma* reported here have only been collected near the City of Kananga and at the Katende site, suggesting that this species may be at higher risk than assessed by the IUCN. Twenty-seven (13.4%) species reported in this study have not been evaluated, and 18 (9%) have been reported as data-deficient by the IUCN. Some of these species such as *Hypsopanchax stiassnyae*, *Amphilius maesii*, *Nannocharax uniocellatus*, and *Clypeobarbus mediosquamatus* appear to have highly localized distributions along the lower Lulua, suggesting that a reevaluation of their conservation status is urgently needed. The remaining species (77%) have been evaluated as of least concern in Central Africa. However, given the intensity of human activities in the LR valley, there is clearly a strong imperative to carry out local evaluation of the conservation status of the LR species.

5. Conclusions

The ichthyofauna of the lower Lulua River is continentally outstanding in terms of fish diversity, and the entire Lulua basin may constitute one of the most species-rich fish communities of the CB. Such an elevated level of fish diversity is likely a result of the basin's extensive habitat diversity ranging from numerous rapids, falls, pools, small and large tributaries, large floodplains, and perennial and permanent swamps, in addition to its location at the intersection of the Kasai and Lualaba ecoregions. Additionally, its shared headwaters with the Upper Zambezi ecoregion have likely also contributed to the high diversity of its ichthyofauna. The present study, which reports more than 200 fish species in the lower LR, represents a baseline documentation that can be used in conservation and future development projects in the Kasai ecoregion in general and in the LR in particular. In the long term, the outcomes of this study are intended as a starting point for monitoring and protecting the biodiversity of the entire basin. Further investigations are necessary to capture the true fish diversity of this exceptional river catchment, and such knowledge will also contribute to a better understanding of the specific composition and biogeographical history of the ichthyofauna of the Kasai basin and that of the CB as a whole.

Supplementary Materials: The following are available online at www.mdpi.com/article/10.3390/d13080341/s1: Table S1. Species distribution among sampling sites.

Author Contributions: J.J.M.M.M., R.J.C.M.I. and M.L.J.S. contributed to the conceptualization of the study; J.J.M.M.M. and T.L.D.L. collected the data and conducted the investigation; M.L.J.S., J.J.M.M.M. and T.L.D.L. identified the species; J.J.M.M.M. and T.L.D.L. prepared the original draft; R.J.C.M.I. and M.L.J.S. edited and reviewed the draft; T.L.D.L. and J.J.M.M.M. prepared visualizations; M.L.J.S. acquired funding; J.J.M.M.M. and R.J.C.M.I. were in charge of the project administration. All authors have read and agreed to the published version of the manuscript.

Funding: Financial support for this project was provided by the AMNH Axelrod Research Curatorship (M.L.J.S.). This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Associated data are accessible at <https://emu-prod.amnh.org/db/emuwebamnh/index.php>.

Acknowledgments: For assistance with collection and exportation permits, as well as logistical support, we are grateful to Julien Punga Kumanenge, Jean Mukulire Malekani, and Koffi Mulumba, Ministère de l’Agriculture et du Développement Rural, Secrétariat Général de l’Agriculture, Pêche et Elevage, Direction des Pêches, and the Université de Kinshasa, Cabinet du Recteur, Democratic Republic of Congo. Our thanks also to Barbara Brown (in memoriam), Radford Arrindell, Tom Vigliotta, and Chloe Lewis (AMNH) for their help with accessioning and cataloging specimens. We are also grateful to BEBUC, through the Else Kroner-Fresenius-Stiftung foundation, for their financial and moral support to T.L.D.L.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Sampling sites: geographic and physicochemical data (* surface temperature). Geographic coordinates are given in decimal degrees with negative latitudes indicating south and positive longitudes indicating east.

Site #	Locality	River Name	Latitude (°)	Longitude (°)	Altitude (m)	T (°C) *	pH	Stream Order
1	Luebo	Lulua	-5.33881	21.40929	377	28	7	Main channel
2	Beya	Lulua	-5.9325	22.33472	524	28	6	Main channel
3	Nsanga Nyembo	Lulua	-5.95317	22.34541	558	28	6.4	Main channel
4	Ntumba Shambuyi	Lulua	-5.973317	22.37388	518	30	7	Main channel
5	Dipumu	Lulua	-6.00328	22.3916	547	27	6.4	Main channel
6	Dijiba	Lulua	-6.17272	22.45215	550	31	5.5	Main channel
7	Kasende	Lulua	-6.23509	22.46443	606	30	6	Main channel
8	Katende	Lulua	-6.34366	22.45036	649	28	6.5	Main channel
9	Kampaya	Lulua	-6.42721	22.41587	649	28	6.9	Main channel
10	Tshimbadi	Lulua	-6.47323	22.41857	680	25.3	7.1	Main channel
11	Ntumbu	Lulua	-6.44484	22.4197	675	28	6.7	Main channel
12	Kabeya Nsaka	Lulua	-6.5201	22.43949	688	26.2	8	Main channel
13	Mbumba	Lulua	-6.59545	22.47788	725	30.3	6.9	Main channel
14	Kakulu	Kaluebo	-5.90237	21.59208	515	25	6.5	Left bank tributary
15	Miao	Miao	-5.93972	22.22158	522	25	6.5	Left bank tributary
16	Tshilumba	Kasonga	-5.92967	22.34352	520	28.9	6.7	Right bank tributary
17	Tshilumba	Tukomba	-5.9254	22.33756	512	30.5	6.6	Right bank tributary
18	Tshilumba	Nkakala	-5.93278	22.34743	519	25.7	6.5	Right bank tributary
19	Mikalayi	Kapelekese	-5.9537	22.33714	529	30.7	7.1	Left bank tributary
20	Mikalayi	Luankadi	-5.96836	22.34208	534	31	6.7	Left bank tributary
21	Mikalayi	Mikalayi	-5.98746	22.33765	540	24.5	6.6	Left bank tributary
22	Tshiyoyi	Nkombua	-6.0044	22.3906	545	26	5.4	Right bank tributary
23	Tshiyoyi	Ngalala	-6.00841	22.39838	550	31.1	6.3	Right bank tributary
24	Kantumanga	Lubi	-600,507	22.52569	621	29	6	Right bank tributary
25	Kantumanga	Lukumbi Kumbi	-6.00413	22.5266	610	26.8	5.3	Right bank sub-tributary
26	Kantumanga	Musangu	-6.00903	22.52278	621	24.7	6	Right bank sub-tributary
27	Bampanya	Lunyenga	-6.12452	22.52636	609	29	5.5	Right bank tributary
28	Kamuandu	Lunyenga	-6.06501	22.653	648	28	5,8	Right bank tributary
29	Dijiba	Moyo	-6.18725	22.48455	562	28	6	Right bank sub-tributary
30	Kankunku	Minkidimbua	-6.10658	22.71375	673	25.5	5	Right bank sub-tributary
31	Kamuandu	Tshimayi	-6.19377	22.73992	702	29.3	5.4	Right bank sub-tributary
32	Kamuandu	Tshina	-6.20182	22.73446	703	24	6	Right bank sub-tributary
33	Tshimbulu	Mitshikiji	-650,417	22.7345	760	28	5.4	Right bank sub-tributary
34	Kazadi	Lubondayi	-6.5259	22.66918	755	30.6	6	Right bank sub-tributary
35	Kazadi	Mbuyi	-6.54477	22.69843	774	28.6	5.8	Right bank sub-tributary
36	Kazadi	Kambambe	-6.54879	22.7045	753	29.2	6.2	Right bank sub-tributary
37	Bunkonde	Tshinkelu	-6.27472	22.4909	678	30.5	6.9	Right bank tributary
38	Bunkonde	Kalulua	-6.27855	22.48777	624	29.7	6.8	Right bank tributary
39	Tshimbawu	Luna	-6.35064	22.51817	722	27	6.5	Right bank tributary
40	Kaloba	Tshimayi	-6.43256	22.43643	678	30	6.7	Right bank tributary
41	Ntumbu	Kabikonyi	-6.44554	22.41882	674	24.3	6.3	Right bank tributary
42	Kaloba	Mukundulu	-6.45628	22.44648	699	25.9	6.6	Right bank tributary
43	Kabeya Nsaka	Munue Mayi	-6.51527	22.44906	906	28	5.8	Right bank tributary

Table A2. List of species collected at sites in the main channel (lower Lulua) and tributaries. Sub-tributary species are listed in their respective tributaries. Species in bold type were collected only in tributaries. Numbers in parenthesis are species numbers. In columns 22 (Kasai) and 23 (Lulua historically), distribution data culled from [25,27,60,62,72–75] were used to indicate which Lulua species are known to occur in the Kasai ecoregion and which were not reported in the catchment prior to this study.

TAXON	AMNH (Selected Representatives)	Lulua main channel	Kaluebo	Miao	Kasongo	Tukumba	Nkakala	Mikalayi	Luankudi	Kapelekese	Nkombua	Ngalala	Lubi	Lunyenga	Moyo	Kalulua	Tshikelu	Luna	Tshimayi	Mukundulu	Kabikonyi	Munue Mayi	Lulua historically	Kasai Basin
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
POLYPTERIFORMES (1)																								
Polypteridae (1)																								
<i>Polypterus ornatipinnis</i> Boulenger 1902	247757, 247472, 268978	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
OSTEOGLOSSIFORMES (37)																								
Pantodontidae (1)																								
<i>Pantodon buchholzi</i> Peters 1876	253358, 253060	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Notopteridae (1)																								
<i>Xenomystus nigri</i> (Günther 1868)	252627, 253052	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Mormyridae (35)																								
<i>Campylomormyrus alces</i> (Boulenger 1920)	253224	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Campylomormyrus curvirostris</i> (Boulenger 1898)	268982	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Campylomormyrus elephas</i> (Boulenger 1898)	253131, 268985, 253131	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Campylomormyrus mirus</i> (Boulenger 1898)	252608	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Campylomormyrus numenius</i> (Boulenger 1898)	252605, 253223	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Campylomormyrus rhynchophorus</i> (Boulenger 1898)	268986, 251106, 268986	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Campylomormyrus tamandua</i> (Günther 1868)	247525, 252609	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	X
<i>Campylomormyrus tshokwe</i> (Poll 1967)	252609, 253222	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Cyphomyrus cubangoensis</i> (Pellegrin 1936)	268992, 268989, 268992	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyphomyrus discorhynchus</i> (Peters 1952)	247444, 253514, 253390	X	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Cyphomyrus psittacus</i> (Boulenger 1897)	253157	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Gnathonemus petersii</i> (Günther 1862)	252799, 252612, 253229	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X	X
<i>Hippopotamyrus macroterops</i> (Boulenger 1920)	251291, 270503	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Marcusenius greshoffii</i> (Schilthuis 1891)	247417, 247446, 243985	X	-	-	X	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Marcusenius intermedius</i> Pellegrin 1924	252800, 253315, 253319	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	X
<i>Marcusenius stanleyanus</i> (Boulenger 1897)	251125	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Mormyrops anguilloides</i> (Linnaeus 1758)	247507, 252645, 268995	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	X	-	X	X	X
<i>Mormyrops lineolatus</i> Boulenger 1898	251068	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
<i>Mormyrops masuianus</i> Boulenger 1898	253338, 252821	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X

<i>Mormyrops microstoma</i> Boulenger 1898	247471, 251067, 268999	X	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X
<i>Mormyrops sirenooides</i> Boulenger 1898	251067, 252730	-	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	X
<i>Mormyrus caballus bumbanus</i> Boulenger 1909	251133, 251243, 269000	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Mormyrus caballus caballus</i> Boulenger 1898	247502, 247405, 253134	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X
<i>Mormyrus ovis</i> Boulenger 1898	269002, 269001, 269002	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Myomyrus macrops</i> Boulenger 1914	247518, 247513, 251242	X	-	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X
<i>Petrocephalus christyi</i> Boulenger 1920	247500, 252819, 253117	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
<i>Petrocephalus</i> cf. <i>schoutedeni</i> Poll 1954	252727	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Petrocephalus sauvagii</i> Boulenger 1887	251065, 252729, 269016	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	X
<i>Pollimyrus castelnaui</i> (Boulenger 1911)	253197, 253328	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Pollimyrus maculipinnis</i> (Nichols and LaMonte 1934)	253350, 252822, 252614	X	-	-	-	X	-	-	X	-	X	-	-	X	-	X	-	X	-	-	X	X
<i>Pollimyrus nigripinnis</i> (Boulenger 1899)	252613	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Pollimyrus osborni</i> (Nichols and Griscom 1917)	247526, 253232, 253339	X	-	-	-	-	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	X
<i>Pollimyrus pulverulentus</i> (Boulenger 1899)	253130	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Stomatorhinus kununguensis</i> Poll 1945	247436	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Stomatorhinus patrizii</i> Vinciguerra 1928	252615	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
CLUPEIFORMES (3)																						
Clupeidae (3)																						
<i>Microthrissa congica</i> (Regan 1917)	268979, 253383	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Microthrissa royauxi</i> Boulenger 1902	252625	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Potamothrissa obtusirostris</i> (Boulenger 1909)	247515, 247479	X	-	X	-	-	-	-	-	-	X	-	X	-	-	X	-	-	-	X	-	X
GONORYNCHIFORMES (2)																						
Kneriidae (2)																						
<i>Parakneria ladiges</i> Poll 1967	251112, 243627	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Parakneria vilhenae</i> Poll 1965	253217, 253305, 253505	X	-	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X
CYPRINIFORMES (41)																						
Cyprinidae (41)																						
<i>Enteromius bifrenatus</i> (Fowler 1935)	253026, 253214	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Enteromius brevidorsalis</i> (Boulenger 1915)	253025, 269220	-	-	-	X	-	X	-	X	X	-	-	-	-	X	-	-	-	-	-	X	X
<i>Enteromius chiumbeensis</i> (Pellegrin 1936)	247422, 269221	X	-	-	-	X	-	-	X	X	-	-	X	-	-	X	-	-	-	-	-	X
<i>Enteromius eutaenia</i> (Boulenger 1904)	252847, 269222	X	X	-	X	-	X	-	X	X	-	X	X	-	-	X	-	X	-	X	-	X
<i>Enteromius fasciolatus</i> (Günther 1868)	252834, 253204	-	-	-	X	-	-	-	X	-	X	-	-	-	X	X	X	-	X	-	-	X
<i>Enteromius haasianus</i> (David 1936)	269226	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Enteromius humeralis</i> (Boulenger 1902)	269095, 251320	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Enteromius lineomaculatus</i> (Boulenger 1903)	253510, 243981	X	-	X	X	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	X	X
<i>Enteromius</i> cf. <i>luluae</i> (Fowler 1930)	257172	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Enteromius miolepis</i> (Boulenger 1902)	247483, 253189	X	-	X	-	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-	X
<i>Enteromius paludinosus</i> (Peters 1852)	253194, 253285	-	-	-	X	-	-	-	X	-	-	-	-	-	X	-	-	-	-	-	-	X
<i>Enteromius radiatus</i> (Peters 1853)	253115, 252725	X	-	-	X	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X
<i>Enteromius thamalakanensis</i> (Fowler 1935)	253195, 269089	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Enteromius unitaeniatus</i> (Günther 1866)	253125	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-

<i>Enteromius</i> sp “purple stripe”	-	X	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-		
<i>Chelaethiops elongatus</i> Boulenger 1899	247817, 253001	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Chelaethiops luluae</i> (Nichols and Griscom 1917)	247812, 251277	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	
<i>Clypeobarbus bellcrossi</i> (Jubb 1965)	253036	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Clypeobarbus bomokandi</i> (Myers 1924)	252753	X	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Clypeobarbus mediosquamatus</i> Poll 1967	269095, 251320	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Garra</i> cf. <i>congoensis</i> Poll 1959	253364, 251061, 269096	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Labeo</i> cf. <i>chariensis</i> Pellegrin 1904	247968, 253454	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	
<i>Labeo</i> cf. <i>cyclorhynchus</i> Boulenger 1899	247971, 247855	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Labeo cyclorhynchus</i> Boulenger 1899	252631	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Labeo</i> cf. <i>dhonti</i> Boulenger 1919	251178	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Labeo fulakariensis</i> Tshibwabwa, Stiassny, and Schelly 2006	247989, 247995	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Labeo greenii</i> Boulenger 1902	253436, 243606	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	
<i>Labeo lineatus</i> Boulenger 1898	247850, 269097	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	
<i>Labeo longipinnis</i> Boulenger 1898	247857, 269100	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Labeo</i> cf. <i>lukulae</i> Boulenger 1902	253465, 269104	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Labeo lukulae</i> Boulenger 1902	253465	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Labeo luluae</i> Fowler, 1930	269111, 247862, 269106	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	
Cyprinidae (continue)																									
<i>Labeo parvus</i> Boulenger 1902	269108	X	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
<i>Labeo</i> sp. nov. (Liyandja in Prep)	247858, 251173	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Labeo altivelis</i> Boulenger 1909	252632	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	
<i>Labeobarbus caudovittatus</i> (Boulenger 1902)	247498, 269115	X	X	-	-	X	-	-	-	-	-	-	-	X	-	-	-	X	X	-	-	-	-	X	
<i>Labeobarbus macrolepidotus</i> (Pellegrin 1928)	247423, 269121	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	X	X	
<i>Leptocypris weynsii</i> (Boulenger 1899)	243660, 253039	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Opsaridium boweni</i> (Fowler 1930)	247516, 269118	X	-	-	-	-	-	X	-	X	-	-	-	X	-	-	-	X	-	-	-	X	X	X	
<i>Opsaridium ubangiense</i> (Pellegrin 1901)	253198, 247476, 253277	X	-	X	-	X	-	X	-	X	X	-	-	X	-	X	X	X	X	X	X	X	X	X	
<i>Raiamas branchrhabdotus</i> Katemo, Snoeks, Chocha, and Vreven 2018	252754, 251232, 253153	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	
CHARACIFORMES (38)																									
Citharinidae (1)																									
<i>Citharinus gibbosus</i> Boulenger 1899	252624, 269038, 269037	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
Distichodontidae (19)																									
<i>Distichodus affinis</i> Günther 1873	247827, 247828	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Distichodus antonii</i> Schilthuis 1891	252719, 253113	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Distichodus atroventralis</i> Boulenger 1898	252619	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Distichodus fasciolatus</i> Boulenger 1898	251196, 247835	X	-	-	-	-	-	X	-	X	-	-	-	X	-	-	-	X	X	X	X	X	X	X	
<i>Distichodus lusosso</i> Schilthuis 1891	252809, 253016, 253050	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X	X	
<i>Distichodus kasaiensis</i> Moelants, Snoeks, and Vreven 2018	247825, 243646, 251289	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X	
<i>Distichodus maculatus</i> Boulenger 1899	253111, 252806	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X	X	
<i>Distichodus polli</i> Abwe, Snoeks, Chocha, and Vreven 2019	247831, 269041	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Distichodus sexfasciatus</i> Boulenger 1897	269045, 252721	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X	X	

<i>Eugnathichthys eetveldii</i> Boulenger 1898	253161, 243649	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Eugnathichthys macroterolepis</i> Boulenger 1899	253152, 252805	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
<i>Mesoborus crocodilus</i> Pellegrin 1900	247838, 252622	X	-	-	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-	X
<i>Nannocharax brevis</i> Boulenger 1902	243637	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Nannocharax elongatus</i> Boulenger 1900	252784, 251091	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Nannocharax macropterus</i> Pellegrin 1926	247846, 253326	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Nannocharax procatopus</i> Boulenger 1920	251056, 269051	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Nannocharax taenia</i> Boulenger 1902	253326	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Nannocharax unio cellatus</i> (Pellegrin 1926)	252717, 252623	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Phago boulengeri</i> Schilthuis 1891	253048	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Alestidae (18)																				
<i>Alestes liebrechtsii</i> Boulenger 1898	247414, 243618	X	-	-	-	-	-	-	-	X	-	X	-	-	X	-	X	X	X	X
<i>Alestes macropthalmus</i> Günther 1867	253147, 252817, 252740	X	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	-	-	X
<i>Bathyaethiops breuseghemi</i> (Poll 1945)	253472	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Brachypetersius altus</i> (Boulenger 1899)	247505, 247440	X	-	X	-	-	-	X	-	X	-	X	-	-	-	-	-	-	-	X
<i>Brycinus comptus</i> (Roberts and Stewart 1976)	252749, 253151	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X
<i>Brycinus grandisquamis</i> (Boulenger 1899)	251080, 252644	X	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X
<i>Brycinus humilis</i> (Boulenger 1905)	247527, 252649	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X
<i>Brycinus imberi</i> (Peters 1852)	247774, 247536	X	-	X	-	-	-	X	-	X	-	-	-	-	-	-	X	X	-	X
<i>Brycinus kingsleyae</i> (Günther 1896)	252787, 251301	X	-	-	-	-	-	X	-	X	-	X	-	-	-	-	-	-	-	X
<i>Brycinus macrolepidotus</i> (Valenciennes 1850)	247771, 252823	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	X
<i>Bryconaeithiops boulengeri</i> Pellegrin 1900	247777, 247510	X	-	X	-	-	-	-	-	X	X	X	-	X	-	-	-	-	-	X
<i>Bryconaeithiops macrops</i> Boulenger 1920	243638, 243600	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Bryconaeithiops microstoma</i> Günther 1873	247775, 247506	X	-	X	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	X
<i>Hydrocynus goliath</i> Boulenger 1898	252594, 253359	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Hydrocynus vittatus</i> Castelnau 1861	269033, 253159	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Micralestes acutidens</i> (Peters 1852)	252750, 252598	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X
<i>Micralestes stormsi</i> Boulenger 1902	251208, 248760	X	-	X	-	-	-	X	-	X	X	-	X	X	-	-	-	-	X	X
<i>Phenacogrammus interruptus</i> (Boulenger 1899)	252593	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
SILURIFORMES (49)																				
Bagridae (1)																				
<i>Bagrus ubangensis</i> Boulenger 1902	252642, 247508	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Clariidae (8)																				
<i>Chamallabes apus</i> (Günther 1873)	253186	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X
<i>Clari allabes variabilis</i> Pellegrin 1926	253313	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X
<i>Clarias camerunensis</i> Lönnberg 1895	252801	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X
<i>Clarias gariepinus</i> (Burchell 1822)	252658, 253031	X	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Clarias pachynema</i> Boulenger 1903	247530, 243989	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X
<i>Clarias platycephalus</i> Boulenger 1902	247473, 253187	X	X	-	-	-	-	-	-	X	X	-	-	X	-	X	-	-	-	X
<i>Clarias theodorae</i> Weber 1897	243628	X	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	X
<i>Heterobranchus longifilis</i> Valenciennes 1840	252657, 269135	X	-	-	X	-	X	-	-	-	-	-	-	-	-	-	X	-	X	X

<i>Pareutropius debauwi</i> (Boulenger 1900)	247460, 269159	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Schilbe congensis</i> (Leach 1818)	251107	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Schilbe grenfelli</i> (Boulenger 1900)	251102, 253154, 253755	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Schilbe marmoratus</i> Boulenger 1911	252617, 253042	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Schilbe yangambianus</i> (Poll 1954)	253325	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
SYNBRANCHIFORMES (1)																					
Mastacembelidae (1)																					
<i>Mastacembelus congicus</i> Boulenger 1896	247514, 252647	X	-	X	-	X	-	-	-	-	-	X	-	-	-	X	-	-	-	-	X
ANABANTIFORMES (8)																					
Anabantidae (6)																					
<i>Ctenopoma acutirostre</i> Pellegrin 1899	25263, 253307, 253045	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Ctenopoma gabonense</i> Günther 1896	251312	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Ctenopoma kingsleyae</i> Günther 1896	252591, 253046, 252591	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Ctenopoma multispine</i> Peters 1844	25321, 253342, 253040	X	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	
<i>Microctenopoma nanum</i> (Günther 1896)	253316, 269209, 253316	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	X	
<i>Microctenopoma nigricans</i> Norris 1995	247474, 252804, 269221	X	X	-	X	-	X	-	X	X	-	X	-	X	-	X	-	X	-	X	
Channidae (2)																					
<i>Parachanna insignis</i> (Sauvage 1884)	252590	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Parachanna obscura</i> (Günther 1861)	253306, 253041	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
CICHLIFORMES (12)																					
Cichlidae (12)																					
<i>Coptodon congica</i> (Poll and Thys van den Audenaerde 1960)	247794, 253420	X	-	-	-	X	-	-	-	-	X	X	X	-	X	-	-	-	-	X	
<i>Coptodon rendalli</i> (Boulenger 1897)	243980, 269195	X	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X	
<i>Ctenochromis luluae</i> (Fowler 1930)	269177, 269248	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	X	
<i>Hemichromis elongatus</i> (Guichenot 1861)	253310	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Nanochromis nudiceps</i> (Boulenger 1899)	253474, 253061	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Oreochromis niloticus</i> (Linneaus 1758)	247842, 253426	X	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X	
<i>Pharyngochromis acuticeps</i> (Steindachner 1866)	253118	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Pseudocrenilabrus philander</i> (Weber 1897)	243677, 247805, 253182	-	-	-	X	-	-	X	-	-	X	-	X	-	-	-	-	-	-	-	
<i>Steatocranus rouxi</i> (Pellegrin 1928)	247805, 251054, 251114	X	-	X	-	-	-	-	-	X	-	-	-	X	-	-	-	-	X	X	
<i>Teleogramma monogramma</i> (Pellegrin 1927)	247532, 247819	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	
<i>Tilapia sparrmanii</i> Smith 1840	253416, 253432	X	-	-	-	-	-	X	-	X	X	-	-	-	-	-	-	-	-	X	
<i>Thoracochromis stigmatogenys</i> (Boulenger 1913)	243679, 24367, 252639	X	-	-	X	X	-	-	-	X	-	X	X	-	X	-	X	-	X	X	
CYPRINODONTIFORMES (8)																					
Nothobranchiidae (3)																					
<i>Epiplatys attractus</i> Van Der Zee, Mbimbi, and Sonnenberg 2013	253839, 253840	-	-	-	-	-	-	X	-	-	X	X	X	-	-	-	-	-	-	-	
Nothobranchiidae (continued)																					
<i>Epiplatys multifasciatus</i> (Boulenger 1913)	253038, 257173	X	-	-	X	-	X	-	-	X	-	-	-	-	-	-	-	-	-	X	
<i>Epiplatys</i> sp. "pale" Van Der Zee, Mbimbi and Sonnenberg (in prep.)	252449, 252459	-	-	-	X	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	
Poeciliidae (5)																					
<i>Hypsopanchax jobaerti</i> Poll and Lambert 1965	252845, 247914	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	X	-	-	-	

Appendix B

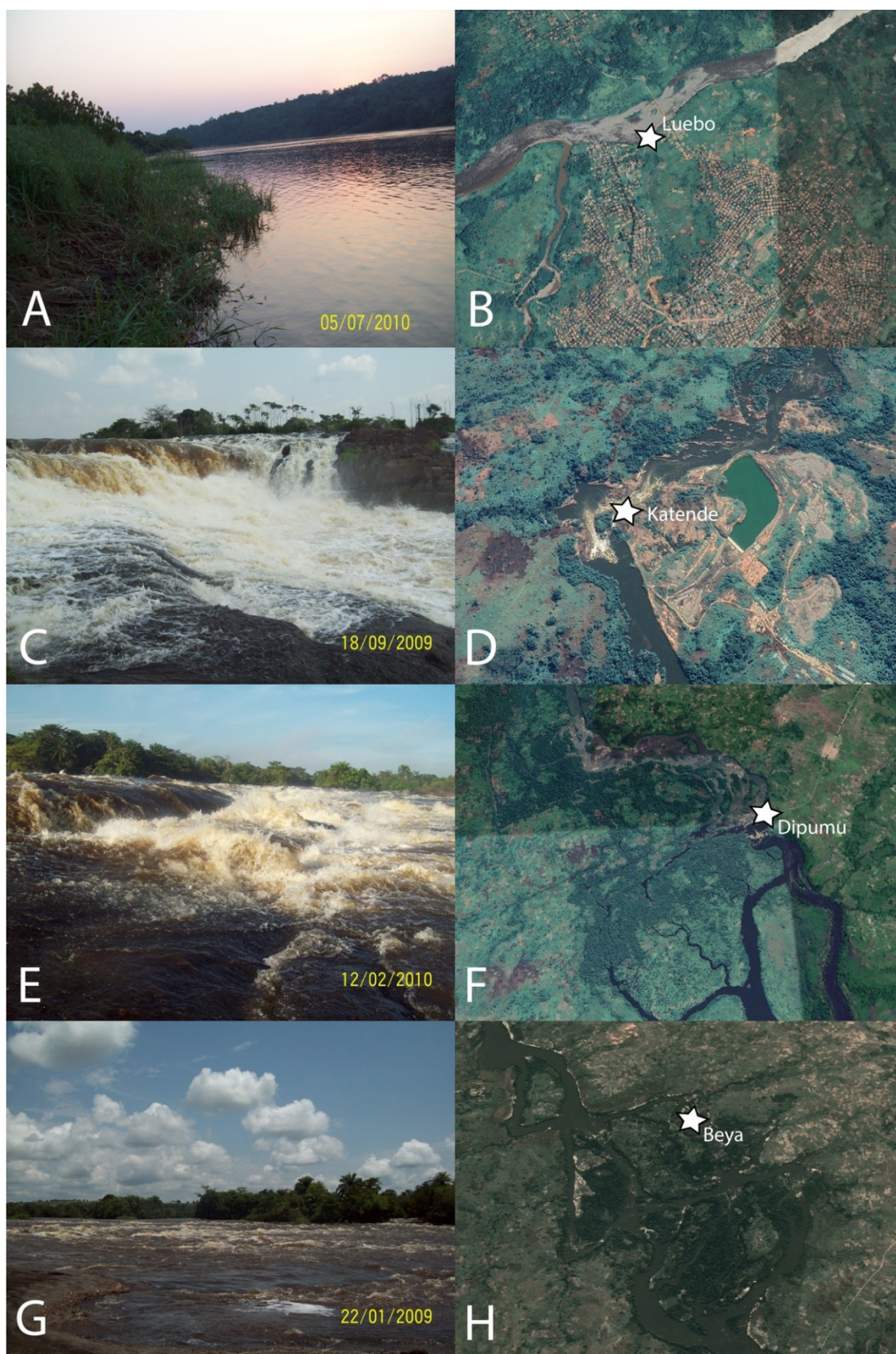


Figure A1. Google Earth projections and biotopes of the collection sites located along the main channel of the LR: (A,B) Luebo (Site 1); (C,D) Katende (Site 8); (E,F) Dipumu (Site 5); (G,H) Beya (Site 2).



Figure A2. Biotopes of collection sites located in tributaries and sub-tributaries of the LR: (A) Lubi River (Site 24); (B) Luna River (Site 39); (C) Luyenga River (Site 28); (D) Tshimayi River (Site 31); (E) Mikindimbua River (Site 30); (F) Mukundulu River (Site 42); (G) Kabikonyi River (Site 41); (H) Tukomba River (Site 17).



Figure A3. Fishing techniques: (A) cast net fishing; (B) passive basket fishing (traps) used in lotic habitat; (C) passive basket fishing (traps) in rapids and waterfalls; (D) active basket fishing in shallow stream; (E) active basket fishing in shallow ponds; (F) dip and seine net fishing.

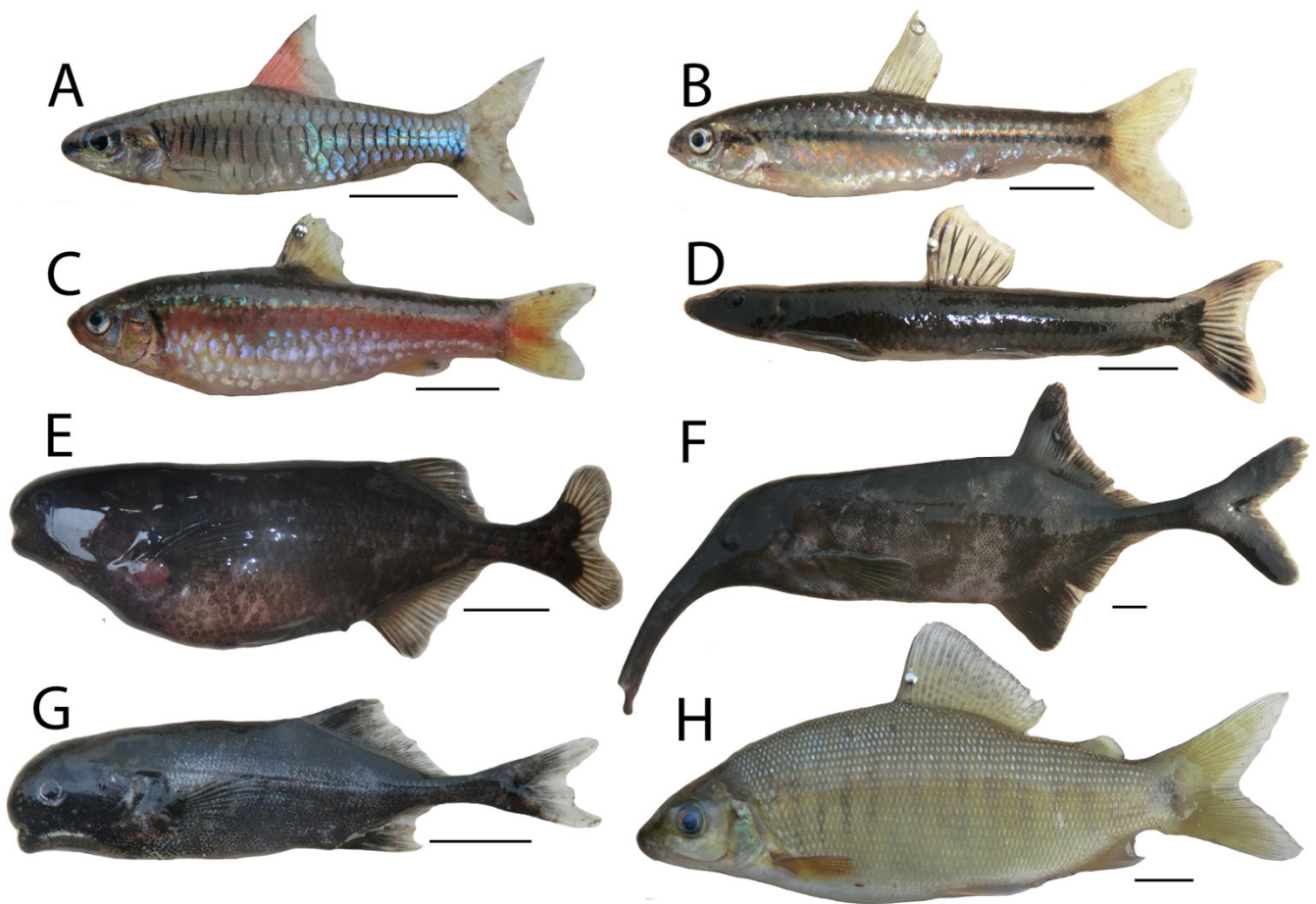


Figure A4. Selected species reported for the first time in the Kasai ecoregion: (A) *Clypeobarbus mediosquamatus*; (B) *Enteromius thamalakanensis*; (C) *Enteromius* sp. "purple stripe"; (D) *Garra* cf. *congoensis*; (E) *Pollimyrus castelnaui*; (F) *Campylomormyrus curvirostris*; (G) *Cyphomyrus cubangoensis*; (H) *Distichodus polli*. Photographed immediately postmortem, scale = 1 cm.

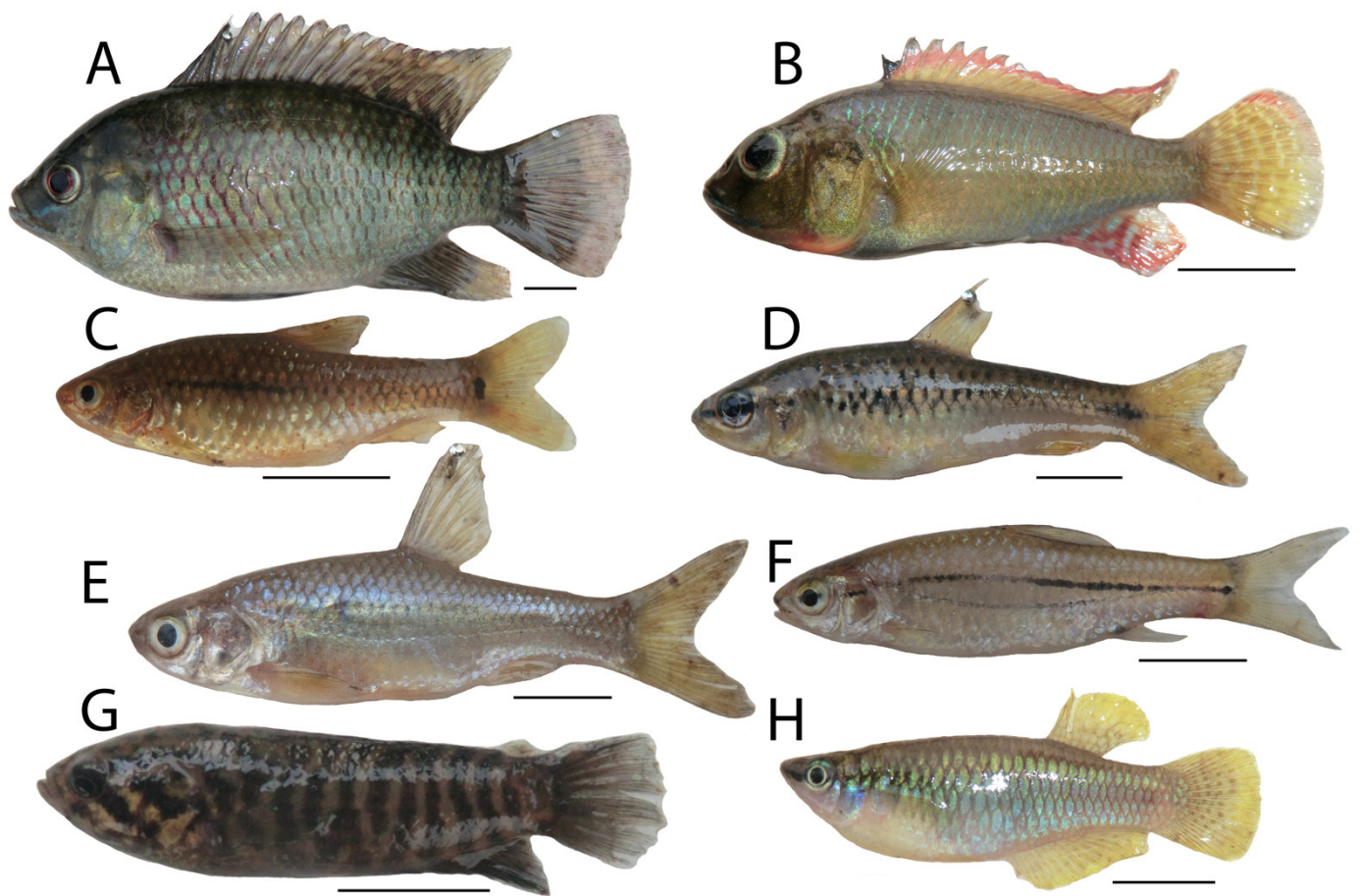


Figure A5. Selected species shared with the Zambezi headwaters: (A) *Coptodon rendalli* (B) *Pseudocrenilabrus philander* (C) *Enteromius brevidorsalis* (D) *Enteromius chiumbeensis* (E) *Enteromius paludinosus* (F) *Enteromius bifrenatus* (G) *Microctenopoma nigricans* (H) *Hypsopanchax jubbi*. Photographed immediately postmortem, scale = 1 cm.

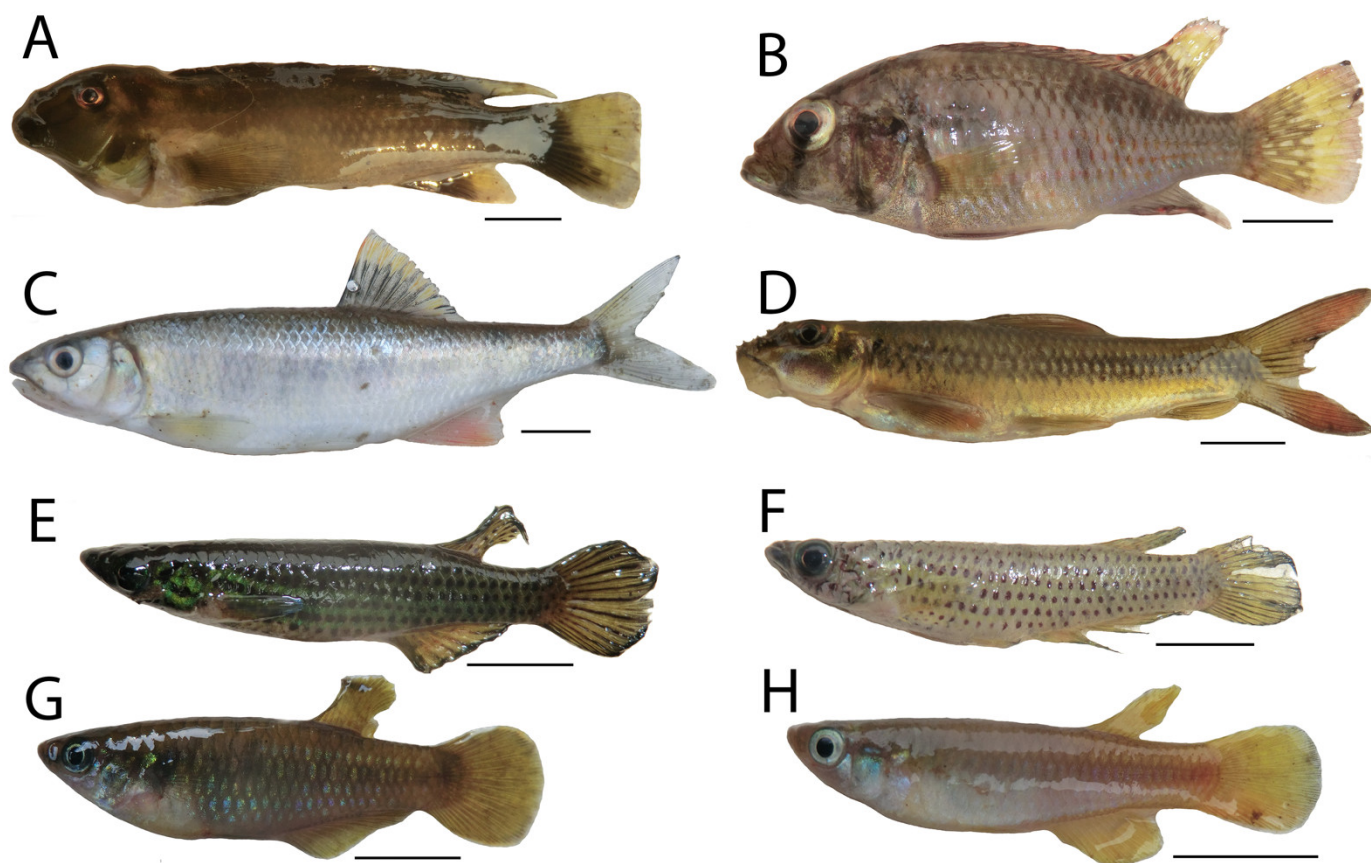


Figure A6. Selected endemic species of the LR: (A) *Steatocranus rouxi* (B) *Ctenochromis luluae* (C) *Opsaridium boweni* (D) *Labeo luluae* (E) *Epiplatys atractus* (F) *Epiplatys* sp. "pale". (G) *Hypsopanchax stiassnyae* (H) *Micropanchax* sp. Photographed immediately postmortem, scale = 1 cm.



Figure A7. Selected images of some human activities with direct and indirect impacts on the ichthyofauna of the LR. (A,B) Shifting agriculture, (C,D) Brick fabrication and clay mining, (E,F) Artisanal diamond mining, (G) Dam prepared for fishing, (H) Vegetal ichthyocide preparation just before use in fishing.

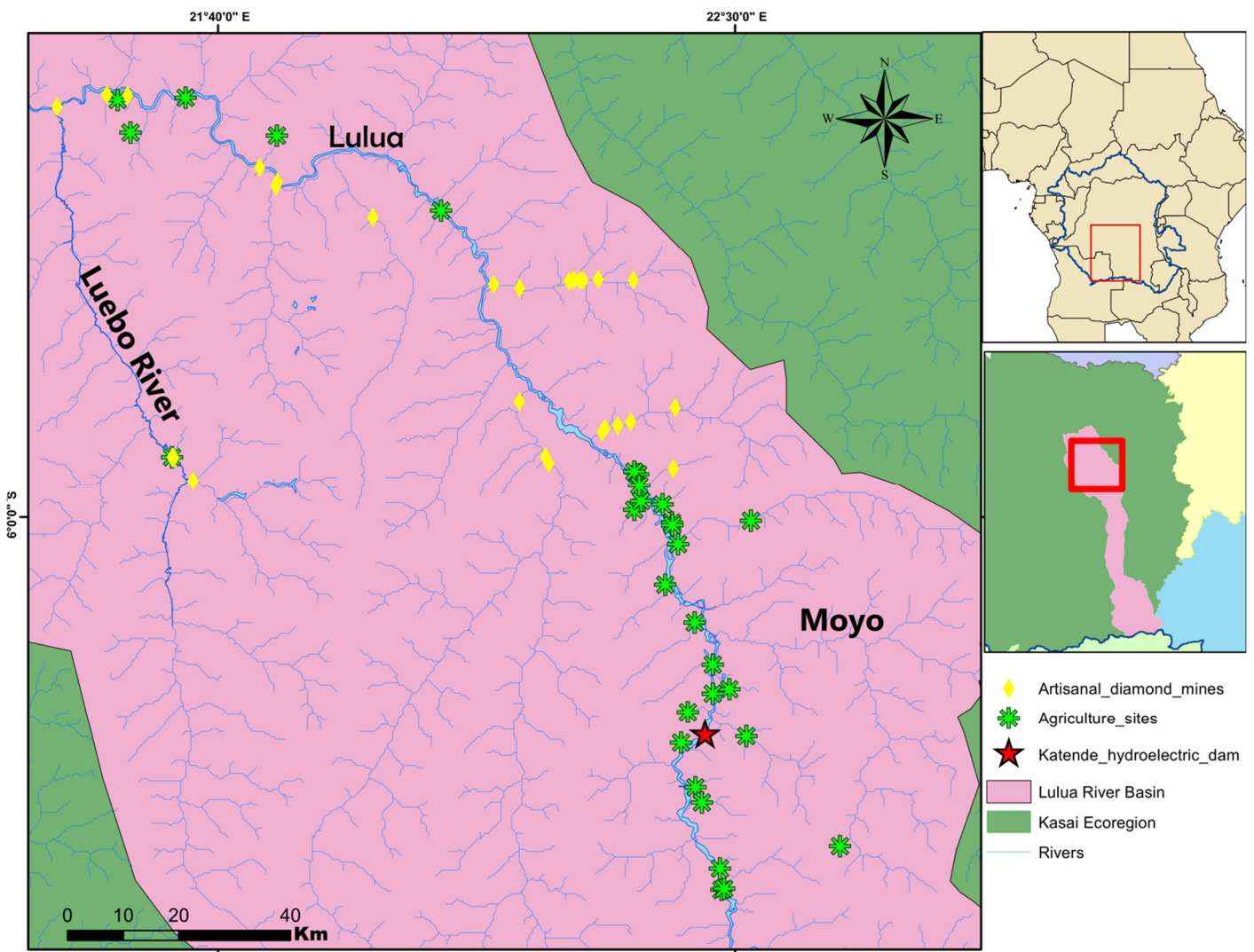


Figure A8. Map of the lower Lulua River showing locations of selected anthropogenic activities in the sampling area.

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