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ICHTHYOFAUNA OF THE ITIMBIRI, ARUWIMI, AND LINDI/TSHOPO RIVERS (CONGO BASIN): DIVERSITY AND DISTRIBUTION PATTERNS

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Background. Although the Congo basin is the second largest river basin in the world and it has been considered a biodiversity hotspot for fish, still many parts of this basin remain poorly studied. In this study, we examined the poorly known ichthyofauna of three major north-eastern tributaries of the Congo basin (Itimbiri, Aruwimi and Lindi/Tshopo). A checklist of the ichthyofauna is provided and two synonymies are presented. As such, it contributes to unraveling the poorly known fish diversity in the whole Congo basin. An improved knowledge of the ichthyofauna is a sound baseline for further studies and conservation

Material and methods. Fish specimens from five recent expeditions have been identified, and the older collection material from the study area, housed at the Royal Museum for Central Africa and other institutions has been checked and re-identified when necessary.

Results. In total, 320 species were recorded, 232 of which from the Itimbiri, 246 from the Aruwimi, and 187 from the Lindi/Tshopo, with the Mormyridae being the most dominant family in all three basins. *Micralestes sardina* Poll, 1938 is relegated to synonymy with *Micralestes humilis* Boulenger, 1899, and *Enteromius trinotatus* (Fowler, 1936) is designated as a replacement name for *Enteromius tetraspilus* (Pfeffer, 1896). Within the Aruwimi, a clear difference in species richness and composition is apparent between the headwaters (Ituri/Epulu) and the lower reaches near the Congo main stream. The headwaters are characterised by low species richness, with the Cyprinidae being the most dominant family, while the lower reaches are more species rich, with mormyrid species being the most dominant. The presence of two waterfalls on the Ituri/Epulu has a noticeable impact on the fish distribution. Finally, the hypothesis that an ancient connection between the north-eastern part of the Congo basin and the region of the Albertine Rift is still reflected in their present ichthyofauna is not confirmed.

Conclusions. This study provides a first checklist of the ichthyofauna in the north-eastern tributaries of the Congo basin, and illustrates the influence of physical barriers on fish diversity and distribution.

Keywords: checklist, north-eastern Congo, fish diversity, Albertine Rift, waterfalls

INTRODUCTION

With a catchment area of about 3 700 000 km^2, the Congo is the second largest river basin in the world, only preceded by the Amazon (Runge 2007, Snoeks et al. 2011). It is known for its very high fish diversity with about 986 valid species, excluding the basin of Lake Tanganyika (Froese and Pauly 2017), and is a recognized hotspot for fish diversity (Snoeks et al. 2011). Additionally, it has a high degree of endemism estimated at about 75%, even when excluding the Lake Tanganyika endemics (Snoeks et al.

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2011). Nevertheless, large parts of the Congo basin remain unexplored and/or poorly studied. The last decade, surveys and studies have been undertaken on several parts of the Congo basin to improve our knowledge of the ichthyofauna (e.g., Hanssens 2009, Lowenstein et al. 2011, Stiassny et al. 2011, Monsembula Iyaba et al. 2013, Van Steenberge et al. 2014, Ibala-Zamba unpublished[*], Wamuini Lunkayilakio unpublished[**]). These studies have led to a significant increase in the number of documented species in the explored areas, and the description of several new species.

The presently reported study focussed on the ichthyofauna of the three most important north-eastern tributaries of the Congo River downstream of the Wagenia Falls, that are not part of the Ubangi system: the Itimbiri, Aruwimi, and Lindi/Tshopo rivers (Fig. 1). These tributaries are the three major right-bank systems of what is considered the *Cuvette Centrale* (Central Basin) according to Abell et al. (2008). The *Cuvette Centrale* covers the largest zone of lowland rainforest in Africa, is completely flat, and its major habitat type is 'moist forest rivers' (Thieme et al. 2005). The Aruwimi has the largest surface area of the three. Its upper part, up to the confluence with the Nepoko, is called the Ituri, with the Epulu River as its most important right bank affluent. The Ituri contains several stretches of rapids and waterfalls that might influence fish species composition (Thieme et al. 2005). One of those, the Arabia Falls, is located just upstream of the confluence of the Epulu with the Ituri, and as such isolates the Epulu from the rest of the Ituri. These upper parts of the Aruwimi are located in the dense Ituri tropical rainforest, which is known to have an organic-rich nature (Koenig 2008). This area is situated relatively high, up to 1350 m on the highest hills near the Epulu, and the bottom of the rivers are here mainly rocky (Katuala et al. 2005).

The easternmost parts of these north-eastern affluents are located close to the Nile system, but are separated from it by a series of mountain chains in the East African Rift System (EARS). Before the tectonic uplifting in the area during the Late Miocene/Pliocene (ca. 7.5–2.5 MYA), a paleo-lake Obweruka existed in the Albertine rift, roughly where now lakes Albert and Edward (currently draining into the Nile system) are situated, and which was connected with the proto-Aruwimi of the Congo basin (Van Damme and Pickford 1999, Van Damme and Van Bocxlaer 2009). This ancient connection between the Congo and the Northern Albertine Rift Lakes may still be reflected in the present ichthyofauna. Although ichthyofaunal exchange between the Congo and Nile systems has been studied via other pathways such as the Lualaba (Cahen 1954, Poll 1963, Banister and Baily 1979, Beadle 1981), such an exchange via the Albertine rift region has never been investigated for the Ituri region. Our study provides:

- A review of the diversity of the ichthyofauna of some poorly explored north-eastern affluents of the Congo basin; and
- An examination of ichthyofaunal similarities between the Congo and the area of the Northern Albertine Rift in the Ituri region.

MATERIAL AND METHODS

The following abbreviations are used through the text: DRC = Democratic Republic of the Congo, HL = head length, SL = standard length. Institutional abbreviations for collection numbers follow Sabaj Perez (2014); hence, the conventional abbreviation MRAC is used for collection numbers of the Royal Museum for Central Africa (RMCA), Tervuren, and BMNH for collection numbers of the Natural History Museum, London (NHM).

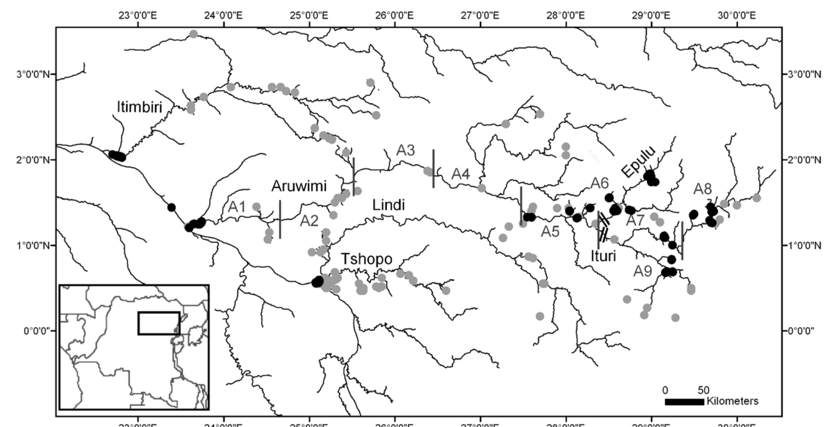

Fig. 1. Map of the area with the north-eastern tributaries of the Congo basin studied; sampling regions of the recent expeditions executed between 2009 and 2014 are indicated (●), as well as the localities of older collection material from the Royal Museum for Central Africa (●), and the 130 km segments within the Aruwimi basin (see text); the waterfalls on the Epulu and the Ituri are indicated with two parallel lines; inset map shows the position of the explored region in the Democratic Republic of the Congo

* Ibala-Zamba A. 2010. Faune des poissons des rivières Luki et Léfini (bassin du Congo): diversité et écologie. PhD thesis, KU Leuven, Leuven, Belgium.
** Wamuini Lunkayilakio S. 2010. Ichtyofaune de l'Inkisi (Bas-Congo/RDC): Diversité et écologie. PhD thesis, Université de Liège, Liège, Belgium.

Fish specimens from five recent expeditions have been identified (RMCA collection numbers given in brackets):

- Congo 2009 (2009–24);
- Congo 2010 (2010–17);
- Okapi Wildlife Reserve (OWR) 2009 (2009–29);
- Ituri 2011 (2011–11);
- Lindi 2014 (2014–17).

The above-mentioned expeditions have been carried out in accordance with the country's regulations.

Older collection material from the study area, curated at the Royal Museum for Central Africa (RMCA), has been checked and re-identified when necessary. The data was complemented with collection records from other institutions: the Natural History Museum, London (NHM), Musée National d'Histoire Naturelle, Paris (MNHN), Cornell University, Ithaca (CU), and the American Museum of Natural History, New York (AMNH); identifications were checked when necessary. Identifications were mainly based on revisions of families and genera, and the original species descriptions. For three groups, identifications were performed by other specialists: Nothobranchiidae and Poeciliidae by Jouke Van der Zee and Rainer Sonnenberg, and *Nannocharax* by Fernando Jerep (MCT-PUCRS). For species numbers and further analyses, only records for which the identification was checked, have been included. In a few cases not all data was available; the voucher specimens could not be traced, were too damaged to allow proper identification, or the collection locality was judged unreliable. When species were only known from the study region from these dubious records, they were considered as possible incorrect species records. They are listed as such in Table 1 (see below) with a question mark, but were excluded from the analyses.

To examine possible ichthyofaunal similarities between the study region and the Albertine Rift region, our compiled species list was compared with museum records (RMCA and other institutions mentioned above) from the region of the Albertine Rift. The identifications of records of shared species in the Congo and Albertine Rift region were then verified.

As both the headwaters and the lower reaches of the Aruwimi basin have been intensively sampled, we had the opportunity to further explore the distribution patterns within this basin and assess the possible influence of rapids and waterfalls in the headwaters. For this, the Aruwimi has been divided into different sections, labelled A1, A2, A3, A4, A5, A6, A7, A8, and A9. The length of the Epulu River, from the most upstream sampling site downstream to the Arabia Falls near its mouth, comprising about 130 km, has been taken as the unit of reference. The Aruwimi basin has thus been divided into sections of about 130 km, with A1 being closest to the main stream, and A9 the most upstream section (Fig. 1). A5 up to A9, the upstream sections of the Aruwimi basin, are called the Ituri River. A5 is the section downstream of the confluence of the Epulu with the Ituri, A6 is the Epulu itself, and A7–A9 are sections of the Ituri River upstream of this confluence.

In order to visualize the degree of (dis)similarities between the different sections of the Aruwimi basin, a correspondence analysis on the presence/absence matrix (Manly 1994) of the ichthyofauna in the Aruwimi has been carried out. The main goal of this analysis was to transform a table of numerical information (0/1 in our case) into a graphical display, in which each column (representing the river sections) is depicted as a point. River sections with a more similar species composition are situated more closely to each other on a two-dimensional graph.

Table 1

List of fish species recorded from the three north-eastern tributaries of the Congo basin studied; in addition, the Ituri River (Aruwimi headwaters) is indicated separately

Species	Itimbiri	Aruwimi	Lindi/ Tshopo	Ituri
POLYPTERIDAE (5)				
Polypterus delhezi Boulenger, 1899	+	–	–	–
Polypterus ornatipinnis Boulenger, 1902	+	+	+	+
Polypterus polli Gosse, 1988	+	–	–	–
Polypterus retropinnis Vaillant, 1899	+	+	–	–
Polypterus weeksii Boulenger, 1898	+	–	–	–
PANTODONTIDAE (1)				
Pantodon bucholzi Peters, 1877	+	+	–	–
NOTOPTERIDAE (2)				
Papyrocranus congoensis (Günther, 1868)	+	+	–	–
Xenomystus nigri (Günther, 1868)	+	+	+	–
MORMYRIDAE (59)				
Campylomormyrus alces (Boulenger, 1920)	–	+	–	+
Campylomormyrus curvirostris (Boulenger, 1898)	–	+	–	+
Campylomormyrus elephas (Boulenger, 1898)	–	+	+	+

Table continues on next page.

Table 1 cont.

Species	Itimbiri	Aruwimi	Lindi/ Tshopo	Ituri
Campylomormyrus mirus (Boulenger, 1898)	–	+	+	+
Campylomormyrus numenius (Boulenger, 1898)	+	+	+	+
Campylomormyrus rhynchophorus (Boulenger, 1898)	+	+	+	+
Campylomormyrus tamandua (Günther, 1864)	+	+	+	+
Cyphomyrus discorhynchus (Peters, 1852)	–	–	+	–
Cyphomyrus psittacus (Boulenger, 1897)	+	+	+	+
Cyphomyrus wilverthi (Boulenger, 1898)	–	+	–	–
Genyomyrus donnyi Boulenger, 1898	+	+	–	+
Gnathonemus echidnorhynchus Pellegrin, 1924	+	+	–	–
Gnathonemus petersii (Günther, 1862)	+	+	+	+
*Hippopotamyrus weeksii (*Boulenger, 1902)	+	+	–	+
Marcusenius angolensis (Boulenger, 1905)	–	+	–	–
Marcusenius greshoffi (Schilthuis, 1891)	+	+	+	+
Marcusenius intermedius Pellegrin, 1924	+	–	–	–
Marcusenius kutuensis (Boulenger, 1899)	+	+	–	–
Marcusenius leopoldianus (Boulenger, 1899)	+	–	–	–
Marcusenius monteiri (Günther, 1873)	+	+	+	+
Marcusenius moorii (Günther, 1867)	+	–	+	–
Marcusenius schilthuisiae (Boulenger, 1899)	+	+	+	–
Marcusenius sp. ‘ruiki’	+	–	–	–
Marcusenius stanleyanus (Boulenger, 1897)	+	+	+	+
Mormyrops anguilloides (Linnaeus, 1758)	+	+	+	+
Mormyrops attenuatus Boulenger, 1898	+	+	+	+
Mormyrops boulengeri (Pellegrin, 1900)	+	–	–	–
Mormyrops furcidens Pellegrin, 1900	+	–	–	–
Mormyrops intermedius Vinciguerra, 1928	?	–	–	–
Mormyrops mariae (Schilthuis, 1891)	–	+	+	+
Mormyrops masuianus Boulenger, 1898	+	+	–	+
Mormyrops nigricans Boulenger, 1899	+	+	+	–
Mormyrops sirenoides Boulenger, 1898	+	+	–	+
Mormyrops zanclirostris (Günther, 1867)	+	–	–	–
Mormyrus caballus Boulenger, 1898	–	+	+	+
Mormyrus ovis Boulenger, 1898	–	+	+	+
Mormyrus rume Valenciennes, 1847	–	+	–	+
Myomyrus macrodon Boulenger, 1898	–	?	–	?
Myomyrus macrops Boulenger, 1914	+	+	+	+
Myomyrus pharao Poll et Taverne, 1967	–	?	–	?
Paramormyrops kingsleyae (Günther, 1896)	–	+	+	+
Petrocephalus binotatus Pellegrin, 1924	+	–	+	–
Petrocephalus christyi Boulenger, 1920	+	+	+	+
Petrocephalus grandoculis Boulenger, 1920	+	+	+	+
Petrocephalus microphthalmus Pellegrin, 1909	+	+	+	+
Petrocephalus sauvagii (Boulenger, 1887)	+	+	+	+
Petrocephalus schoutedeni Poll, 1954	+	+	+	–
Petrocephalus sp. ‘simus Congo’	–	+	–	?
Pollimyrus adspersus (Günther, 1866)	–	+	+	–
Pollimyrus nigripinnis (Boulenger, 1899)	+	+	+	+
Pollimyrus osborni (Valenciennes, 1847)	+	+	+	+
Pollimyrus plagiostoma (Boulenger, 1898)	+	+	+	+
Pollimyrus pulverulentus (Boulenger, 1899)	+	–	–	–
Pollimyrus tumifrons Boulenger, 1902	–	+	+	+

Table continues on next page.

Table 1 cont.

Species	Itimbiri	Aruwimi	Lindi/ Tshopo	Ituri
Stomatorhinus corneti Boulenger, 1899	+	–	–	–
Stomatorhinus fuliginosus Poll, 1941	+	+	+	–
Stomatorhinus humilior Boulenger, 1899	+	+	+	–
Stomatorhinus kununguensis Poll, 1945	+	+	+	–
Stomatorhinus patrizii Vinciguerra, 1928	+	–	+	–
CLUPEIDAE (6)				
Microthrissa congica (Regan, 1917)	+	+	+	+
Microthrissa royauxi Boulenger, 1902	+	+	+	+
Odaxothrissa losera Boulenger, 1899	–	+	+	–
Potamothrissa acutirostris (Boulenger, 1899)	+	+	+	+
Potamothrissa obtusirostris (Boulenger, 1909)	+	+	+	+
Potamothrissa whiteheadi Poll, 1974	–	–	+	–
KNERIIDAE (2)				
Grasseichthys sp. 'Congo'	–	–	?	–
Parakneria cameronensis (Boulenger, 1909)	+	+	–	+
CYPRINIDAE (45)				
Enteromius amanpoae (Lambert, 1961)	–	–	+	–
Enteromius atromaculatus (Nichols et Griscom, 1917)	+	+	+	?
Enteromius brazzai (Pellegrin, 1901)	+	–	+	–
Enteromius candens (Nichols et Griscom, 1917)	+	–	+	–
Enteromius cf. *brazzai* (Pellegrin, 1901)	–	E	–	E
Enteromius cf. *apleurogramma* (Boulenger, 1911)	–	+	–	+
Enteromius holotaenia (Boulenger, 1904)	+	?	+	–
Enteromius humeralis (Boulenger, 1902)	+	+	–	+
Enteromius jae (Boulenger, 1903)	+	+	+	+
Enteromius miolepis (Boulenger, 1902)	+	+	+	+
Enteromius sp. '10 cps'	–	+	+	+
Enteromius trinotatus (Fowler, 1936)	–	E	–	E
Chelaethiops congicus (Nichols et Griscom, 1917)	+	+	+	+
Chelaethiops elongatus Boulenger, 1899	+	+	+	+
Clypeobarbus congicus (Boulenger, 1899)	+	–	–	–
Clypeobarbus pleuropholis (Boulenger, 1899)	+	+	+	+
Garra dembeensis (Rüppel, 1835)	–	+	+	+
Labeo altivelis Peters, 1852	+	+	+	+
Labeo annectens Boulenger, 1903	+	+	–	+
Labeo barbatus Boulenger, 1898	–	+	–	+
Labeo cyclopinnis Nichols et Griscom, 1917	+	–	–	–
Labeo chariensis Pellegrin, 1904	+	+	–	+
Labeo cyclorhynchus Boulenger, 1899	–	+	+	+
Labeo greenii Boulenger, 1902	–	+	+	+
Labeo lineatus Boulenger, 1898	+	+	+	–
Labeo longipinnis Boulenger, 1898	+	+	+	+
Labeo lukulae Boulenger, 1902	–	+	–	+
Labeo macrostomus Boulenger, 1898	–	+	–	–
Labeo nasus Boulenger, 1899	–	+	–	+
Labeo parvus Boulenger, 1902	+	+	+	+
Labeo reidi Tshibwabwa, 1997	–	–	+	–
Labeobarbus caudovittatus (Boulenger, 1902)	+	+	+	+
Labeobarbus humphri (Banister, 1976)	–	E	–	E
Labeobarbus iturii (Holly, 1929)	–	? (E)	–	? (E)
Labeobarbus longidorsalis Pellegrin, 1935	–	+	–	+
Labeobarbus macroceps (Fowler, 1936)	–	E	–	E

Table continues on next page.

Table 1 cont.

Species	Itimbiri	Aruwimi	Lindi/ Tshopo	Ituri
Labeobarbus mawambiensis (Steindachner, 1911)	–	+	–	+
Labeobarbus mirabilis (Pappenheim et Boulenger, 1914)	–	E	–	E
Leptocypris lujae (Boulenger, 1909)	–	+	+	+
Leptocypris modestus Boulenger, 1900	–	+	+	+
Leptocypris weeksii (Boulenger, 1899)	+	–	+	–
Leptocypris weynsii (Boulenger, 1899)	–	+	+	+
Opsaridium ubangense (Pellegrin, 1901)	+	+	+	+
Raiamas christyi (Boulenger, 1920)	+	+	–	+
Raiamas salmolucius (Nichols et Griscom, 1917)	+	+	+	+
DISTICHODONTIDAE (35)				
Belonophago hutsebouti Giltay, 1929	+	–	+	–
Distichodus affinis Günther, 1873	+	+	+	+
Distichodus antonii Schilthuis, 1891	+	+	+	+
Distichodus atroventralis Boulenger, 1898	+	+	–	+
Distichodus decemmaculatus Pellegrin, 1926	+	–	–	–
Distichodus fasciolatus Boulenger, 1898	+	+	+	+
Distichodus langii Nichols et Griscom, 1917	–	+	–	+
Distichodus lusosso Schilthuis, 1891	+	+	+	+
Distichodus maculatus Boulenger, 1898	–	+	+	+
Distichodus noboli Boulenger, 1899	+	+	–	–
Distichodus sexfasciatus Boulenger, 1897	+	+	+	+
Distichodus teugelsi Mamonekene et Vreven, 2008	+	+	–	–
Eugnathichthys eetveldii Boulenger, 1898	+	+	+	+
Eugnathichthys macroterolepis Boulenger, 1899	+	+	+	+
Eugnathichthys virgatus Stiassny, Denton et Monsembula Iyaba, 2013	+	+	–	–
Hemigrammocharax uniocellatus (Pellegrin, 1926)	+	–	–	–
Hemistichodus mesmaekersi Poll, 1959	+	–	+	–
Ichthyborus besse congolensis Giltay, 1930	–	–	+	–
Ichthyoborus ornatus (Boulenger, 1899)	+	–	+	–
Mesoborus crocodilus Pellegrin, 1900	+	+	+	+
Microstomatichthyoborus bashforddeani Nichols et Griscom, 1917	+	–	–	–
Nannocharax brevis Boulenger, 1902	+	+	+	+
Nannocharax elongatus Boulenger, 1900	+	+	+	+
Nannocharax gracilis Poll, 1939	–	–	?	–
Nannocharax macropterus Pellegrin, 1926	+	–	–	–
Nannocharax procatopus Boulenger, 1920	+	+	+	+
Nannocharax pteron Fowler, 1936	+	–	–	–
Nannocharax schoutedeni Poll, 1939	+	–	–	–
Nannocharax taenia Boulenger, 1902	+	+	–	–
Neolebias philippei Poll et Gosse, 1963	+	–	+	–
Neolebias trewavasae Poll et Gosse, 1963	–	–	+	–
Neolebias trilineatus Boulenger, 1899	+	+	–	–
Phago boulengeri Schilthuis, 1891	+	+	+	–
Phago intermedius Boulenger, 1899	+	+	+	–
Xenocharax spilurus Günther, 1867	+	+	–	–
CITHARINIDAE (3)				
Citharinus congicus Boulenger, 1897	–	–	+	–
Citharinus gibbosus Boulenger, 1899	+	+	+	+
Citharinus macrolepis Boulenger, 1899	+	+	+	–
HEPSETIDAE (1)				
Hepsetus microlepis (Boulenger, 1901)	+	+	–	?

Table continues on next page.

Table 1 cont.

Species	Itimbiri	Aruwimi	Lindi/ Tshopo	Ituri
ALESTIDAE (29)				
Alestes liebrechtsii Boulenger, 1898	+	+	+	?
Alestes macrophthalmus Günther, 1867	+	+	+	+
Alestopetersius caudalis (Boulenger, 1899)	+	+	+	+
Alestopetersius compressus (Poll et Gosse, 1963)	+	+	+	–
Bathyaethiops caudomaculatus (Pellegrin, 1925)	+	–	–	–
Brachypetersius altus (Boulenger, 1899)	+	+	+	–
Brachypetersius pseudonummifer Poll, 1967	–	+	+	+
Brycinus bimaculatus (Boulenger, 1899)	+	+	–	–
Brycinus epuluensis (Decru et al., 2016)	–	E	–	E
Brycinus grandisquamis (Boulenger, 1899)	+	+	+	+
Brycinus imberi (Boulenger, 1899)	+	+	+	+
Brycinus kingsleyae (Günther, 1896)	–	+	+	+
Brycinus poptae (Pellegrin, 1906)	+	+	+	–
Brycinus sp. 'hepsetus'	+	+	+	+
Bryconaethiops boulengeri Pellegrin, 1900	+	+	+	+
Bryconaethiops macrops Boulenger, 1920	+	+	+	+
Bryconaethiops microstoma Günther, 1873	+	+	+	+
Hydrocynus goliath Boulenger, 1898	–	+	+	+
Hydrocynus vittatus Castelnau, 1861	+	+	+	+
Micralestes acutidens (Peters, 1852)	+	+	+	+
Micralestes holargyreus (Günther 1873)	–	?	–	?
Micralestes humilis Boulenger, 1899	+	+	+	+
Micralestes lualabae Poll, 1967	+	+	+	+
Micralestes stormsi Boulenger, 1902	+	+	+	+
Phenacogrammus aurantiacus (Pellegrin, 1930)	+	–	+	–
Phenacogrammus deheyni Poll, 1945	–	+	–	–
Phenacogrammus interruptus (Boulenger, 1899)	+	+	+	–
Phenacogrammus polli Lambert, 1961	–	–	+	–
Rhabdalestes yokai Ibala Zamba et Vreven, 2008	+	–	–	–
AMPHILIIDAE (9)				
Amphilius brevis Boulenger, 1902	+	+	+	–
Amphilius zairiensis Skelton, 1986	–	+	–	+
Belonoglanis tenuis Boulenger, 1902	+	+	–	–
Congoglanis alula Nichols et Griscom, 1917	+	+	–	+
Phractura lindica Boulenger, 1902	–	–	+	–
Phractura tenuicauda (Boulenger, 1902)	+	–	+	–
Leptoglanis xenognathus Boulenger, 1902	–	+	–	–
Trachyglanis ineac (Poll, 1954)	+	–	–	–
Zaireichthys mandevillei (Poll, 1959)	–	–	+	–
MOCHOKIDAE (24)				
Acanthocleithron chapini Nichols et Griscom, 1917	–	+	–	+
Atopochilus christyi Boulenger, 1920	+	+	+	+
Chiloglanis micropogon Poll, 1952	–	+	–	+
Euchilichthys dybowskii (Vaillant, 1892)	–	+	–	+
Euchilichthys guentheri (Schilthuis, 1891)	–	?	–	?
Euchilichthys royauxi Boulenger, 1902	–	+	+	+
Microsynodontis christyi Boulenger 1920	+	+	–	–
Synodontis acanthomias Boulenger, 1899	+	+	+	+
Synodontis alberti Schilthuis, 1891	+	+	+	–
Synodontis angelicus Schilthuis, 1891	+	+	–	–
Synodontis centralis Poll, 1971	+	+	–	–

Table continues on next page.

Table 1 cont.

Species	Itimbiri	Aruwimi	Lindi/ Tshopo	Ituri
Synodontis congicus Poll, 1971	+	+	–	–
Synodontis contractus Vinciguerra, 1928	+	+	–	–
Synodontis decorus Boulenger, 1899	+	+	+	+
Synodontis depauwi Boulenger, 1899	–	?	–	–
Synodontis flavitaeniatus Boulenger, 1919	+	–	–	–
Synodontis greshoffi Schilthuis, 1891	+	+	+	+
Synodontis iturii Steindachner, 1911	–	E	–	E
Synodontis nigriventris David, 1936	+	+	–	–
Synotontis notatus Vaillant, 1893	+	–	–	–
Synodontis nummifer Boulenger, 1899	+	+	+	–
Synodontis pleurops Boulenger, 1897	+	+	+	+
Synodontis schoutedeni David, 1936	+	–	–	–
Synodontis smiti Boulenger, 1902	–	+	–	+
MALAPTERURIDAE (6)				
Malapterurus electricus (Gmelin, 1789)	?	?	–	–
Malapterurus melanochir Norris, 2002	+	+	–	–
Malapterurus microstoma Poll et Gosse, 1969	+	+	+	?
Malapterurus monsembeensis Roberts, 2000	+	+	+	+
Paradoxoglanis cryptus Norris, 2002	E	–	–	–
Paradoxoglanis parvus Norris, 2002	+	–	–	–
CLARIIDAE (19)				
Channallabes apus (Günther, 1873)	+	+	+	–
Clariallabes laticeps (Steindachner, 1911)	–	+	+	–
Clariallabes melas (Boulenger, 1887)	–	+	+	–
Clariallabes simeonsi Poll 1941	E	–	–	–
Clariallabes uelensis (Poll, 1941)	+	–	–	–
Clariallabes variabilis Pellegrin, 1926	+	+	+	–
Clarias angolensis Steindachner, 1866	+	+	+	+
Clarias buthupogon Sauvage, 1879	+	+	+	+
Clarias camerunensis Lönnberg, 1895	+	+	+	+
Clarias dumerilii Steindachner, 1866	+	+	+	+
Clarias gabonensis Günther, 1867	+	+	+	–
Clarias gariepinus (Burchell, 1822)	–	–	+	–
Clarias hilli Fowler, 1936	+	+	+	+
Clarias liocephalus Boulenger, 1898	+	+	–	+
Clarias pachynema Boulenger, 1903	+	+	+	–
Clarias sp. *pachynema* 'very long barbels'	–	+	+	+
Clarias sp. *pachynema* 'long barbels and pectorals'	+	+	+	+
Clarias platycephalus Boulenger, 1902	+	+	+	+
Heterobranchus longifilis Valenciennes, 1840	+	+	–	?
CLAROTEIDAE (15)				
Auchenoglanis occidentalis (Valenciennes, 1840)	+	+	+	+
Chrysichthys brevibarbis (Boulenger 1899)	–	–	+	–
Chrysichthys cranchii (Leach, 1818)	+	+	+	+
Chrysichthys duttoni Boulenger, 1905	–	+	+	+
Chrysichthys habereri Steindachner, 1912	+	+	+	+
Chrysichthys longibarbis (Boulenger, 1899)	+	+	+	–
Chrysichthys longipinnis (Boulenger, 1899)	+	+	+	–
Chrysichthys ornatus Boulenger, 1902	+	–	+	–
Chrysichthys punctatus Boulenger, 1899	+	+	–	–
Chrysichthys thonneri Steindachner, 1912	–	+	+	–

Table continues on next page.

Table 1 cont.

Species	Itimbiri	Aruwimi	Lindi/ Tshopo	Ituri
Chrysichthys wagenaari Boulenger, 1899	–	+	+	+
Gephyroglanis congicus Boulenger, 1899	–	+	–	+
Parauchenoglanis balayi (Sauvage, 1879)	+	+	+	+
Parauchenoglanis punctatus (Boulenger, 1902)	+	+	+	+
Parauchenoglanis sp. 'Itimbiri'	E	–	–	–
BAGRIDAE (1)				
Bagrus ubangensis Boulenger, 1902	+	+	–	+
SCHILBEIDAE (8)				
Parailia congica Boulenger, 1899	+	+	+	–
Pareutropius debauwi (Boulenger, 1900)	+	+	+	+
Pareutropius mandevillei Poll, 1959	–	–	+	–
Schilbe grenfelli (Boulenger, 1900)	+	+	+	+
Schilbe intermedius Rüppell, 1832	+	+	+	–
Schilbe laticeps (Boulenger, 1899)	+	+	–	–
Schilbe marmoratus Boulenger, 1911	+	+	+	–
Schilbe yangambianus (Poll, 1954)	+	–	–	–
NOTHOBRANCHIIDAE (13)				
Aphyosemion cf. *mustafiri* Van der Zee et Sonnenberg, 2011	–	+	–	+
Aphyosemion castaneum Myers, 1924	–	–	+	–
Aphyosemion christyi (Boulenger, 1915)	?	+	–	+
Aphyosemion cf. *elegans* (Boulenger, 1899)	+	–	–	–
Aphyosemion pseudoelegans Sonnenberg et Van der Zee, 2012	–	+	–	–
Aphyosemion schoutedeni (Boulenger, 1920)	+	+	–	–
Aphyosemion sp. 'northeast'	+	+	–	–
Epiplatys chevalieri (Pellegrin, 1913)	+	+	+	–
Epiplatys dubiosi Poll, 1952	–	+	–	–
Epiplatys multifasciatus (Boulenger, 1913)	+	+	+	–
Epiplatys singa (Boulenger, 1899)	–	+	–	–
Fenerbahce cf. *devosi* Sonnenberg, Woeltjes et Van der Zee, 2011	–	+	–	–
Fenerbahce sp. 'Epulu'	–	E	–	E
POECILIIDAE (6)				
Aplocheilichthys huterauti (Boulenger, 1913)	+	–	–	–
Hylopanchax silvestris (Poll et Lambert, 1958)	+	+	+	–
Hypsopanchax platysternus (Nichols et Griscom, 1917)	–	+	+	+
Pantanodon stuhlmanni (Ahl, 1924)	–	+	–	–
Platypanchax cf. *modestus* (Pappenheim, 1914)	–	+	–	+
Poropanchax myersi (Poll, 1952)	+	–	–	–
MASTACEMBELIDAE (2)				
Mastacembelus congicus Boulenger, 1896	+	+	+	+
Mastacembelus niger Sauvage, 1879	+	+	–	–
LATIDAE (1)				
Lates niloticus (Linnaeus, 1758)	–	–	+	–
CICHLIDAE (20)				
Congochromis dimidiatus (Pellegrin, 1900)	+	–	+	–
Congochromis squamiceps (Boulenger, 1902)	+	+	+	–
Congolapia crassa (Pellegrin, 1903)	+	–	–	–
Coptodon congica (Poll et Thys van den Audenaerde, 1960)	+	+	+	–
Coptodon rendalli (Boulenger, 1896)	–	+	+	+
Coptodon zilli (Gervais, 1848)	+	+	+	+
'Haplochromis' aeneocolor (Greenwood, 1973)	–	I	–	I
Hemichromis elongatus (Guichenot, 1861)	+	+	+	+
Hemichromis lifalili Loiselle, 1979	+	+	+	–

Table continues on next page.

Table 1 cont.

Species	Itimbiri	Aruwimi	Lindi/ Tshopo	Ituri
Heterochromis multidens (Pellegrin, 1900)	+	+	–	–
Lamprologus mocquardi Pellegrin, 1903	+	+	+	+
Oreochromis leucostictus (Trewavas, 1933)	–	I	–	I
Oreochromis macrochir (Boulenger, 1912)	–	I	–	I
Oreochromis niloticus (Linnaeus, 1758)	I	I	–	I
Orthochromis stormsi (Boulenger 1902)	–	–	+	–
Pelmatochromis nigrofasciatus (Pellegrin, 1900)	+	–	–	–
Pelmatochromis ocellifer Boulenger, 1899	+	+	–	–
Sarotherodon galilaeus (Linnaeus, 1758)	+	+	–	+
Tylochromis lateralis (Boulenger, 1898)	+	+	+	+
Tylochromis robertsi Stiassny, 1989	+	+	–	+
ELEOTRIDAE (2)				
Kribia kribensis (Boulenger 1907)	+	–	–	–
Kribia nana (Boulenger, 1901)	+	+	–	–
ANABANTIDAE (11)				
'Ctenopoma' acutirostre (Pellegrin, 1899)	+	–	–	–
'Ctenopoma' kingsleyae Günther, 1896	+	+	–	–
'Ctenopoma' ocellatum Pellegrin, 1899	+	+	–	–
'Ctenopoma' weeksii Boulenger, 1896	+	–	–	–
Ctenopoma nigropannosum Reichenow, 1875	+	+	+	–
Microctenopoma ansorgii (Boulenger, 1912)	–	+	–	–
Microctenopoma congicum (Boulenger, 1887)	+	–	–	–
Microctenopoma fasciolatum (Boulenger, 1899)	–	+	–	–
Microctenopoma lineatum (Nichols, 1923)	+	–	–	–
Microctenopoma nanum (Günther, 1896)	+	+	+	+
Microctenopoma uelense Norris et Douglas, 1995	+	+	–	+
CHANNIDAE (2)				
Parachanna insignis (Sauvage, 1884)	+	+	–	–
Parachanna obscura (Günther, 1861)	+	–	+	–
TETRAODONTIDAE (2)				
Tetraodon mbu Boulenger, 1899	+	+	+	+
Tetraodon miurus Boulenger, 1902	+	+	+	+
PROTOPTERIDAE (1)				
Protopterus dolloi Boulenger, 1900	+	–	–	–

+ = present, – = absent, E = endemic to the study region, I = introduced, ? = record not confirmed.

RESULTS

THE ICHTHYOFAUNA OF THE NORTH-EASTERN TRIBUTARIES

The identifications of the specimens from the five expeditions from 2009–2014, combined with the older collections at the RMCA and other institutions, resulted in a total of 320 species, belonging to 28 families and 114 genera: 232 in the Itimbiri, 246 in the Aruwimi, and 187 in the Lindi/Tshopo. These numbers include all species that were recognized in the region, including species that still need to be described (see below), but excluding the doubtful records (see above). An overview is given in Table 1. Presence or absence is indicated for the three tributaries studied. In addition, we provided separate entries for the Ituri to better illustrate its particular species composition. In all three tributaries, the Mormyridae was the most dominant family, representing respectively 17.7%, 17.9%, and 19.3% of the species richness of the basins (Fig. 2). The next three dominant families, though not in the same order in each of the three systems, were the Distichodontidae, Alestidae, and Cyprinidae. Eleven out of the 320 species (3.4%) are endemic to the region, eight of which from the Ituri (Table 1). The other three are endemic to the (lower reaches) of the Itimbiri. Four species have been introduced (Table 1), all of them belonging to the family Cichlidae and occurring in the Ituri River.

Several records of the collections of the RMCA, NHM, AMNH, and CU have been re-identified, resulting in the removal of some species from the species list of (a part of) the study area. These re-identifications have been listed in Table 2.

Among the 320 listed species, 10 are (probably) new to science and await formal description. These possible new species, and species that have an uncertain taxonomic status are discussed below, together with some other taxonomic issues.

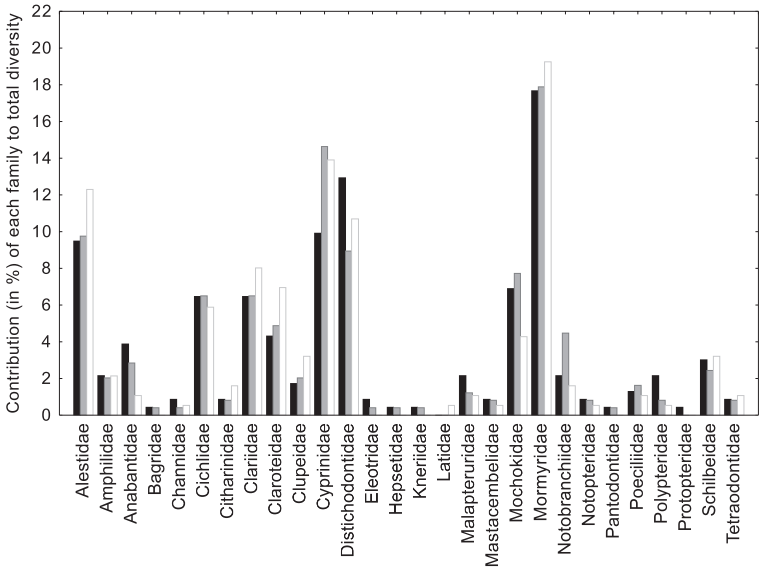

Fig. 2. Graph of the relative contributions of every family to the species richness in each basin explored: Itimbiri (black), Aruwimi (grey) and Lindi/Tshopo (white)

Mormyridae. The region is characterized by an extraordinary diversity of mormyrid taxa, 59 species in 13 genera (Table 1). One species awaits formal description: *Marcusenius* sp. 'ruiki' (Sullivan pers. comm.). This species resembles the most *Marcusenius moorii* (Günther, 1867) but differs from the latter mainly by its straighter head profile, higher number of anal fin rays, and lower dorsal fin/anal fin ratio.

One mormyrid specimen of the genus *Petrocephalus* could not be assigned to any of the valid Congolese species, but fitted the description of *Petrocephalus simus* Sauvage, 1879 described from the ichthyofaunal province Lower Guinea. Since *P. simus* most probably does not occur in the Congo basin (Lavoué et al. 2010, Lavoué and Sullivan 2014), the specimen is identified as *Petrocephalus* sp. 'simus Congo' (see also Decru et al. 2016a).

We experienced identification problems for *Petrocephalus binotatus* Pellegrin, 1924; *Petrocephalus arnegardi* Lavoué and Sullivan, 2014; and *Petrocephalus boboto* Lavoué et Sullivan, 2014. The latter two have recently been described from the Odzala National Park in the north-western part of the Congo basin (Lavoué and Sullivan 2014). However, when identifying, we were unable to assign the *P. binotatus*-like specimens from our study region with certainty to one of these three species. The specimens examined often displayed a combination of characteristics of *P. binotatus* and *P. arnegardi.* We encountered for example specimens with a large mouth like *P. binotatus*, but with only 21–22 branched dorsal rays, which is characteristic for *P. arnegardi*. Furthermore, morphological variation within *P. boboto* is currently unknown, because the only specimen is the holotype. Lavoué and Sullivan (2014) also described differences in electric organ discharges between the three species. However, since no live specimens were available to us, this identification technique could not be used. Therefore, in this study, the three species are grouped together and given the oldest name: *P. binotatus.*

Kneriidae. Kneriidae is a family of small fish species. *Grasseichthys* is considered a paedomorphic kneriid genus, due to its rather peculiar, larval-like appearance, very small size, and lack of skeletal ossification (Schelly 2007). To date, the genus is still monospecific, with *Grasseichthys gabonensis* Géry, 1964 as the only valid species, occurring in a few scattered localities in the Ivindo and Ogowe basins in Gabon, and in the Congo basin. The population in the Congo, however, represents a separate species that still needs to be described (Schelly 2007), and which is for now indicated as *Grasseichthys* sp. 'Congo'. Only one specimen of *G.* sp. 'Congo' has been recorded from the study area (RMCA collections), but the specimen was on loan and the identification could therefore not be checked. In addition, because the specimen is recorded from a doubtful locality, it is listed with a question mark in Table 1. The fact that few specimens of this putative new species are recorded (only one from the study region), could be due to sampling bias, as the species is very small and can virtually only be captured with small mesh size scoop-nets, a fishing technique which in our case has only been used when sampling the Ituri/Epulu region.

The only other species of the Kneriidae occurring in the study region is *Parakneria cameronensis* (Boulenger, 1909). Apart from the records from the study region, the species only occurs in Lower Guinea and the Dja River (Schelly 2007). Therefore, the occurrence of the species in the Aruwimi and Itimbiri would mean that the species has a very wide and scattered distribution, which seems rather unlikely. However, no morphological differences could be found between the specimens from the study region and *P. cameronensis*.

Cyprinidae. After the Mormyridae, the Cyprinidae was the most species-rich family in the area. Especially in the Aruwimi, the diversity of Cyprinidae was very high. This family is one of the most abundant freshwater fish families in Africa. Many cyprinid fish have a wide distribution and

Table 2

Re-identifications of collection material, that resulted in the removal of some species from the species list of (a part of) the study area, and that are not already discussed in the text

Species	Re-identification	Remark
Alestes liebrechtsii (from the Epulu)	*Alestes macrophthalmus*	
Alestopetersius hilgendorfi (Boulenger, 1899)	*Alestopetersius compressus*	
Alestopetersius leopoldianus (Boulenger, 1899)	*Alestopetersius compressus*	
Brycinus macrolepidotus Valenciennes, 1850	Some *B. grandisquamis*, some *Brycinus* sp. 'hepsetus'	*B. macrolepidotus* is absent from the Congo basin (unpublished study)
Brachypetersius altus (from the Ituri)	*Brachypetersius pseudonummifer*	
Hydrocynus forskahlii (Cuvier, 1819)	*Hydrocynus vittatus*	*H. forskahlii* probably absent from the Congo basin (Goodier et al. 2011), confirmed by a morphometric study (Kisekelwa pers. observ.)
Micralestes occidentalis (Günther, 1899)	*Micralestes acutidens*	
Microctenopoma fasciolatum (from the Itimbiri)	*Microctenopoma congicum*	
Fenerbahce formusus (Huber, 1979)	*Fenerbahce* sp. 'Epulu'	
Hemichromis fasciatus Peters, 1857	*Hemichromis elongatus*	*H. fasciatus* probably absent from the Congo basin (Lamboj, pers. comm.; Bitja Nyom, pers. comm.); Awaiting further studies, all records are identified as *H. elongatus*
Hemichromis bimaculatus Gill, 1862	*Hemichromis lifallili*	
Orthochromis polyacanthus (Boulenger, 1899)	*Orthochromis stormsi*	
Clariallabes longicauda (Boulenger, 1902)	Some *Clariallabes uelensis,* some *Clariallabes laticeps*	
Chrysichthys delhezi Boulenger, 1899	*Chrysichthys cranchii*	
Chrysichthys macropterus (Boulenger, 1920)	One syntype is *C. wagenaari*, other is *C. thonneri*	According to an unpublished revision of the genus *Chrysichthys* (Risch, 2003),
Parauchenoglanis punctatus (from the Epulu)	*Parauchenoglanis balayi*	
Enteromius neumayeri (Fischer, 1884)	*Enteromius* sp.	Specimen too damaged for correct ID, but is certainly not *E. neumayeri*
Labeo cylindricus (Peters, 1852)	*Labeo annectens*	*L. cylindricus* probably absent from the Congo basin
Labeo luluae Fowler, 1930	*Labeo parvus*	
Distichodus notospilus Günther, 1867	*Distichodus affinis*	
Nannocharax fasciatus Günther, 1867	*Nannocharax brevis*	*N. fasciatus* probably absent from the Congo basin (Jerep, pers. comm.)
Euchilichthys guentheri (Schilthuis, 1891)	*Euchilichthys royauxi*	
Microsynodontis batesii Boulenger, 1903	*Microsynodontis christyi*	
Petrocephalus pallidomaculatus Bigorne et Paugy, 1990	*Petrocephalus christyi*	
Papyrocranus afer (Günther; 1868)	*Papyrocranus congoensis*	
Hylopanchax stictopleuron (Fowler, 1949)	*Hylopanchax silvestris*	Van der Zee et al. 2013
Polypterus palmas Ayres, 1850	*Polypterus polli*	

display geographical variation; revisions are scarce and often confined to small study areas. As such, many species of this family are difficult to identify, especially species of the genera *Enteromius* and *Labeo.* From the former, 90 species are known to occur in the Congo River; many display only minor morphological differences and identification keys are lacking (Van Ginneken et al. 2017). Therefore, we depended mostly on the original descriptions and a compilation of the main characteristics made by EV. Some *Enteromius* specimens could not be assigned with certainty to any of the valid species. The first group of specimens is listed as *Enteromius* sp. '10 cps', which is most similar to *Enteromius atromaculatus* (Nichols et Griscom, 1917) but has 10 caudal peduncle scales instead of 12. The second group is called *Enteromius* cf. *brazzai,* the specimens of which are more slender than *Enteromius brazzai* (Pellegrin, 1901)*,* and have a different colour pattern*.* A DNA barcoding study (Decru et al. 2016a) also revealed that these specimens formed a separate genetic lineage from specimens identified as *E. brazzai.* The third group is called *Enteromius* cf. *apleurogramma*. *Enteromius apleurogramma* (Boulenger, 1911) was described from Lake Victoria and has not been reported from the Congo basin. However, we found three specimens within the RMCA collection identified as *E. apleurogramma* from the Ituri. We re-identified them as *E.* cf. *apleurogramma*. They indeed resemble mostly *E. apleurogramma*, but have 11 scales around the caudal peduncle (although in one specimen the caudal peduncle was damaged), and 5 to 6 perforated lateral line scales. In contrast, according to the original description, *E. apleurogramma* has 8 scales around the caudal peduncle, and no lateral line pores. However, the notion of *E. apleurogramma* has evolved since its original description. After the synonymization of several species with *E. apleurogramma,* the ranges of caudal peduncle scales and the number of perforated scales have expanded, now comprising the range of the Ituri population; hence our identification as *E.* cf. *apleurogramma.*

Enteromius pellegrini (Poll, 1939) was recorded from the Ituri basin (Lambert 1961, RMCA database), although it was described from Lake Kivu. Specimens from the Ituri identified as *E. pellegrini* have been compared with the type series of *E. pellegrini.* The Ituri specimens have a longer dorsal fin, but this could be due to damage, as the dorsal fins in the four types of *E. pellegrini* seem to be slightly broken. A recent study on some *Enteromius* species (Van Ginneken et al. 2017) revealed that in every river stretch in the Congo basin that was studied, morphologically very similar, but distinct species occurred. Therefore, we assume that the population in the Ituri River is not conspecific with *E. pellegrini* from Lake Kivu, although a further morphological and genetic revision will be necessary. The meristics and colour pattern of these Ituri specimens fit the description of *Enteromius trinotatus* (Fowler, 1936), described from the Ituri River near Saidi's village (3°50′N, 27°19′E), the type series of which could not be sent on loan and examined. Hence, we consider the Ituri population previously identified as *E. pellegrini* to be conspecific with *E. trinotatus* (see below).

Additional problems exist within the genus *Enteromius*, since the study of Van Ginneken et al. (2017) revealed the existence of several cryptic species. Further examination and comparison with more specimens is needed, however, to delineate and describe the putative new species. Thus, although we are aware that our samples of *Enteromius miolepis* (Boulenger, 1902); *Enteromius holotaenia* (Boulenger, 1904); and *E. atromaculatus* are probably polyspecific, they are still presented here under one taxon name.

Labeobarbus mirabilis (Pappenheim, 1914) and *Labeobarbus mawambi* (Pappenheim, 1914) are both species described from the Ituri River at Mawambi, and only known from their holotype. As a morphological study indicates that *L. mawambi* is most probably a junior synonym of *L. mirabilis* (see Decru et al. in preparation[*]), only the latter name is mentioned in the species list.

For the genus *Labeo,* despite the two existing revisions (Reid 1985, Tshibwabwa 1997a, 1997b), many species delineations remain unclear, and identification problems persist (see also Decru et al. 2016a). A separate morphological study has been done on *Labeo altivelis* Peters, 1852 and *Labeo weeksii* Boulenger, 1909 revealing that both species are synonyms (Van Steenberge et al. 2017). Therefore, only the oldest available name, *L. altivelis*, is listed in the present paper.

Within the genus *Leptocypris*, several specimens from the study area resemble *Leptocypris lujae* (Boulenger, 1909), but lack the characteristic black dots on the flanks. Since we could not find any additional morphological differences, even after a more in-depth morphological examination, we identified them as *L. lujae.*

Hepsetidae. Recent revisions revealed the existence of six species instead of one species within this family (Decru et al. 2015). The specimens of the north-eastern tributaries belong to *Hepsetus microlepis* (Boulenger, 1901).

Alestidae. Two new alestid species were recently found in the study area. The first is *Brycinus* sp. 'hepsetus', which is mainly characterized by its prognathous upper jaw and high number of premaxillary teeth (Kone and Vreven pers. comm.). Initially, the specimens of this species were usually identified as *Brycinus macrolepidotus* Valenciennes, 1850, which was supposed to occur in West Africa, the Nile system, as well as the Congo basin. Since the population of the Congo turned out to represent a new species, *B. macrolepidotus* is now considered absent from the Congo basin (Kone and Vreven pers. comm.). The second new species in the region is *Brycinus epuluensis* Decru, Vreven, Sadio et Snoeks, 2016, an Epulu River endemic which has recently been described (Decru et al. 2016b). Taxonomic uncertainties still remain in *Brycinus imberi* (Peters, 1852), a widespread species that appears to be morphologically very variable. An on-going study at the RMCA revealed that the species is most probably polyspecific, but awaiting further results, the non-Epulu specimens are in our study still referred to as *B. imberi.*

Clariidae. Despite the fact that the genus *Clarias* has been revised by Teugels (1986), the correct identification of specimens remains challenging, and some taxonomic problems remain. In the presently reported study, two groups of specimens resembled *Clarias pachynema* Boulenger, 1903, but displayed some differences with this species. Therefore, they were listed as separate taxa which we designated as *Clarias* sp. 'pachynema very long barbels' and *Clarias* sp. 'pachynema long barbels and pectorals'. The first group differed from *C. pachynema* by a maxillary barbel length that ranged from 204.3% HL to 323.2% HL (vs. 106% HL–188.1% HL); the other by a maxillary barbel length of 171.5% HL–235.6% HL, a premaxillary tooth plate width of 26.3% HL–31.4% HL (vs. 19.6% HL–27.6% HL), and long pectoral fins (12.6% SL–15.4% SL vs. 9.3% SL–12.5% SL) and pelvic fins (8.9% SL–11.7% SL vs. 4.9% SL–8.7% SL). A DNA barcoding study revealed these two groups indeed to be genetically distinct (Decru et al. 2016a).

[*] Decru E., Walanga A., Snoeks J., Vreven E. (in preparation) Disentangling the diversity of the *Labeobarbus* taxa (Cypriniformes: Cyprinidae) from the Epulu basin (DR Congo, Africa).

Additionally, the identification of specimens, according to Teugels (1986) belonging to *Brevicephaloides*, a subgenus of *Clarias*, is very difficult. Within the study region, *Clarias camerunenis* Lönnberg, 1895; *Clarias dumerilii* Steindachner, 1866; *Clarias hilli* Fowler, 1936; and *Clarias liocephalus* Boulenger, 1898 belong to this group. The distinction between the species is for a large part based on the development of lateral head bones, but several exceptions are known to this diagnostic character, which is moreover size dependent in some species (Teugels 1986). Other diagnostic characteristics to distinguish certain species have largely overlapping values.

Claroteidae. Two specimens were encountered in the Itimibiri that could not be assigned to any of the valid species within this family, and were designated as *Parauchenoglanis* sp. 'Itimbiri'. They resemble mostly *Parauchenoglanis punctatus* (Boulenger, 1902), but display a more mottled colour pattern, have a deeper caudal peduncle and longer barbels.

Nothobranchiidae. Several new species of this family have been described from the Congo basin the last couple of years, even from the north-eastern part (Sonnenberg et al. 2011, Van der Zee and Sonnenberg 2011, Sonnenberg and Van der Zee 2012). In our study region, two species, possibly new to science, were found: *Fenerbahce* sp. 'Epulu', and *Aphyosemion* sp. 'northeast'. Additionally, the identification of some specimens was uncertain (Van der Zee pers. comm.); in those cases the designation 'cf.' was used. An on-going study indicates that some of the specimens identified as *Platypanchax* cf. *modestus* (Pappenheim, 1914) and *Hypsopanchax platysternus* (Nichols et Griscom, 1917) may represent a new species (Bragança pers. comm.). Awaiting further conclusions, these specimens are still listed as *Platypanchax* cf. *modestus* or *Hypsopanchax platysternus.* According to Wildekamp (2004), *H. platysternus* also occurs in the lower reaches of the Itimbiri. However, we did not find any collection records of this species from that area, nor were collection numbers given by Wildekamp (2004). Also in Van der Zee et al. (2015; their fig. 1), *H. platysternus* was recorded from the lower reaches of the Itimbiri. However, this was based on an error (Van der Zee pers. comm.).

Cichlidae. This family gains a lot of attention of scientists, mainly because the species' flocks in the African Great Lakes provide a unique perspective to study speciation events. Riverine members of this family are less diverse. Yet, 20 species from 12 genera occurred in the study area, though four of them were most probably introduced in the wake of aquacultural activities.

'*Haplochromis*' is the most species-rich genus within the Cichlidae. The genus has been revised by Greenwood (1979, 1980), resulting in 25 lineages, which he considered distinct genera. This revision was however questioned and Hoogerhoud (1984) proposed to refer to '*Haplochromis*' sensu lato as prior to Greenwood's revision, and to place the genus name between quotation marks, a practice we also have chosen to follow.

Even after the revision of the genus *Tylochromis* by Stiassny in 1989, identification problems remain for three species: *Tylochromis lateralis* (Boulenger, 1898), *Tylochromis labrodon* Regan, 1920; and *Tylochromis variabilis* Stiassny, 1989. According to the revision, *T. labrodon* can be distinguished from *T. lateralis* by a more robust lower pharyngeal jaw with mill-like, molariform teeth (vs. not robust and not mill-like), a fully ossified, closed post-temporal latero-sensory canal (vs. open), and shorter pectoral fins which rarely reach the level of the vent (vs. longer and usually reaching the level of the vent). However, when identifying our specimens, discriminating between the two species based on these characteristics was not obvious. Additionally, *T. variabilis* was described as a variable species (hence its name) without unambiguous morphological traits that characterise the species (Stiassny 1989). A morphological comparison of the three species (Musschoot pers. comm.) could not confirm the proposed diagnostic characters. Therefore, they are in the present work considered a single species, for which the oldest name *T. lateralis* is chosen.

Anabantidae. Within this family of labyrinth fishes, the genus *Ctenopoma* has proven to be paraphyletic (Norris 1995, Norris unpublished[*]), and should be restricted to only three species. The remaining species are transferred to either *Microctenopoma* (see Norris 1995), or to another, not yet described genus. This undescribed genus is referred to as '*Ctenopoma*' (see Norris 2007), which has also been applied in the presently reported study.

MICRALESTES SARDINA POLL, 1938 RELEGATED TO SYNONYMY WITH *MICRALESTES HUMILIS* BOULENGER, 1899

Micralestes humilis is a widespread species that occurs throughout the whole Congo basin. Elsewhere, it is known from Lower Guinea (Cross, Ntem, and Ogowe rivers), the Niger, and Zambezi rivers and lakes Chad, Mweru, and Tanganyika (Paugy and Schaefer 2007). *Micralestes sardina* on the other hand is only known from the Upper Congo, from which it was also described (Kandulu, Luembe River, 12°46′S, 28°38′E), and a few records from the Middle Congo near Kisangani (RMCA collection). Both species are only slightly different, based on some overlapping characteristics (Poll 1967): *Micralestes humilis* is said to have a larger head (3.4–3.8 vs. 3.75–4.1 times in the standard length) and fewer lateral line scales (24–27 vs. 26–28) than *M. sardina*. However, upon examining the types and 90 other specimens (see material examined below), no differences between the two species could be found, not even for the two diagnostic features according to Poll (1967). Specimens of both *M. humilis* and *M. sardina* had a range of 22–28 lateral line scales and highly overlapping values for head length (as %SL). Head length was found to be negatively allometric. As the types of *M. sardina* are larger than the holotype of *M. humilis* (67.5–70.7 vs. 42.0 mm), the larger head length in *M. humilis* according to Poll (1967) could be explained by this negative allometry. The number of lateral line scales of the holotype of *M. humilis*

[*] Norris S.M. 1994. The osteology and phylogenetics of the Anabantidae (Osteichthys, Perciformes). PhD Dissertation, Arizona State University, Tempe, AZ, USA.

(27) fell into the range of the types of *M. sardina* (26–29). In addition to allometry, a possible wrong allocation of specimens to the species, could also have blurred the delineation of the two species. However, even when taking only specimens from the type region of both species into account, a very high overlap remained. As such, *M. sardina* is hereby considered a junior synonym of *M. humilis*.

Material examined. *Micralestes humilis*: MRAC 805, 1, holotype, 42.0 mm SL; DRC: Kutu. —MRAC 118808-809, 2, 40.8–50.4 mm SL; DRC: Pool Malebo. —MRAC 57666-57667, 2, 43.2–51.4 mm SL; DRC: Kunungu. — MRAC 47832-47833, 2, 41.8–44.5 mm SL; DRC: Flandria. — MRAC 47848, 1, 58.1 mm SL; DRC: Flandria. — MRAC 95-042-P-0171-0174, 1, 68.2 mm SL; DRC: Dja basin, Mpoo River near Dumo, next to Maleng V. — MRAC 7907-7910, 4, 60.6–67.8 mm SL, DRC: Bosabangi. —MRAC 88-025-P-1153-1155, 3, 49.8–63.0 mm SL, DRC: Kinombwe creek, km 42 road Kisangani-Bafwasende. —MRAC 8094-8098, 5, 40.7–52.5 mm SL, DRC: Poko. — MRAC 74648-74651, 4, 50.4–60.5 mm SL; DRC: Kasai basin, Bushimaie River. — MRAC 100609, 1, 62.2 mm SL; DRC: Lulua River, Katendi Falls. — MRAC 8165-8166, 2, 52.7–60.0 mm SL; Zambia: Lake Mweru. —MRAC 81312-81315, 1, 59.5 mm SL; Zambia: Lake Mweru, Kilwa.

Micralestes woosnami (Boulenger, 1907) (now considered a junior synonym of *M. humilis*): BMNH 1907.4.20.35, 1, lectotype, 61.8 mm SL; DRC: Aruwimi River.

Micralestes sardina Poll, 1938: MRAC 50040, 1, lectotype, 69.4 mm SL; DRC: Kandulu, near Sakania, tributary of Luembe River. —MRAC 50041, 1, paralectotype, 70.7 mm SL; same data as lectotype. —MRAC 50042-50051, 10, 63.3–70.6 mm SL; same data as lectotype. —MRAC 120868, 1, 72.5 mm SL; DRC: Yangambi, Congo basin. —MRAC 189348-349, 2, 47.2–48.4 mm SL; DRC: Wilia, Congo basin near Kisangani. — MRAC 144807-812, 2, 41.4–44.5 mm SL; DRC: Kimilolo River, Katanga. —MRAC 124986-996, 2, 58.6–71.3 mm SL; DRC: Kiambi, Luvua River. —MRAC 120864-866, 2, 56.8–56.9 mm SL; DRC: Katanga, Luapula River, downstream of Kasenga. —MRAC 144729-735, 2, 55.3–69.5 mm SL; DRC: Kafubu River, Kiniama near Katanga bridge. —MRAC 144736-746, 2, 49.8–56.1 mm SL; DRC: Katanga, Kafubu River near Kitanda. — MRAC 144776, 1, 35.2 mm SL; Katanga, River Kimilolo, sources. —MRAC 144778-792, 2, 31.2–32.3 mm SL; DRC: Katanga, Kamatété River. —MRAC 44832-44833, 2, 63.5–66.2 mm SL; DRC: Kasenga, Luapula River. —MRAC 46685-46687, 2, 51.2–66.4 mm SL; DRC: Elisabethville. —MRAC 81422-81424, 2, 67.3–74.8 mm SL; DRC: Kafushia, road Mambirima-Kwele, Wiswila River, Sakania. —MRAC 73-24-P-24, 1, 74.2 mm SL; DRC: Kimbeshie, Luizi River, 100 m downstream of the Luizi-Luanza confluence. —MRAC 97-093-P-0118, 1, 76.1 mm SL; Zambia: Nchelenge, Lake Mweru. —MRAC 97-093-P-0119-0120, 2, 68.3–73.4 mm SL; Zambia: Nchelenge, Lake Mweru. —MRAC 97-093-P-0121-0122, 2, 58.8–62.0 mm SL; Zambia: Nchelenge, Lake Mweru.

ENTEROMIUS TRINOTATUS (FOWLER, 1936) AS A REPLACEMENT NAME FOR *ENTEROMIUS TETRASPILUS* (PFEFFER, 1896)

Enteromius tetraspilus was described, based on a single specimen from the Kavalli River, Upper Ituri (±1°24′N, 30°15′E), by Pfeffer (1896) as *Barbus tetraspilus*, a name actually preoccupied by *Barbus tetraspilus* Günther, 1868. Although *B. tetraspilus* Günther, 1868 has been transferred to the genus *Puntius* (see Pethiyagoda et al. 2008), *B. tetraspilus* Pfeffer, 1896 (now in the genus *Enteromius*) remains an invalid name according to the International Code of Zoological Nomenclature (ICZN 1999: Article 57.2) as both taxa are primary homonyms. The holotype of *E. tetraspilus*, which is the only known specimen, is too damaged to be measured for morphometrical analysis to assess the taxonomic status of the species. Based on the original description, *E. tetraspilus* was compared with all *Enteromius* species from the Congo basin, using an unpublished list compiled by EV. In the combination of 31 lateral line scales, 4.5 scales above the lateral line, 7 branched dorsal fin rays and the presence of a series of round black spots on both lateral sides, *E. tetraspilus* resembles most *E. pellegrini* and *E. trinotatus*. However, all specimens of "*E. pellegrini*" from the Ituri were (re-) identified as *E. trinotatus* (see above). As the description of *E. tetraspilus* matches the one of *E. trinotatus,* and both species are described from the Ituri River, we regard them to be synonyms. Based on the principle of priority, *E. trinotatus* is a junior synonym of *E. tetraspilus* (ICZN 1999: Article 23.1). However*,* since *E. tetraspilus* is an invalid name, it has to be replaced by the name of the oldest available junior synonym (ICZN 1999: Article 60.1 and 60.2). As, at present, there is only one synonym known, *E. trinotatus*, this consequently becomes the replacement name for *Enteromius tetraspilus* (Pfeffer, 1896).

Material examined. *Enteromius pellegrini:* MNHN 1935-0080, 1, lectotype, 52.9 mm SL; DRC: Lake Kivu. — MNHN 1935-0081-0082, 2, paralectotypes, 36.2–38.0 mm SL; same data as lectotype. —MNHN 1996-0265, 1, 43.3 mm SL; same data as lectotype. —MRAC 87514, 1, 83.8 mm SL; DRC: Ituri basin, camp Putnam, Epulu River and small affluents. —MRAC 172482-489, 7, 59.1–72.5 mm SL; DRC: Lubero, Biambwa, affluents of Biena River. —MRAC A9-029-P-881-883, 3, 40.7–50.8 mm SL; DRC: Ituri basin, Nepuse creek, small affluent of Epulu River near Epulu. —MRAC A9-029-P-884-889, 6, 54.7–62.2 mm SL; DRC: Ituri basin, Akokora, Koukou Falls, Epulu affluent. —MRAC A9-029-P-890, 1, 55.9 mm SL; DRC: Ituri basin, confluence Nduye and Biasa, downstream of the bridge near Nduye, Epulu affluent.

EXAMINATION OF CONGO-ALBERTINE RIFT ICHTHYOFAUNAL SIMILARITIES

After examination of the existing collections, 22 shared species were found between the north-eastern tributaries studied and the region of the Albertine Rift (Nile system). Taxonomic considerations concerning these species are listed below.

Six species are reported from only a single capture locality in the region of the Albertine Rift, Mahagi (Ituri district, near Lake Albert, 02°18′N, 30°59′E) and all caught during the same expedition by Schouteden in 1925: *Brycinus imberi* (Peters, 1852); *Ctenopoma acutirostre* Pellegrin, 1899; *Clarias angolensis* Steindachner, 1866; *Clarias hilli*; *Enteromius atromaculatus*; and *Mastacembelus congicus* Boulenger, 1896. We assume, in support of the suggestion by Norris (unpublished*) on the presence of *C. acutirostre* in the Nile basin, that there is a problem with the accurateness of the locality reported. As Mahagi is situated very close to the Congo–Nile divide, it is possible that, during the expedition of Schouteden, collections were made in parts of the Nile as well as of the Congo basin. As such, it is possible that the specimens were actually caught in the Congo system, and that the locality is indicating the nearest large city without further detail. We thus suspect that the occurrences of these six species in the region of the Albertine Rift are incorrect and based on an imprecise notation of the capture locality.

Four of the species are tilapiines that are commonly used in aquaculture and therefore regularly introduced, i.e., *Coptodon zillii* (Gervais, 1848); *Oreochromis leucostictus* (Trewavas, 1933); *Oreochromis niloticus* (Linnaeus, 1758); and *Sarotherodon galilaeus* (Linnaeus, 1758); only the former is native to the Congo basin. Indeed, fish-farming and the introduction of tilapiine fish have been reported from the Ituri region (Depasse 1956, Decru et al. 2017). These introduced species thus do not represent the region-specific ichthyofauna and are not considered evidence for historical ichthyofaunal exchange between the Congo system and region of the Albertine Rift. *'Haplochromis' aeneocolor* is a cichlid species that is not used for aquaculture, but has probably been accidentally introduced in the Ituri. In the 1950s, several unregistered transports have taken place in the region, containing juvenile and small-sized tilapiine fish. It is not unlikely that small *'H'. aeneocolor* specimens have been mixed up with these tilapiine fish (Decru et al. 2017).

Auchenoglanis occidentalis (Valenciennes, 1840); *Clarias gariepinus* (Burchell, 1822); *Heterobranchus longifilis* Valenciennes, 1840; *Lates niloticus* (Linnaeus, 1758); *Mormyrops anguilloides* (Linnaeus, 1758); and *Schilbe intermedius* Rüppell, 1832 are species with a very wide distribution in Africa, beyond the Congo and Nile systems (Bigome 2003, Paugy 2003, Risch 2003, Teugels 1986, Teugels et al. 1991). These taxa should be examined further in order to get more insight into their evolutionary and biogeographic history, as well as the phylogenetic relations between different populations. Since such information is lacking at present, these five species are not considered as evidence for ichthyofaunal exchange between the Congo and Albertine Rift system in the Ituri region. Moreover, some widespread taxa may be polyspecific. *Schilbe intermedius* for example contains a very high degree of intraspecific variation in e.g., the length of the barbels, head profile, snout morphology, and the presence or absence of an adipose fin (De Vos 1995). An in-depth study of the different populations is needed and could reveal multiple species within the taxon (FishBase team RMCA and Geelhand 2016); hence the populations from the Congo and Nile systems may in fact represent separate species.

Platypanchax modestus is an aplocheiloid killifish that inhabits streams emptying into Lake Edward/George, the Semliki River, and the Upper Ituri System in north-eastern DRC and western Uganda (Wildekamp 2004). However, preliminary morphological results indicate that the population in the Ituri in fact represents a new species (Bragança pers. comm.).

Micralestes acutidens (Peters, 1852) is another species reported from both river systems. Its presence in the Nile system is based on a single record from Kasenyi (01°24′N, 30°26′E), on Lake Albert (MRAC 52851-52854). The identification could not be verified as the specimens could not be traced. *Micralestes acutidens* is often confused with *Micralestes elongatus* Daget, 1957 (see Paugy and Schaefer 2007), a species that does not occur in the Congo basin; hence a misidentification cannot be ruled out.

The African tigerfish, *Hydrocynus vittatus* Castelnau, 1861, has a wide distribution and occurs in the Congo basin as well as the Nile system. Recently, a cytochrome *b* gene study (Goodier et al. 2011) suggested possible cryptic diversity in the species, with possibly five separate species in the Congo basin. Although no samples of *H. vittatus* from the Nile basin were included in their analyses, their results highlight the need of a taxonomic revision and the possibility of detecting additional species in areas outside their study region. Therefore, the population in our study region and the population(s) in the Nile system might represent separate species.

Clarias liocephalus is described from Lake Tanganyika and has, according to Teugels (1986), a distribution area that also includes lakes Victoria, Edward/George and Kivu, smaller lakes in Uganda and Rwanda, the Bangwelu-Mweru system, the lake Malawi system, the Kagera, Malagarazi, Ruzizi, and Tana rivers. The collections of the RMCA also harbour specimens from the Itimbiri and the Aruwimi/Ituri. *Clarias liocephalus* belongs to a group of species which are hard to identify (see above). In several species within this subgenus, the dermosphenotic and supraorbital (lateral bones on each side of the head) are not joined to each other and may be reduced. In some species, such as *C. liocephalus*, this character is size dependent, with the bones being separated in small specimens and joined in larger specimens. Moreover, exceptions have been noted for this species, with large specimens in which the joining never has taken place (Teugels 1986). Due to these identification difficulties, we could not confirm or reject with certainty whether the records from the Itimbiri and Aruwimi/Ituri (RMCA collections) were correctly identified as *C. liocephalus*.

Enteromius apleurogramma is described from Lake Victoria but three records from the Ituri were present in the RMCA collections. Re-examination of these specimens however revealed that they are most probably not conspecific with *E. apleurogramma* (see above).

* See footnote on page 238.

As the records of shared species are either based on questionable localities, widespread species, introduced species or species in need of taxonomic revision, they hardly represent evidence of a possible ichthyofaunal exchange through the former connection between the Congo and the Nile basin via the northern Albertine Rift area.

DISCUSSION

The contribution of five years of exploration. This study provides a first comprehensive list of the ichthyofauna in some important north-eastern tributaries of the Central Congo basin. However, several taxa still cause taxonomic problems. Before the onset of this study, a list of 300 species from the region could be compiled based on the RMCA records. After a re-examination of the existing collections and those of five recent expeditions, the total number is now 320. This does not mean that only 20 additional species were discovered during the process. Indeed, after re-identification of the collections, the total number of species decreased to 279, which then added up to 320 after the recent expeditions. In the Itimbiri and Aruwimi, both the older RMCA collections and the material from recent expeditions contributed considerably to the total species diversity (Table 3). On the other hand, not many additional species were recently captured in the Lindi/Tshopo. This is most probably due to a low sampling effort, with only one small expedition done on a small river stretch that had already been explored before. The many additional species encountered after additional sampling efforts in the Itimbiri and Aruwimi confirm that the area was until recently still poorly sampled. Especially for the Aruwimi, the contribution of the recent expeditions is relatively high (28.3%). This is mostly due to the two sampling expeditions (2009 and 2011) to the Ituri headwaters, a particularly poorly explored part of the Aruwimi. The Ituri has a very different species composition compared to other parts of the basin (see below). Many species present in the RMCA collections, were not found during the recent expeditions, especially in the Itimbiri and Lindi/Tshopo with respectively 47.8% and 58.9%. This is not unexpected as the expeditions to the Itimbiri (2009 and 2010) and Lindi (2014) only covered small parts close to the main stream.

Table 3

Percentages of the species diversity covered by the older collections at the Royal Museum for Central Africa (old), the recent expeditions carried out between 2009 and 2014 (new), and both (common)

River	'Old'%	'New'%	Common%
Itimbiri	47.8	19.6	32.6
Aruwimi	25.3	28.2	46.5
Lindi/Tshopo	58.9	4.0	37.1

The fact that additional surveys led to many additional recorded species in the region indicates that possibly the presented inventory may not yet reflect the complete diversity in the region. Hence, the non-appearance in the list of some species from certain river stretches may as well be the result of a real absence as of insufficient sampling. However, our inventory is based on a relatively high degree of sampling compared to other areas in the basin and should cover a good representation of the actual diversity.

Endemics and introduced species. Only 11 of the documented species (3.4%) are endemic to the study region (Table 1). Eight of these occur in the headwaters of the Aruwimi (Ituri/Epulu). The multiple waterfalls and rapids on these headwaters could form a barrier for fish dispersal and isolate the upstream sections. As such, they most probably contribute to this relatively high number of endemics, despite that the overall number of species is low in this area (see below). In the lower reaches of the Aruwimi, such barriers are absent. Indeed, the number of species in the lower reaches is much higher (see below), but mainly consist of species that also occur in the Congo main stream, and no endemics are recorded from this river stretch. Five of the endemics in the Ituri/Epulu belong to the family Cyprinidae, which is also by far the most dominant family in this stretch. These include *Labeobarbus humphri* (Banister, 1976); *Labeobarbus mirabilis*; and *Labeobarbus macroceps* (Fowler, 1936). These are large species and strong swimmers that can negotiate fast-flowing waters. As such, they could be particularly adapted to zones with rapids (Welcomme and de Merona 1988), which are abundant in the area.

All introduced species are cichlid species found in the Ituri River (Table 1). Aquacultural activities and the presence of fish ponds have been reported from the Ituri region (Depasse 1956), and specifically the use of *Oreochromis leucostictus*; *Oreochromis macrochir* (Boulenger, 1912); and *O. niloticus* has been mentioned in the framework of the aquaculture project described by Depasse (1956). *'Haplochromis' aeneocolor* is not a species that is used for aquaculture, but was probably accidentally introduced in the Ituri (see above).

Distribution patterns within the Aruwimi. Species richness and the relative representation of every family in the different sections of the Aruwimi basin (see material and methods) are presented in Table 4. Even though extensive sampling has been undertaken in the Epulu, only 39 species have been documented from this river. This low species richness could be the result of the Arabia Falls on the downstream part of this river, forming a physical barrier for fish dispersal. Similarly, the Ngoy Falls on the Ituri, just upstream of the Epulu/Ituri confluence (in the downstream section of A7; Fig. 1) seem to have influenced the species richness. Indeed all sections of the Aruwimi headwaters, upstream of the two waterfalls (A6–A9) yielded a similarly small number of species (Table 4). The species numbers in A2 to A4 (especially A2) were rather low compared to the other sections; this is most probably because very few records were available from these sections of the Aruwimi. From A1 and A5 on the other hand, many records were available, including those from the recent expeditions. In these regions, the number of species was much higher than that of the areas in between and of the headwaters. A gradual increase in species richness along an upstream-downstream gradient (Hawkes 1975, Matthews 1986) could also be a cause of the low species richness in the headwaters compared to the lower reaches. This is a well-known phenomenon for temperate and tropical stream fish communities, and has already been reported in several studies on African fishes (Kamdem Toham and Teugels 1998, Kouamélan et al. 2003, Ibanez et al. 2007). In the Aruwimi, this pattern was not that pronounced, which could be due to the fact that sampling has not been carried out in a standardized way, meaning that not every section is sampled equally intensive. The presence of the two barriers on the Epulu and the Ituri, could also explain the abrupt break in species richness between A5 and the more upstream sections, instead of a more gradual decrease that would be expected based on the upstream gradient alone. Not only in species richness, but also in species composition, differences exist throughout the Aruwimi basin (Table 4), with the main dissimilarities found between the headwaters (A6–A9) and the lower reaches. In the lower reaches (A1), the Mormyridae was by far the most dominant family, covering 21.2% of the species richness. In the headwaters, above the falls (A7–A9), the Mormyridae covered only about 15% of the species richness, and even only 2.6% (one single species) in the Epulu (A6). The same trend, but to a somewhat lesser degree was noticeable in the Distichodontidae with a share of 10.6% of the species richness in the lower reaches, and only 5.1% to 5.8% in the Ituri upstream of the confluence with the Epulu, and even no recorded species from the Epulu. A reverse pattern was visible for the Cyprinidae. In the lower reaches, only 6.8% of the species were cyprinids, while these percentages increased greatly when moving up to the headwaters. In the Epulu, the Cyprinidae was clearly the most dominant family with 15 out of 39 species (38.5%), and in the majority of upstream sections of the Ituri (A7–A9) percentages varied between 28.2% and 34.6%. For the Alestidae, also a well-represented family in terms of species diversity in the area studied (Fig. 2), no substantial differences were observed between various sections of the Aruwimi basin.

Mormyridae is the most dominant family in the Congo main stream (Poll 1963). As no geographical barriers exist in the lower reaches of the Aruwimi, fish species can easily disperse from the Congo main stream to this part of the tributary. As such, the ichthyofauna in the lower reaches greatly resembles the one of the Congo main stream, with also the Mormyridae being by far the most dominant family. Also, a high diversity of Cyprinidae has already been documented for the peripheral parts of the Congo basin in general (Matthes 1964), which is thus confirmed by our recorded species composition in the Ituri.

Noteworthy is the absence of the families Pantodontidae, Notopteridae, Eleotridae, Channidae, and Protopteridae in the headwaters (Table 1), though representatives of these families, e.g., *Pantodon*, *Kribia*, and *Protopterus* (*P. dolloi*) (Matthes 1964), commonly occur in the central part of the Congo basin. The fact that Eleotridae have not been encountered in the headwaters could also be due to sampling bias, as these very small species are not captured with gill nets or fykes, but only with scoop-nets (see above). However, scoop nets have been intensively used during the OWR 2009 expedition to the Ituri/Epulu. Therefore, the absence of this family in the Ituri is more likely to be real than the result of sampling bias. Interestingly, except for the Eleotridae, all these families that are absent from the Ituri, display morphological adaptations for air breathing. It is, however, difficult to link this observation to their absence in the Ituri. A possible explanation could be that these adaptations are less useful in the Ituri, where large oxygen-poor flooded areas, typical for the *Cuvette Centrale*, are lacking.

The presence of the two sets of waterfalls (the Arabia on the Epulu near its confluence with the Ituri, and the Ngoy just upstream of this confluence on the Ituri itself; Fig. 1), and the fact that the Ituri/Epulu is relatively well sampled offers an opportunity to evaluate whether the falls have a large influence on its species composition. Indeed, to some degree, the ichthyofauna in the Epulu has some specific characteristics not found in the other sections of the Ituri. First, three species seem to be endemic to the Epulu: *Labeobarbus macroceps*, *Brycinus epuluensis*, and *Fenerbahce* sp. 'Epulu'. In addition, nine families are absent from Epulu although they do occur in the rest of Ituri (e.g., Bagridae, Distichodontidae, Mastacembelidae, and Schilbeidae). The falls on the Ituri seem to have a somewhat lower impact on the species composition than the falls on the Epulu, with only five of the families occurring downstream that are absent upstream of these falls. In addition, two endemics occur in the upper sections of the Ituri, but they are species only known from their type specimens (*Labeobarbus mirabilis* and *L. humphri*). Despite the presence of these two waterfalls that can act as barriers, the ichthyofauna of the Epulu was generally similar to the upstream part of the Ituri, and more pronounced differences in species composition were noticed between the combined Ituri/Epulu headwaters and the lower reaches of the Aruwimi (discussed above).

In order to analyse differences and similarities between the different sections of the Aruwimi basin, a correspondence analysis was performed. A first analysis, including all sections of the Aruwimi (not illustrated), showed mainly that section A2 was largely separated from the rest. As only very few records were available from this part, sampling bias most probably caused these results. Therefore, section A2 was omitted from further analysis. On a scatterplot of the two dimensions of a subsequent analysis, the main differences are situated on the first axis (Fig. 3). Along this axis, three groups of river stretches can be distinguished:

- The lower reaches (A1) on the negative part of this axis;
- The middle sections (A3–A5) also on the negative part of this axis, but closer to the point 0.0;
- The headwaters of the Ituri (i.e., upstream of the confluence with the Epulu) and the Epulu (A6–A9), located on the positive part of this axis.

Table 4

Species richness and relative representation of every family in the different parts (see text and Fig. 1) of the Aruwimi basin

Family	A1		A2		A3		A4		A5		A6 (Epulu)		A7		A8		A9	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Alestiidae	16	12.1	2	20.0	8	8.3	6	13.6	16	11.9	3	7.7	5	9.6	6	15.4	5	13.5
Amphilidae	0	0.0	0	0.0	4	4.2	0	0.0	1	0.7	2	5.1	0	0.0	0	0.0	1	2.7
Anabantidae	5	3.8	0	0.0	3	3.1	2	4.5	2	1.5	1	2.6	1	1.9	1	2.6	0	0.0
Bagridae	0	0.0	0	0.0	0	0.0	0	0.0	1	0.7	0	0.0	1	1.9	1	2.6	1	2.7
Channidae	1	0.8	0	0.0	1	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cichlidae	7	5.3	0	0.0	4	4.2	3	6.8	6	4.4	3	7.7	5	9.6	2	5.1	4	10.8
Citharinidae	2	1.5	0	0.0	0	0.0	0	0.0	1	0.7	0	0.0	0	0.0	0	0.0	0	0.0
Clariidae	9	6.8	3	30.0	5	5.2	8	18.2	6	4.4	6	15.4	3	5.8	3	7.7	2	5.4
Claroteidae	9	6.8	0	0.0	3	3.1	1	2.3	7	5.2	1	2.6	1	1.9	1	2.6	1	2.7
Clupeidae	3	2.3	0	0.0	1	1.0	1	2.3	4	3.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyprinidae	9	6.8	1	10.0	16	16.7	4	9.1	28	20.7	15	38.5	18	34.6	11	28.2	11	29.7
Distichodontidae	14	10.6	0	0.0	15	15.6	8	18.2	13	9.6	0	0.0	3	5.8	2	5.1	2	5.4
Eleotridae	1	0.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Hepsetidae	1	0.8	0	0.0	0	0.0	1	2.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Kneriidae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.6	0	0.0	0	0.0	0	0.0
Latidae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Malapteruridae	2	1.5	0	0.0	1	1.0	0	0.0	1	0.7	0	0.0	0	0.0	0	0.0	0	0.0
Mastacembelidae	1	0.8	0	0.0	1	1.0	1	2.3	1	0.7	0	0.0	1	1.9	1	2.6	1	2.7
Mochokidae	7	5.3	0	0.0	10	10.4	3	6.8	10	7.4	2	5.1	2	3.8	2	5.1	1	2.7
Mormyridae	28	21.2	0	0.0	16	16.7	1	2.3	31	23.0	1	2.6	9	17.3	6	15.4	5	13.5
Notobranchiidae	5	3.8	3	30.0	2	2.1	4	9.1	2	1.5	3	7.7	0	0.0	0	0.0	1	2.7
Notopteridae	2	1.5	0	0.0	1	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Pantodontidae	1	0.8	0	0.0	1	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poeciliidae	1	0.8	1	10.0	0	0.0	0	0.0	0	0.0	1	2.6	2	3.8	2	5.1	1	2.7
Polypteridae	1	0.8	0	0.0	0	0.0	0	0.0	1	0.7	0	0.0	0	0.0	0	0.0	0	0.0
Protopteridae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Schilbeidae	6	4.5	0	0.0	2	2.1	1	2.3	2	1.5	0	0.0	1	1.9	1	2.6	1	2.7
Tetraodontidae	1	0.8	0	0.0	2	2.1	0	0.0	2	1.5	0	0.0	0	0.0	0	0.0	0	0.0
Total *N*	132		10		96		44		135		39		52		39		37	

The Aruwimi basin has been divided into sections of about 130 km, with A1 being closest to the main stream, and A9 the most upstream section; A5 up to A9, the upstream sections of the Aruwimi basin, are called the Ituri River; A5 is the section downstream of the confluence of the Epulu with the Ituri, A6 is the Epulu itself, and A7–A9 are sections of the Ituri River upstream of this confluence; *N* = number of species; Total *N* = total number of species.

As such, the different sections are structured along an upstream-downstream gradient, from the lower reaches up to the headwaters. On axis 2, sections A3–A5 are clearly separated from the remaining sections. This separation could be due to the fact that A3 and A4 (with the most positive values) are the most poorly sampled river sections in the dataset (apart from the excluded A2). However, section A5 is also located on the positive part of axis 2, while it has been intensively sampled.

The correspondence analysis confirms that the Epulu (A6) only slightly differs in species composition from the other sections of the Ituri River (A7–A9), upstream from the confluence Epulu/Ituri, which points to only a limited impact of the waterfalls on the Epulu. The most downstream section, of what is called the Ituri (A5), does not cluster with the other sections of the Ituri on axis 1. Instead, it is situated closer to the more downstream sections of the Aruwimi, which could be explained by the effect of the Arabia and Ngoy Falls (see above).

Environmental parameters could also play an important role in the fish distribution in the area. Data of online available GIS layers (Foley et al. 1996) indeed indicates differences in environmental conditions between headwaters and lower reaches of the Aruwimi. For example, in the headwaters, annual precipitation and mean water temperature is lower than the middle and lower sections (respectively about 1300 mm vs. 1700 mm; and 17°C vs. 25°C). Thus, in addition to the influence of physical

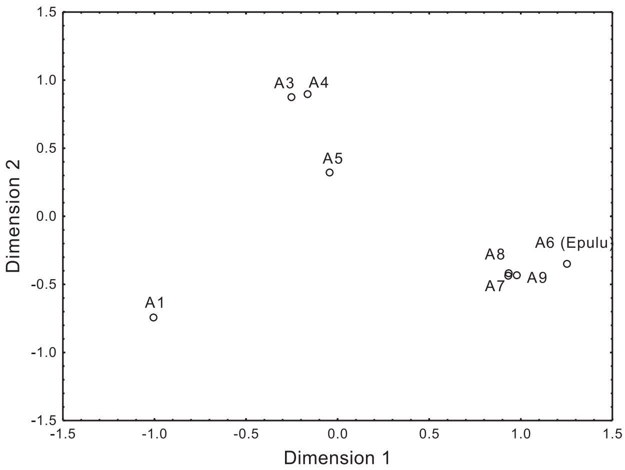

Fig. 3. Scatterplot of dimension 2 (19.87% of inertia) against dimension 1 (28.06% of inertia) of a correspondence analysis executed on a presence matrix (0–1) of recorded species in different parts of the Aruwimi basin; for delineation of the different parts, see Fig. 1

barriers, these differences in environmental conditions could also explain the differences in species composition between the headwaters and the lower reaches. The fact that the most upstream sections of the Ituri (including the Epulu) all seem to have similar environmental conditions, could also explain the similar ichthyofauna in the Epulu and the other sections of the headwaters. The dissimilarities between sections of a basin and the presence of endemics in smaller (isolated) river stretches (e.g., three in the Epulu River), is something to consider for conservational issues, as protected areas often only comprise a small part of river basins. As such, only the ichthyofauna of that specific part will fall under protective regulations. In the Aruwimi basin, the Okapi Wildlife Reserve comprises a part of the Ituri headwaters and a large part of the Epulu River. The location of this reserve is beneficial as the specific ichthyofauna of the headwaters is protected. Indeed, our results indicate that these headwaters have a different species composition from the lower reaches and harbour several endemics, while most species from the lower reaches also occur in the Congo main stream. However, in the more upstream part of the Ituri River, outside of the reserve, there are important mining activities (AW pers. comm.). These activities may have a severe negative impact on the fish species due to runoff of sediments, and also affect the fish populations in more downstream parts, including the parts of the basin that fall within the Okapi Wildlife Reserve.

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