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An Updated Checklist of the Fishes from the Upper Malagarazi (Lake Tanganyika Basin) in Burundi: Implications for an under Implementation Malagarazi Nature Reserve

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Abstract: The upper Malagarazi (uM) Basin is situated in Southeastern Burundi and Northwestern Tanzania, and partially covered by the Malagarazi Nature Reserve (MNR). A checklist of fishes from the uM, in Burundi, is presented based on a literature review, a re-examination of historical collections, and a study of new collections (2013–2022). A total of 74 native species, including 14 endemics and two introduced *Oreochromis*, distributed over 38 genera and 16 families, are reported. Of the aforementioned species, 60 native (81%) and one introduced are present in the MNR. The most important families in the uM and the MNR are the Cyprinidae (21 versus 17 species, respectively) and Cichlidae (12 versus 11). Other families are represented by less than 10 species in both the uM and the MNR. Furthermore, of the 14 species endemic to the uM (19%), only eight (57%) are reported from the MNR; the others are confined to some non-included affluent rivers. Moreover, eight taxa still await formal description. Finally, as some endemic and native species are not included within the current borders of the MNR, adjustments are proposed and the need for a new protected area is considered.

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1. Introduction

The Malagarazi Basin is situated in the southeastern part of Burundi and the northwestern part of Tanzania [1,2]. Its catchment area covers over 50% of the Lake Tanganyika (LT) Basin, including the Lake Kivu Basin [2,3]. It is situated at an altitude between about 2500 m, at the source of some of its left bank affluents in Burundi, and 776 m, where it flows into the LT (Figure 1). The upper Malagarazi (uM) Basin has its source near the village of Mugina (Makamba Province, Burundi), at an altitude of about 1600 m, and reaches downstream up to the Kibuyo Rapids, located in the mountainous region in the northern part of the Kigoma Province (Tanzania) [1,4,5] near the village of Kibuyo, being at about 1100 m of altitude (Figure 1).

The uM Basin is partially covered by the Malagarazi Nature Reserve (MNR: Burundi), the latter largely corresponding to the Muyovozi Marshland complex of Burundi [3,6] (Figure 1). Furthermore, the middle Malagarazi (mM) Basin corresponds to the central stretch of the Malagarazi Basin, consisting mainly of floodplains, and extends downstream to the last rapid region below the Igamba Falls, i.e., near the village of Kasagwe (Tanzania), being at about 800 m of altitude (Figure 1). The mM Basin is partially covered by the Moyowosi Game Reserve (MGR) of the Malagarazi–Moyowosi Wetlands (Tanzania) [1,3,5]. Both the MGR and the MNR constitute protected areas (PAs) of national and international importance as illustrated also by their identification as Ramsar Convention Sites [3,6]. Finally, the lower Malagarazi (lM) Basin extends from the rapids below the Igamba Falls to its mouth where it meets the LT (Figure 1) [1,7]. Furthermore, following the delimitation of the freshwater ecoregions of Africa (sensu [8,9]), the uM and mM, together, form the Malagarazi–Moyowosi ecoregion, while instead the lM is part of the LT ecoregion (Figure 1).

The MNR covers (i) the main course of the uM River and its marshy area on the left bank of the uM River in Burundi and (ii) part of the open and gallery forests around the village of Muvumu (municipality of Giharo, Rutana Province) (Figure 1). This area has first been proposed as a potential and good candidate region for the installation of the envisioned MNR in 2009 [10]. Since 2014, it has been known as a Ramsar Convention Site, thus as one of the PAs of Burundi under the law n°1/10 of 30 May, 2011 related to the creation and management of PAs of Burundi. However, until now it has not yet received specific legal status for its management, hence its name, MNR, since it is still under implementation. Nevertheless, it has already been added to the 13 other PAs of Burundi [11].

As for the MNR, the current delimitation of the other PAs of Burundi was designed without a priori consideration of the hydrographic basin(s) draining these areas and, consequently, the fish fauna inhabiting them. The earliest known scientific publication dealing with the fish fauna of uM is from the Belgian Mrs Lore David [12]. However, to our knowledge, few or no (published) ichthyological inventories have been conducted in the river basins draining the Pas of Burundi. Indeed, only three studies are currently available: one for the Ruvubu National Park (Ruv NP) [13]; one for the Rusizi National Park (Rus NP) ([14], D.R.M. et al., in prep.); and one for all basins draining Burundi, based on: (i) the re-examination of available fish specimen samples collected before 2008 and deposited in European natural history museums; and (ii) large new sampling efforts organised by [2], and for which the collected specimens were deposited at the RMCA. These PAs are all drained by an important hydrographic network and the current boundaries of some are, unfortunately, formed by rivers and/or lakes themselves, thus rendering their inhabiting ichthyofauna vulnerable. Instead, complementary studies on the terrestrial vertebrate fauna and/or flora have been conducted in 10 out of the 14 PAs of Burundi [15–21]. Moreover, studies on birds, plants, and, somehow, fish in the uM in Burundi confirmed the importance

of protecting this area, and some have already proposed an extension of the current delimitation of the MNR [2,18,22]. Indeed, the uM contains 63 fish species versus 108 (58%) for the entire Malagarazi Basin [1], and versus 90 species (70%) for all rivers of Burundi [2], making it a Key Biodiversity Area (KBA) [23,24] for both the basin and the country.

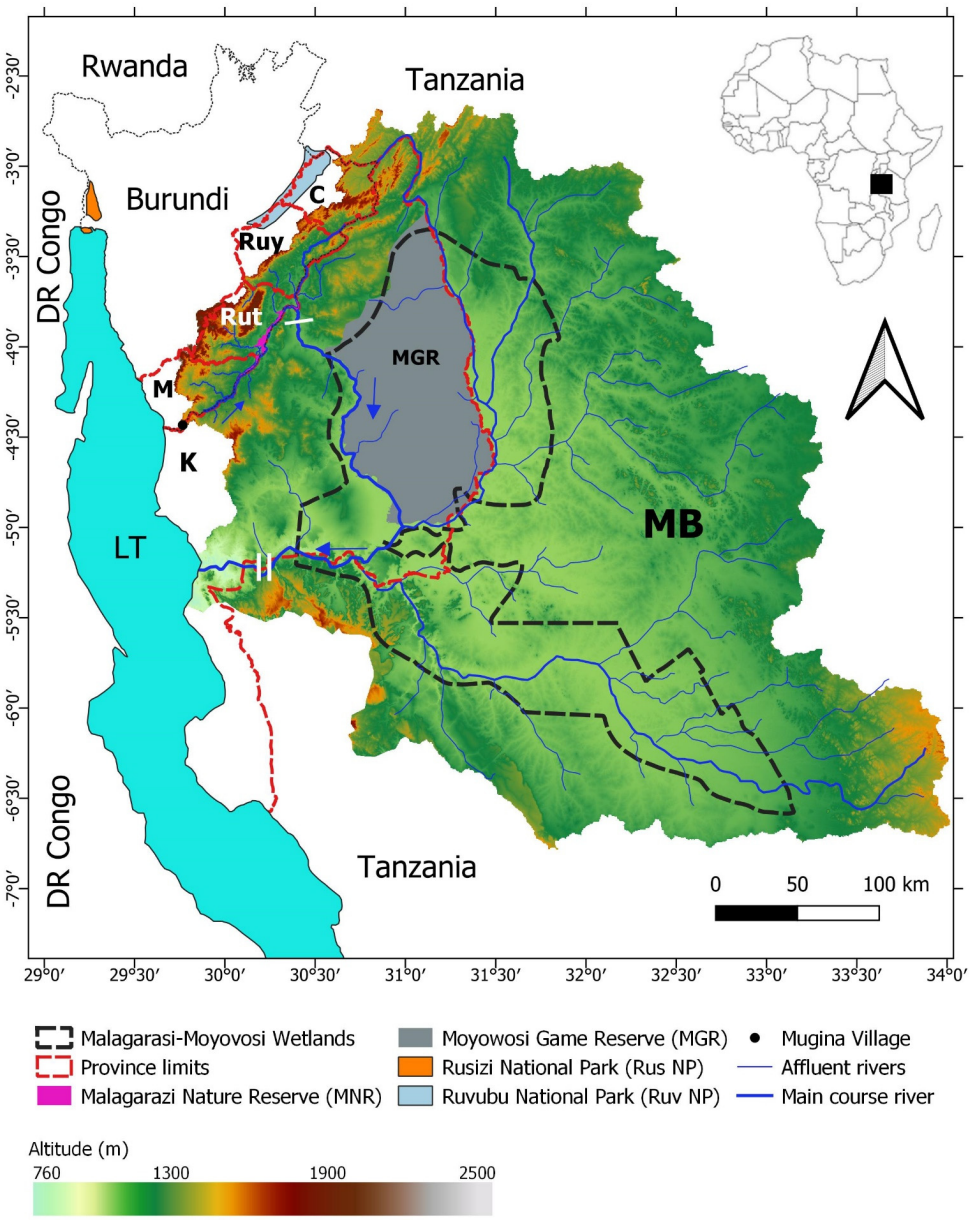

Figure 1. Location of the Malagarazi Basin (MB) with its major subdivision. White bars: 1. Kibuyo Rapids (single); 2. Igamba Rapids/Falls (double). Upper Malagarazi (uM): upstream of the Kibuyo Rapids; middle Malagarazi (mM): between Kibuyo Rapids and Igamba Rapids/Falls; and lower Malagarazi (lM): downstream of the Igamba Rapids/Falls. MB: Malagarazi Basin. The five major provinces of the upper Malagarazi Basin: four in Burundi, i.e., Cankuzo (C), Makamba (M), Rutana (Rut), and Ruyigi (Ruy), and one in Tanzania, i.e., Kigoma (K). LT: Lake Tanganyika.

To further complete our knowledge of the ichthyofauna of the uM in Burundi in general, and of the MNR in particular, new ichthyological diversity surveys were conducted (2013–2022). Thus, the major overall objectives of the present paper are: (i) to update a list of fishes of the uM Basin; (ii) to document their distribution by subbasin in the uM; (iii) to document, based on the previous information, to what extent the current proposed delimitation of the MNR will allow an effective protection of the entire, endemic and

native, ichthyofauna of the uM in Burundi; and, finally, (iv) to also document the major anthropogenic threats to this fish fauna. Finally, it is hoped that the present study provides additional argumentation, in terms of the ichthyofauna of both the uM and the MNR, to highlight the crucial importance of fully and effectively legalising the MNR as a PA and considering the need to envision an additional one to maximise the uM conservation effort in Burundi as a whole.

2. Materials and Methods

2.1. Hydrography and Sampling of the Study Area

The sampling area covers all the main rivers of the uM Basin in Burundi, therefore excluding the Tanzanian area of the upper Malagarazi. Nevertheless, for ease of reading, the study area will henceforth be referred to as the uM Basin (or uM), unless otherwise indicated (Figure 2). As such, it contains the main course of the uM and all its left bank affluents, including the Rumpungwe as the largest of those. The presented fish species list was compiled based on: (i) a study of the literature, i.e., scientific publications; (ii) a re-examination of the historical collections available at the Royal Museum for Central Africa (RMCA, Tervuren, Belgium); and (iii) a study of recently newly made collections (2013–2022). Both internet databases, i.e., Eschmeyer's Catalog of Fishes [25] and FishBase [26], were consulted to validate all species and author name(s) and year of original publication. Furthermore, the current conservation status, according to the IUCN Red List [27], was also compiled for each species for which an assessment is currently available. The order of the families follows Fricke et al. (2024) [25], while within each family, the genera and species are all listed in alphabetical order. Additionally, local names (in Kirundi language) were, when available, also added for each species for easy communication with the local populations in matters of species diversity. Note that some species had more than one name according to different localities. That may be due to the uM constituting a border area between two communities speaking different languages [28]. Indeed, for those with more than one name, some are, in origin, names in Swahili. Others are confirmed to be different names in the Kirundi language, but it is, indeed, doubtful that they could be originally names in the Giha language, a language similar to Kirundi and commonly spoken in the western part of Tanzania.

Recent new collection efforts were organized between 2013–2022, with part of the collections deposited at the University of Burundi (UB) in Burundi, while the remaining part was deposited at the RMCA (Figure 2). For these recent collection efforts, both subbasins of uM were explored, i.e., the Malagarazi River itself and seven of its major left bank affluents (Malagarazi subbasin: Msb), located in the south–southeastern part of the country, and the Rumpungwe River, being the main left bank affluent of the uM and seven of its right bank affluents (Rumpungwe subbasin: Rsb), with these all located along the east-southeastern border of the country (see Figure 2). These two rivers flow in opposite directions until they merge in the more or less central zone of the uM, where the Malagarazi River itself makes a radical turn to the south and thus exits Burundi to enter Tanzania. Several sites sampled in the past were further resampled, and new sites from less explored river sections, such as the upper stretches of most left bank affluents of Malagarazi, were added (Figure 2). Thus, a total of 55 sampling sites were visited, including nine sites on the main course of the uM River, six sites on the main course of the Rumpungwe River, and 40 sites along both, with the left bank affluents of the former (n = 26), and the right bank affluents of the latter (n = 14) (Figure 2; see Supplementary Material: Table S1). The administrative delimitations of the communes currently already partially covered by the MNR, and which could be affected by the possible extension of the limits of the MNR, were also illustrated (Figure 2).

Fish samples were collected using a combination of fishing techniques, including gill, fyke, dip, and cast nets [see Supplementary Materials (SM): Figure S1]. This allowed us to sample the different habitat types available in the uM (Appendix A: Figure A1). Note that the use of ichthyotoxins is forbidden by law in Burundi, even for scientific purposes (see Article 38 of Law N° 1/17 of 30 November 2016 on the organisation of fisheries

and aquaculture in Burundi). Whenever necessary, specimens of species not sampled by ourselves were purchased from local fishermen, women, and/or children. At each sampling locality, representative specimens of each species were photographed. Additionally, fin clips from the right pelvic and, when needed, also from the pectoral fin, were taken from at least two specimens per identified species/taxon and preserved in absolute alcohol (98%) for further molecular studies. Representative specimens selected of each species sampled at a certain locality, including all the photographed and/or fin-clipped specimens, were labelled and fixed in 10% formalin before being deposited at the UB or RMCA. The specimens deposited at the Biology Department of the UB are still stored in 5% formalin as to be part of the collections of the Lake Tanganyika Museum. Once at the RMCA, all specimens were thoroughly rinsed with water and subsequently transferred to 70% ethanol for long-term preservation.

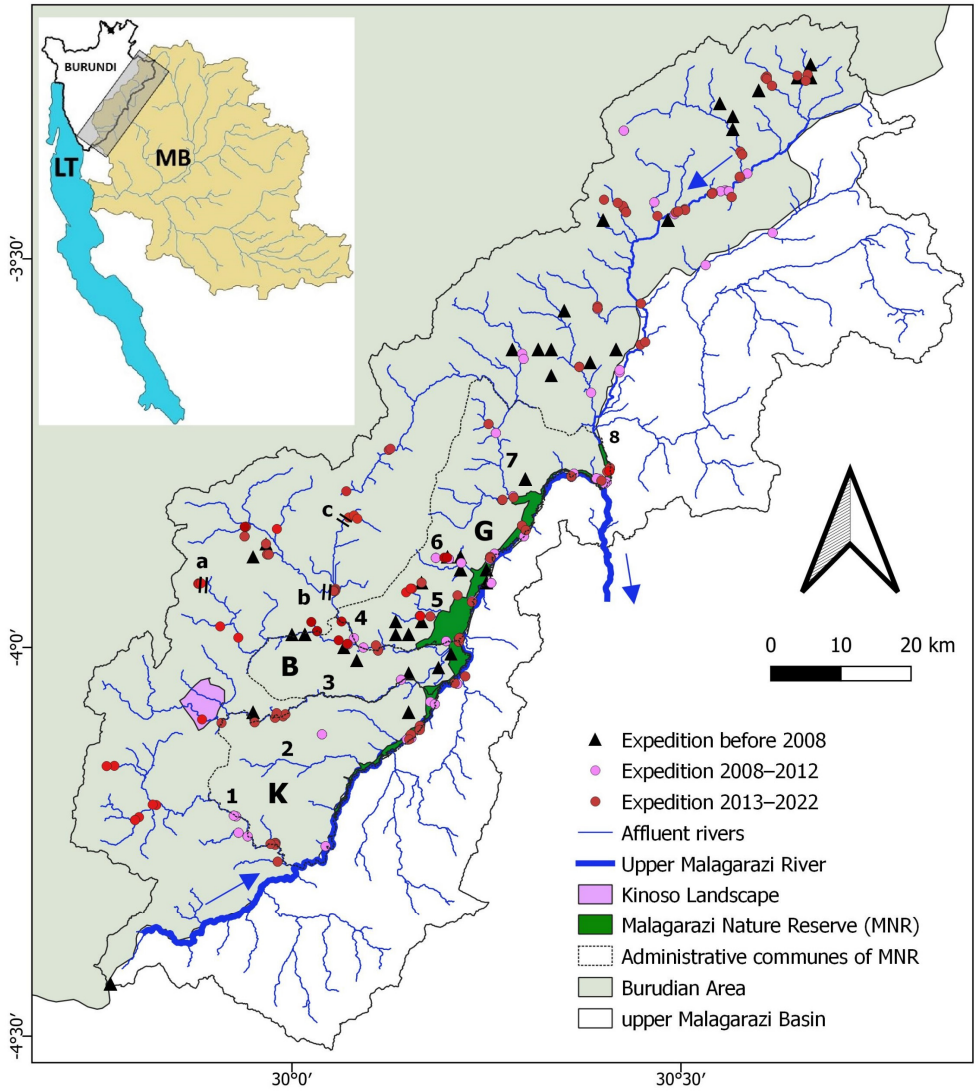

Figure 2. Previous (before 2013) and recent fish sampling efforts in the upper Malagarazi (uM) Basin in Burundi. Names of the major affluents of the uM (from up to downstream): 1. Rukoziri, 2. Nyakabanda, 3. Mutsindozi, 4. Muyovozi, 5. Kinwa, 6. Mazimero, 7. Mukazye, and 8. Rumpungwe. Capital letters refer to the first letter of the names of the administrative communes covered by the MNR: B. Bukemba, G. Giharo, and K. Kayogoro. Double black bars indicate location of main falls: a. Cikinga Falls (Musasa River, right bank affluent of the Muyovozi River), b. Nyaganza Falls (Muyovozi River), and c. Karera Falls (Karera River, left bank affluent of the Muyovozi River). Blue arrows indicate the flow direction.

Doubtful field identifications of some specimens/species were verified, firstly, at the Laboratory of Biodiversity, Ecology, and Environment [LBEE (UB)]. Secondly, these were also verified by comparison with the historical museum specimens housed at the RMCA and, when needed, with type specimens housed at the RMCA or other home institutions as well. For a limited number of alpha-taxonomic problems encountered, a case study has been developed using an integrative approach based on colour, morphometric (meristic and metric), and also genetic (mtDNA, COI and/or Cytb) data, the last one whenever fin clips were available. A Nikon SMZ 745 microscopic binocular and a 0.01 mm precision calipers were used for detailed observations, counts, and measurements, respectively, and mtDNA (COI and/or Cytb) sequences were generated in the RMCA genetic laboratory. The key scientific literature was also consulted, including the original descriptions of all species previously reported from the uM, and complemented with, when available, family or genus revisions [i.e., De Vos [29] for Schilbeidae; Teugels [30] for Clariidae; Trewavas [31] for *Oreochromis* and Thys Van den Audenaerde [32] for *Tilapia* (both Cichlidae); Norris [33] for Malapteruridae; Norris [34] for Anabantidae; and Vreven [35] for Mastacembelidae], and other relevant publications when comparing the ichthyofauna of the uM with that of adjacent river basins (i.e., [36,37]).

Specimens for which their identification remained doubtful were expressed by nomenclatorial qualifiers following Abwe et al. [28], Sigovini et al. [38], and Katemo Manda et al. [39]: 'sp.' followed by a working name, usually the name of the river where they were sampled, denotes specimens not corresponding to any described species; 'cf.' followed by a valid species name, designates specimens that clearly differ from the corresponding species, but for which a thorough investigation is warranted to confirm the differences observed; and 'aff.' followed by a valid species name, designates specimens that may correspond to this species, but with slight morphological differences that we could not evaluate due to limited number of currently available specimens. All species occurring in the uM are presented in Appendix B Table A1 with their respective authority and year. Therefore, only species not reported from the uM will present, in their first indication, the author(s) and year.

2.2. Exploring Intra- and Inter-Basin Similarities

The ichthyofaunal composition of the uM was discussed by comparing both of its subbasins (sbs), i.e., the Malagarazi sb (Msb) and the Rumpungwe sb (Rsb), with each other and with the MNR. For more details, the comparison between sbs was made between (i) the main course of both; (ii) the main course of both and their affluents rivers as a whole; and (iii) between the affluents rivers of both sbs. All entities of both sbs were also compared with the fauna of the MNR.

Further, to better understand the importance of the ichthyofauna of the entire uM, its ichthyofauna was compared to that of the two other main basins of Burundi, i.e., the Rusizi and the Ruvubu. Likewise, to better understand the degree of protection of the Burundian ichthyofauna, i.e., on the national level, as a whole, the species diversity of both the uM and the MNR was compared to that of the Rusizi National Park (RusNP) [14] and the Ruvubu National Park (RuvNP) [13], the two other Burundian protected areas (PAs) whose ichthyofauna have been relatively well studied. The degree of ichthyofaunal similarity between the different hydrographic entities, as delimited for the uM (see above), was calculated with Jaccard similarity index,

$$J = C/(N_1 + N_2 - C)$$

with N_1, the number of species occurring in the hydrographic unit 1; N_2, the number of species occurring in the hydrographic unit 2; and C, the number of species shared by units 1 and 2 (see [40]). To note, the ichthyofaunal similarity was based only on the native species.

2.3. Abbreviations

For Museums: AMNH: American Museum of Natural History, New York, NY, USA; BMNH: British Museum of Natural History, London, UK (for the fish collection); CU:

Cornell University (Museum of Vertebrates), New York, NY, USA; NHM: Natural History Museum, London, UK (for the institution); RMCA: Royal Museum for Central Africa, Tervuren, Belgium; and SAIAB: South African Institute for Aquatics Biodiversity, Makhanda (previously Grahamstown), South Africa.

Other abbreviations: ADECA: Action pour le Développement Economique axé sur l'Aquaculture intégré, Burundi; CNDAPA: Centre National de Développement d'Aquaculture et de Pêche Artisanale, Burundi; DRC: Democratic Republic of the Congo; HL: head length; IUCN: International Union for Conservation of Nature, Gland, Switzerland; LL: lateral line; lM: lower Malagarazi; MEEATU: Ministère de l'Environnement, Eau, Aménagement du Territoire et de l'Urbanisme, Burundi; mM: middle Malagarazi; MNR: Malagarazi Nature Reserve, Burundi; Msb: Malagarazi subbasin; PA: Protected Area; PNSADR-IM: Programme National pour la Sécurité Alimentaire et le Développement Rural de l'Imbo et du Moso, Burundi; Rsb: Rumpungwe subbasin; RusNP: Rusizi National Park; RuvNP: Ruvubu National Park; sb(s): subbasin(s); SL: standard length; SOSUMO: Société sucrière de Moso, Gihofi, Rutana, Burundi; UB: Université du Burundi; and uM: upper Malagarazi.

3. Results

3.1. The Fish Diversity of the Upper Malagarazi (uM) Basin in Burundi and the Malagarazi Nature Reserve (MNR)

A total of 76 species, distributed over 38 genera and 16 families (see Table 1, Appendix B: Table A1), were collected in the uM. These represent 74 native species and two introduced ones, being *Oreochromis niloticus* (Linnaeus, 1758) and *O. leucostictus* (Trewavas, 1933) (Table A1). The 74 native species include (i) 61 described and valid species, (ii) nine new species for science that still await formal description, including one being described (*Enteromius* sp. 'ascutelatus' [41]), and (iii) four species (named with cf. or aff.) under study that require further investigation regarding their status. Furthermore, they include 14 endemic species to the uM, i.e., 10 already known to science and four that still need formal scientific description. Among the 16 families, Cyprinidae is the most specious with 21 species (28% of 74 native species), followed by Cichlidae (11 species, 15%), and Mormyridae (eight species, 11%), together covering over half of the species diversity (54%) of the uM. The other families are represented by less than eight species (<10%).

Table 1. Species richness by families: (i) in the upper Malagarazi Basin (uM) in Burundi; (ii) in both its subbasins (sbs), i.e., the Malagarazi sb and the Rumpungwe sb; and (iii) in the Malagarazi Nature Reserve (MNR). Species numbers in bold refer to families for which there is a difference in species numbers between the uM and MNR. In parentheses: Ex, endemic species, where x: number of endemic species; I, number of introduced species. mc: main course; affl.: affluent(s).

Family	uM	Malagarazi sb			Rumpungwe sb			MNR
		Mc	Affl.	Total	mc	Affl.	Total	
Mormyridae	8	8	5	8	8	5	8	8
Cyprinidae	**21**(E_3)	17(E_1)	18(E_3)	21(E_3)	15(E_2)	14(E_2)	16(E_2)	**17**(E_2)
Danionidae	2(E_1)	2(E_1)	2(E_1)	2(E_1)	1(E_1)	2(E_1)	2(E_1)	2(E_1)
Citharinidae	1	1	0	1	1	0	1	1
Distochodontidae	1	1	1	1	0	0	0	1
Alestidae	5	5	4	5	4	2	4	5
Clariidae	**7**(E_2)	4(E_0)	6(E_2)	7(E_2)	3(E_0)	5(E_1)	6(E_1)	**4**(E_0)
Amphiliidae	**3**	0	3	3	2	2	2	**0**
Malapteruridae	1	1	0	1	1	0	1	1
Mochokidae	**6**(E_1)	4(E_0)	4(E_1)	6(E_1)	4(E_0)	4(E_1)	5(E_1)	**4**(E_0)
Schilbeidae	1	1	1	1	1	0	1	1
Mastacembelidae	**3**(E_2)	2(E_1)	3(E_2)	3(E_2)	2(E_1)	3(E_2)	3(E_2)	**2**(E_1)
Anabantidae	1	1	1	1	1	1	1	1
Cichlidae	**11**(E_5)n+ 2(I)	10(E_4) + 1(I)	11(E_5) + 2(I)	11(E_5) + 2(I)	8(E_3)	7(E_3) + 1(I)	8(E_3) + 1(I)	**10**(E_4) + 1(I)
Procatopodidae	2	2	2	2	1	1	1	2
Protopteridae	1	1	0	1	1	0	1	1
Total	**74(E_{14}) + 2(I)**	**60(E_7) + 1(I)**	**61(E_{14}) + 2(I)**	**74(E_{14}) + 2(I)**	**53(E_7) + 0(I)**	**46(E_{10}) + 1(I)**	**60(E_8) + 1(I)**	**60(E_8) + 1(I)**

In terms of the two sbs identified within the uM, all 74 native species, as well as the two introduced species reported for the uM, are also known from the Msb. However, only 60 native species (80%) and one introduced species, i.e., *O. niloticus*, are reported from the Rsb, distributed over 35 genera and 15 families (Tables 1 and A1). The 60 native species of the Rsb are composed of (i) 51 described and valid species, (ii) seven new species for science awaiting formal description, and two under study. Furthermore, these native species include 10 out of 14 species endemics to the uM, with six already described and four new species for science that still need formal description (Tables 1 and A1).

Furthermore, 61 species (out of 76; 80%) are reported from the Malagarazi Nature Reserve (MNR). This comprises 60 native species, i.e., 53 known and four new species for science, and three under further study, as well as one introduced species, i.e., *O. niloticus*. Moreover, eight endemic species out of the 14 (57%) identified, i.e., seven described and one new species, were identified within the borders of the MNR (Tables 1 and A1). Fish species identified for the MNR are distributed over 34 genera and 16 families (Table 1). The most important family is Cyprinidae with 17 species (28% of 60 species), followed by Cichlidae with 10 species (16%) and Mormyridae with eight species (13%), together covering over half of the species diversity (57%) of the PA. The other families are represented by less than four species (<6%). Nevertheless, the family Amphiliidae (Table 1) and both the genera *Clariallabes* and *Chiloglanis* (Table A1) have not been reported yet from the MNR as, so far, these have been no collection records from the main course of the uM (Table S1). Therefore, although some species of the genera *Clarias*, *Enteromius*, *Labeobarbus*, *Mastacembelus*, and *Orthochromis* are reported from the MNR, others are only known from the affluent rivers of the uM and thus absent from the MNR.

3.2. Degree of (Di)Similarity between the Different Hydrographic and/or Protection/Conservation Entities in the uM Basin in Burundi

A quite high degree of similarity (J = 0.81) is noted between the two main sbs of uM, i.e., the Malagarazi sb (Msb) and the Rumpungwe sb (Rsb), indicating, nevertheless, that the distribution of the species diversity in the uM is not fully homogeneous (Table 2). Indeed, all species known from Rsb are also present in the Msb. However, the latter is home to 14 more native species (Table A1). According to each sb considered separately, a higher degree of similarity is observed between the Msb versus its main course (J = 0.81) and versus its affluents rivers (J = 0.82) than between the Rsb versus its main course (J = 0.88) and versus its affluents rivers (J = 0.77). Furthermore, a higher degree of similarity is observed between the main courses of both (J = 0.74) and also between the affluent rivers of both sbs (J = 0.70) than between the main rivers of the two sbs compared to the affluent rivers of the other sb (J = 0.57–0.65). Indeed, the similarity between the main courses of both sbs with their respective affluents is limited (J = 0.57–0.65), illustrating that both parts of the same subbasin have a rather different ichthyofauna (Table 2).

In addition, with regard to the fish fauna of the MNR, a higher degree of similarity is found between the Msb and the MNR (J = 0.81) than with that of between the Rsb and the MNR (J = 0.77). Further, the highest degree of similarity is found between the main course of the Msb and the MNR (J = 0.97), while the lowest degree of similarity is found between the affluent rivers of this sb and the MNR (J = 0.65). Instead, for the Rsb, a higher degree of similarity is found between the affluents rivers and the MNR (J = 0.80) (Table 2) than between that of the main course and the MNR (J = 77) (Table 2).

Table 2. Comparison of the degree of similarity (J) within the upper Malagarazi Basin (uM). The provided numbers are: (A: horizontal) total number of species (*n*: in parentheses); (B: vertical) number of species unique to each subbasin (in parentheses); shared species (above diagonal); and J (below diagonal), between the two subbasins of the uM being the Malagarazi itself and the Rumpungwe and also their main courses versus their affluents, and the MNR. Msb, Malagarazi subbasin; Mmc, Malagarazi main course; Maff, Malagarazi affluent rivers; Rsb, Rumpungwe subbasin; Rmc, Rumpungwe main course; Raff, Rumpungwe affluent rivers; and MNR, Malagarazi Nature Reserve.

		Malagarazi			Rumpungwe			MNR
	A	**Msb (*n* = 74)**	**Mmc (*n* = 60)**	**Maff (*n* = 61)**	**Rsb (*n* = 60)**	**Rmc (*n* = 53)**	**Raff (*n* = 46)**	**(*n* = 60)**
	B							
Msb	(14)		60	61	60	53	46	60
Mmc	(0)	0.81		44	52	48	39	59
Maff	(0)	0.82	0.57		48	41	44	47
Rsb	(0)	0.81	0.76	0.66		53	46	52
Rmc	(0)	0.72	0.74	0.56	0.88		39	49
Raff	(0)	0.62	0.58	0.70	0.77	0.65		38
MNR	(0)	0.81	0.97	0.64	0.76	0.77	0.56	

3.3. Degree of Similarity between Upper Malagarazi (uM) Basin in Burundi and the Malagarazi Basin as a Whole, the Adjacent Burundian Basins, and Their Protected Areas (PAs)

The degree of similarity between the uM and the Malagarazi Basin, as a whole, reaches almost 70% (J = 0.67) (Table 3). Instead, between the uM and the surrounding basins of Burundi, i.e., Rusizi and Ruvubu, it is much lower, being less than 20% (J < 0.2).

Table 3. Comparison of the degree of similarity (J) between the upper Malagarazi Basin (uM) with: (i) the Malagarazi Basin, as a whole; (ii) its major surrounding hydrogeographic basins in Burundi, i.e., the Rus and Ruv; and (iii) the major PAs of these Burundian basins concerned, i.e., the MNR, RusNP, and RuvNP. The provided numbers are: (A: horizontal) total number of species (*n*: in parentheses) for each hydrographic entity mentioned; (B: vertical) number of species unique in each hydrographic entity (in parentheses); shared species (above diagonal); and J (below diagonal), between hydrographic entities. uM, upper Malagarazi Basin in Burundi; Mal, Malagarazi Basin, as a whole; Rus, Rusizi Basin; Ruv, Ruvubu Basin; MNR, Malagarazi Nature Reserve; RusNP, Rusizi National Park; and RuvNP, Ruvubu National Park.

		uM	Major Ssurrounding Basins			Major PAs		
	A	**(*n* = 74)**	**Mal (*n* = 111)**	**Rus (*n* = 58)**	**Ruv (*n* = 12)**	**MNR (*n* = 60)**	**RusNP (*n* = 32)**	**RuvNP (*n* = 11)**
	B							
uM	(0)		74	20	5	60	15	5
Mal	(21)	0.67		30	6	60	19	6
Rus	(26)	0.18	0.22		7	18	32	7
Ruv	(4)	0.06	0.05	0.11		6	5	11
MNR	(0)	0.81	0.54	0.18	0.09		15	5
RusNP	(0)	0.16	0.15	0.55	0.13	0.19		3
RuvNP	(0)	0.06	0.05	0.11	0.92	0.08	0.08	

Likewise, the degree of similarity between the MNR of the uM and the PAs of the two other major basins of Burundi for which their ichthyofauna has been studied is also less than 20% (J < 0.2) (Table 3). Note that, compared to the Ruvubu National Park (RuvNP) versus Ruvubu River Basin (Ruv) (J = 0.92), both the Rusizi National Park (RusNP) and the MNR only rather poorly represent the species diversity of, respectively, the Rusiizi and the Malagarazi basins as a whole (J = 0.55 and J = 0.54, respectively).

3.4. Taxonomic Problems: An Overview

Several alpha-taxonomic problems for the fish species of the uM are presented and discussed below. Indeed, some specimens present (i) morphological differences with the original description, i.e., with the holotype, or other type specimens, of the species to which they have been, previously, tentatively assigned, while others reveal (ii) morphological characters similar to the described species but are still distinguished by other (small) morphological differences, not necessarily documented in the original description of the species to which they have been, previously, tentatively, also been assigned. All case studies that revealed taxonomical issues are noted. However, for those where more details are available, these have been provided in Supplementary Materials (SM: Text S1). Furthermore, for some of those case studies already under study, e.g., *Enteromius* sp. 'ascutelatus' [41], an integrative study, including some molecular analyses, is a priority.

Some representatives of the species endemic to the uM were illustrated (Appendix A: Figure A2). In addition, some of the species shared between all three main hydrographical basins of Burundi, and some of the species discussed under the present heading of taxonomic problems, were also illustrated (Appendix A: Figure A3).

3.4.1. Mormyridae

Among the examined Mormyridae specimens, those previously identified as *Cyphomyrus discorhynchus* (Peters, 1852) (Figure A3a) raised some doubts. Indeed, a comparison of *C. discorhynchus* identified specimens (n = 4) from the uM with the holotype and four of its paratypes from the lower Zambezi Basin [42], as well as some specimens (n = 8) collected by Kramer and van der Bank in the Batoka Gorge in the middle Zambezi Basin, revealed small meristic differences between both, which were: a low number of scales on the lateral line (LL), 62–65 (median = 64) [versus higher, 66–71 (67) in *C. discorhynchus* and 66–70 (68) in *C. tanganicanus*; the latter nominal species is currently considered a junior synonym of *C. discorhynchus* [43], although preliminary marginal differences (e.g., body depth, preanal distance) were observed in a recent study suggesting that *C. discorhynchus* could exhibit intraspecific variation or that *C. tanganicanus* could be a valid species, but further study is needed to make a taxonomic decision [44]]; usually a low number of dorsal fin rays, 27–32 (median = 29) [versus usually higher 31–37 (35) in *C. discorhynchus* (type specimens) and 31–34 (33) in syntypes of *C. tanganicanus*]; and usually a lower number of anal fin rays, 21–23 (22) [versus usually higher 23–26 (25) in *C. discorhynchus* and 23–25 (24) in *C. tanganicanus*]. These recorded differences may point to the fact that the specimens from uM may represent a distinct species from both *C. discorhynchus* and *C. tanganicanus*, to which they have currently been assigned. However, such small meristic differences might be due to distribution range variation. As such, a detailed study including, for instance, morphometric, EODs, and genetic (COI barcoding) data is still needed to further test the hypothesis of potential heterospecificity. However, pending further study, the identification of Banyankimbona et al. [2], i.e., *C. discorhynchus*, is followed here.

3.4.2. Cyprinidae

In this family, two new species for science have previously been identified from the uM [1,45], i.e., *Enteromius* sp. 'ascutelatus' (De Vos et al. [1]) (Figure A2c) and *Labeo* sp. 'kumana' Banyankimbona [45]). Although the former has been identified as conspecific with *E. lineomaculatus* (Boulenger, 1903) by Banyankimbona et al. [2], a detailed integrative study of historical and newly collected specimens confirmed its identification as a new species for science different from the latter mainly based on its long pre-dorsal distance, 52.3–56.3 (mean = 53.8)% SL [versus shorter, 46.8–51.7 (49.0)% SL]; its long head, 27.0–31.0 (28.5)% HL [versus shorter 22.9–26.7 (25.3)% HL]; and its usually short dorsal fin base length, 11.6–14.2 (13.0)% SL [versus longer, 14.0–17.1 (15.6)% SL]. As such, its formal description is underway [41].

Additionally, two more *Enteromius* species with taxonomic problems have been reported from the basin. The first concerns *E. apleurogramma* (Boulenger, 1911), originally

described from the Kisumu Bay, at Kavirondo Village, on Lake Victoria (Kenya) [46]. It is considered to have a widespread distribution covering three ichthyogeographic provinces (IPs), being the East Coast, Nilo–Sudan, and part of the Congo IP, with the last one only covering the upper and middle Congo Basin, but including the Lake Tanganyika Basin with the Malagarazi and Rusizi, with the latter also including Lake Kivu [2,47]. Currently, six synonyms, including one (partim) senior synonym, of *E. apleurogramma* are known [25,48,49]. Nevertheless, a comparison of morphological data (meristic) for the specimens from uM (Figure A3d), holotype and topotypic specimen(s), and mtDNA barcoding (COI) data with those from adjacent basins, i.e., the Rusizi, lakes Kivu and Edward basins, revealed that the specimens of the uM belong, probably, to a new species for science awaiting formal description and are here referred to as *Enteromius* sp. 'rugoma' (for a detailed argumentation, see Supplementary Materials Text S1: Cyprinidae 1).

Enteromius cf. *cercops* (Figure A3c) has also previously been reported from the uM [1,2]. The most important character that identified them as similar to *E. cercops* (Whitehead, 1960), originally described from Luambwa Village on the Nzoia River, an affluent of the northeast coast of Lake Victoria (Kenya) [50], is the presence of sensory pit lines on the cheeks, which in some specimens from uM are however not discernible [1,2]. Currently, *E. cercops* has been identified as a junior synonym of *E. alberti* (Poll, 1939) [51], which was described from May-Ya-Moto Village on the Rutshuru River, a southern affluent of Lake Edward (DRC) [52]. The morphological data revealed that the specimens of the uM probably belong to a new species for science awaiting formal description and are thus here referred to as *Enteromius* sp. 'nyamabuye' (for a detailed argumentation, see Supplementary Materials Text S1: Cyprinidae 2).

For the *Labeo* sp. 'kumana' case, its identification as a new species for science was first evidenced by Banyankimbona [45]. It differs from the four sympatric species also known from the uM by an inner surface of the upper lip with transverse plicae (versus with rows of conical papillae in *L. weeksii*, currently a junior synonym of *L. altivelis* Peters, 1852) [53], the absence of a black lateral band (versus present in *L. cylindricus* Peters, 1852, *L. parvus* Boulenger, 1902, and *L. dhonti* Boulenger, 1920), and a uniformly dark grey–green body combined with well-developed tubercles on snout (versus a dark grey–blue body with none or a limited number of tubercles on the snout in *L. fuelleborni* Hilgendorf and Pappenheim, 1903) [2,45].

Finally, there are specimens of *Labeobarbus* Rüppell, 1835 from the uM previously identified as *L.* cf. *macrolepis* [2] and thus similar to *L. macrolepis* (Pfeffer, 1889), which was originally described from Mbusine Village, Rukagura Stream, Wami River, i.e., a coastal basin of the east coast of Africa (Tanzania) [54]. The most important character that identified these specimens as similar to *L. macrolepis* was the important overlap in the range of their total number of LL scales, 22–29 (versus 23–25 in *L. macrolepis*). However, these specimens differ from *L. macrolepis* by the lower lip lacking a mental lobe (versus present in *L. macrolepis*) [2]. Furthermore, considering (i) the phenotypic diversity in their mouth and (ii) the important species diversity in otherwise often highly similar specimens, which was documented in several parts of the Congo Basin already [55–57], further attention should also be directed to specimens from the uM. However, no additional *Labeobarbus* specimens were recently sampled (2013–2022). Awaiting a more in-depth study, their previous identification as *L.* cf. *macrolepis* has thus been retained.

3.4.3. Danionidae

Chelaethiops congicus (Nichols and Griscom, 1917) (Figure A3f), originally described from Poko locality, Bas-Uele Province, DRC [58], has previously been identified from the uM [1,2]. However, the uM specimens show a higher number of scales on the LL (40–44) when compared to the *C. congicus* type specimens (38–41). Thus, as this species was described based on a limited amount of specimens, i.e., one holotype and four paratypes [25,58], with these originating from a quite distant locality, this small difference could be due to intraspecific range variation. Furthermore, these uM specimens were

considered as the morphologically closest relative of *C. rukwaensis* (Ricardo, 1939), an endemic species of Lake Rukwa [37]. Nevertheless, they differ from it by their higher number of scales on the LL also, 40–44 (versus 35–39 in *C. rukwaensis*) [45]. In terms of colouration, Seegers [37] observed greenish specimens in the middle and lower Malagarazi. However, the uM specimens presently studied are also similar to *C. rukwaensis* by exhibiting silvery flanks and belly and a silverish-blue dorsum (Figure A3f) [45]. Thus, further in-depth documentation of colour variation is necessary to understand its possible origin as either possibly due to sexual dimorphism or size related.

3.4.4. Amphiliidae

Some specimens (Figure A3g) from the uM have been assigned to *Amphilius uranoscopus* (Pfeffer, 1889) [1,2]. However, this species has been described from the Wami River, i.e., a coastal basin of the east coast of Africa (Tanzania), and is currently considered known only from this and the Rufiji River, i.e., another coastal basin of the east coast of Africa (Tanzania) [59]. A comparison of morphological data with all species of *A. uranoscopus* group from Kenya (see [59]) revealed that the specimens from the uM probably belong to a new species for science, here named *Amphilius* sp. 'mutsindozi' (for a detailed argumentation, see Supplementary Materials Text S1: Amphiliidae; see also [60–62]).

Specimens attributed to *Zaireichthys* aff. *rotundiceps* (one specimen: RMCA 91-62-P-892) and to *Zaireichthys* sp. (18 specimens: RMCA 93-116-P-1-18) were first identified from the uM by De Vos et al. [1], based on specimens collected in the Mutsindozi River, the major left bank affluent of the uM. Both lots of specimens were identified as *Z.* aff. *rotundiceps* by Banyankimbona et al. [2] based on their unclear identification due to the revision of specimens historically identified as *Zairechthys rotundiceps* (Hilgendorf, 1905) [36,63,64]. Indeed, *Z. rotundiceps* has originally been described from the Bubu River, a left bank affluent of Ruaha in Rufiji Basin, i.e., a coastal basin of the east coast of Africa (Tanzania), where its occurrence has been confirmed [63]. Instead, other specimens reported from the Lake Rukwa Basin, Malagarazi Basin, and Kenyan specimens still need re-examination [63]. Unfortunately, during the two most recent series of field expeditions (G.B., 2008–2012; A.B., 2013–2022), no new *Zaireichthys* specimens were collected. As such, no fin clip samples are currently available from the uM. Thus, awaiting more in-depth research, the provisional denomination *Z.* aff. *rotundiceps* was retained.

3.4.5. Mochokidae

Specimens identified as *Chiloglanis* sp. 'musasae' were previously reported from the uM. These were first identified by Luc De Vos et al. in 1992 among the specimens collected from the basin by Tyson Roberts in 1986 and by Luc De Vos and Philippe Weiler in 1991. The species was subsequently sampled again by De Vos in 1993 and subsequently reported as an undescribed species from Burundi (see [1,2,65]). During recent samplings (2013–2022), no new specimens of *Chiloglanis* sp. 'musasae' were collected. Unfortunately, the historical specimens were not available for re-examination at the RMCA during one of our study visits (A.B., 2018–2023). Nevertheless, a comparison of the available morphological data [2,45] for the uM specimens with those of the other *Chiloglanis* species known in Malagarazi Basin as whole, i.e., *C. kazumbei* Friel and Vigliotta, 2011; *C. igamba* Friel and Vigliotta, 2011; and *C. orthodontus* Friel and Vigliotta, 2011 [65], revealed them to be different (for a detailed argumentation, see Supplementary Materials Text S1: Mochokidae 1). Based on these data, indeed, the specimens from uM belong, probably, to a new species.

During recent sampling efforts in the uM (G.B.: 2008–2012), six *Synodontis* specimens were identified as not conspecific with the two species known from this part of the basin [1,2], i.e., *S. afrofischeri* and *S. victoriae*, both previously collected in the main course of the uM and its major left bank affluent, the Rumpungwe River. Among these specimens, half of them were identified as *S. melanostictus* (see Figure A3h), while the other half was identified as *S.* aff. *nigromaculatus* (see Figure A3i) (for a detailed argumentation, see Supplementary Materials Text S1: Mochokidae 2; see also [66–71]).

3.4.6. Clariidae

Five valid species of this family are known from the uM [2]. One of them is *Clariallabes mutsindoziensis* (Figure A2g) described based on two type specimens from the Mutsindozi River, a left bank affluent of the uM [72]. However, according to the key to African clariid genera from the Lower Guinea IP (see [73]), these two specimens do not fit the diagnosis of the genus *Clariallabes* Boulenger, 1900. Indeed, both specimens have a longer head, 27–28% SL (versus 11–26% SL in *Clariallabes*) and a shorter distance from the anus to the caudal fin base, 47–48% SL (versus 50–65% SL). Instead, both character states correspond to those of the genus *Clarias* Scopoli, 1777, with a length of the head of 20–34% SL and a distance from the anus to the caudal fin base of <50% SL (see [73]). However, as *C. mutsindoziensis* has separated lateral head bones (versus lateral head bones in contact, i.e., often fused in larger specimens in *Clarias*), one of the key characters listed by Devaere et al. [73] for the diagnosis of the genus *Clariallabes*, it is retained in that genus despite its close resemblance with *Clarias* species for those two other key characters.

Recent sampling in the uM (G.B., 2008–2012; A.B., 2013–2022) led to the identification of newly collected clariid specimens (Figure A2h) as members of the genus of *Clariallabes*. This generic identification was based on their relatively shorter head length, 21–26 (mean = 23)% SL [or 11–26 (mean = no data)% SL in *Clariallabes* [73] (versus 20–34% SL in *Clarias*)]; usually a longer distance from the anus to the base of the caudal fin, 49–56 (51)% SL (or 50–65% SL in *Clariallabes* versus usually <50% SL in *Clarias*); and its separated lateral head bones (versus contiguous or fused lateral head bones in *Clarias*). As a result, these specimens turned out to be different from *C. mutsindoziensis* by these two first morphometric, generic characters. In addition, other characters differentiate these specimens from *C. mutsindoziensis*, such as their slender body, resulting in a shallower body depth at the anus, 11–15% SL (versus 21–22% SL in *C. mutsidoziensis*); a shorter pre-pelvic distance, 40–46% SL (versus 48–52% SL); and a narrower head width, 16–21% SL (versus 22–24% SL). Therefore, according to these differences, these newly collected specimens from the uM represent a new species for science currently under description and here provisionally named *Clariallabes* sp. 'nyaruhandazi' ([45]; A.B., in prep.).

These observations also prompted a reassessment of the identification of some of the historical clariid specimens from the uM available at the RMCA. As such, some specimens identified as *C. lioceplalus*, a species originally described from Kinyamkolo, Lake Tanganyika, Zambia [8°48′ S 31°06′ E defined by [30,71], but also considered to be present in the uM (see [2,30]), were more similar to the new species (for a detailed argumentation, see Supplementary Materials Text S1: Clariidae 1; see also [73]). Thus, all specimens from uM were re-examined. Furthermore, the holotype of *C. ornatus* Poll, 1943, currently a junior synonym of *C. liocephalus* following Teugels [30] and considered originally described from the uM, was also studied, and, in our opinion, its status as a junior synonym of *C. liocephalus* is questionable (for a detailed argumentation, see Supplementary Materials Text S1: Clariidae 2; see also [74]). In addition, some specimens identified as *C. dhonti* (Boulenger, 1920) (see [2]), a species originally described from Kabeke Village, Niemba River, near the west coast of Lake Tanganyika [70], have contiguous lateral head bones, a character absent in the syntypes of *C. dhonti*, while others (n = 8; 63.1–185.8 mm SL) have separate lateral head bones. The results, obtained by re-examining these uM specimens and comparing them with the nine syntypes of *C. dhonti*, show that *C. dhonti* is not present in uM. Thus, the uM specimens with contiguous lateral head bones were here reidentified as *C. liocephalus*, while those with separate lateral head bones have all been reidentified as *Clariallabes* sp. 'nyaruhandazi' (for a detailed argumentation, see Supplementary Materials Text S1: Clariidae 3).

Other specimens of *Clarias* differ from all *Clarias*/*Clariallabes* species reported from the uM. These uM specimens, compared to other 16 *Clarias* species from the Congo Basin sensu lato (s.l.), as described by Teugels [30], are more similar to *C. theodorae* and are here, pending a more detailed study, provisionally named *C.* aff. *theodorae* (for a detailed argumentation, see Supplementary Materials Text S1: Clariidae 4).

3.4.7. Cichlidae

Oreochromis malagarasi, a species considered endemic to the Malagarazi Basin [31], was originally described from Malagarazi swamps at Katare Village (Tanzania), based on specimens previously identified as *O.* aff. *niloticus* and *O. upembae* by Thys van den Audenaerde [32,75]. However, *Oreochromis malagarasi* is distinguished from *O. upembae*, described from Nyonga Village along the Kamalondo Depression (KD), i.e., the Upper Lualaba Basin in the Upemba National Park (DRC) [32], by its soft part of the caudal fin in-between the caudal fin rays and the range of the number of dorsal spines and soft rays (for a detailed argumentation, see Supplementary Materials Text S1: Cichlidae). Indeed, the study of the specimens recently collected from the uM (2013–2022), all pre-identified as *O. upembae* (Figure A3j), for both these diagnostic characters, also taken on the holotype and two out of the 16 paratypes of *O. upembae*, shows that the specimens from uM are more similar to *O. upembae* (for detailed argumentation, see Supplementary Materials Text S1: Cichlidae; see also [76]).

In addition, five other *Oreochromis* specimens, clearly different from *O. upembae*, were also collected from the uM (A.B., 2013–2022). One of these specimens is here identified as *O. leucostictus* based on the presence of white spots on the body, these being more abundant above the anal fin and on the dorsal, caudal and anal fins, 28 LL scales and XV 12 dorsal fin spines and soft rays, which are the diagnostic characters of *O. leucostictus* as listed by Trewavas [31]. The four remaining specimens were tentatively identified as *O. niloticus* based on: the presence of regular black vertical stripes on the caudal fin; 22–24 gill rakers on the first gill arch; 30–34 LL scales; 5–6 vertical bars on the flank; and one or two vertical bars on the caudal peduncle in live specimens. However, on the preserved specimens, three of them present usually these vertical bars linked to smaller blotches both on the flanks and the caudal peduncle, while one specimen presented three large blotches, more or less well visible, on its sides as in specimens of both species, i.e., *O. malagarasi* and *O. upembae* [31]. For the latter, the first blotch is situated at the level of the second vertical bar, the second at the level of the third vertical bar, and the third at the level of the last vertical bar observed on the flanks (either the fifth or sixth bar) or, eventually, one or two blotches on the caudal peduncle. These spots resemble those observed in *O. upembae* identified specimens from the uM (see above), both in shape and position along the body. Based on (i) the presence of these black, roundish spots, which are similar to those of the *O. upembae* identified specimens from the uM Basin, as well as those from the type locality, i.e., the KD; (ii) the presence of vertical stripes on the caudal fin, typical of *O. niloticus* from Nile River [31]; and (iii) the range of the number of spines and soft rays on the dorsal fin of these specimens of the uM overlaps with those of type specimens of *O. niloticus* and *O. upembae* and those identified from the uM Basin, XV–XVII 12–13 (versus usually XVII 13 in *O. niloticus* and XVI–XVII 12–13 in *O. upembae* from the uM). Considering their mixed character state, these four specimens might be hybrids between both *O. niloticus* and *O. upembae*. Also, in this case, a genetic approach might be helpful to further solve the issue.

Interestingly, both species, i.e., *O. leucostictus* and *O. niloticus*, have never been reported from the uM and are thus identified as introduced into the basin.

3.4.8. Procatopodidae

Only two species of Procatopodidae, i.e., '*Lacustricola*' *centralis* (Seegers, 1996) and Micropanchax *fuelleborni* (Ahl, 1924), are known from the uM [1,2,37]. Two other species previously listed as occurring in the upper part of this basin [1], i.e., *L. pumilus* (Boulenger, 1906) and *M. loati* (Boulenger, 1901), correspond to misidentifications of '*L.*' *centralis* and *M. fuelleborni*, respectively [45]. Indeed, M. loati is currently reported as an endemic species to the Nile Basin [77], while, in Burundi, *L. pumilus* is now reported to occur only in the Rusizi Basin [2].

3.4.9. Mastacembelidae

Mastacembelus frenatus (Figure A3k), a widely distributed species, is also present in the uM [2,35]. In addition, two new species for science are also present, *Mastacembelus* sp. 'devosi' (Figure A2i) and *Mastacembelus* sp. 'malagarazi' (Figure A2j). Both are still awaiting their formal description [1,35]. These three species have a uniformly light brown overall background colour. Nevertheless, *Mastacembelus* sp. 'devosi' is distinguished by the presence of a series of partially confluent and more or less squared dark-brown spots, which usually form like a lateral band along the flanks and especially well-demarcated along their upper edge (versus a well-demarcated dark-brown band along the flanks, and a series of roundish less dark-brown spots sometimes confluent with each other and situated below the dark brown band along the flanks, but confluent with this band at the base of the caudal fin in *M. frenatus* and no lateral band along the flanks in *Mastacembelus* sp. 'malagarazi') (for a detailed argumentation, see Supplementary Materials Text S1: Mastacembelidae).

4. Discussion

4.1. Contribution to the Knowledge of the Ichthyofauna of the Upper Malagarazi (uM) Basin Bas in Burundi and the Malagarazi Nature Reserve (MNR)

A total of 74 fish species are reported from the uM (Table A1). Of these, 14 (19%) are endemic to the uM (Tables 1 and A1). In terms of both its main subbasins, all species known from the uM, as a whole, are present in the Malagarazi subbasin (Msb), and, as a result, all species from Rumpungwe subbasin (Rsb) are also shared with the Msb (Figure 3, Table A1). Further, only six (42% of all endemics species of the uM) of the endemic species are known from the Rsb.

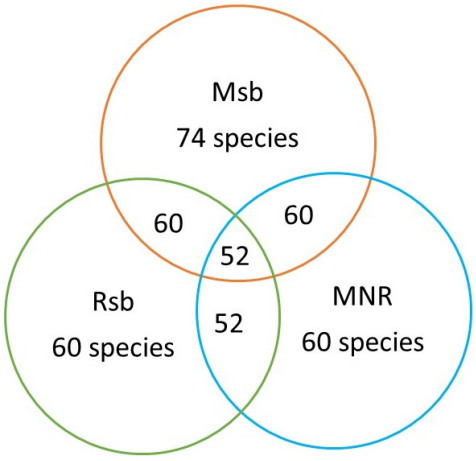

Figure 3. Unique and shared fish species for the two main subbasins of the uM, Malagarazi (Msb) and Rumpungwe (Rsb), and between both and the Malagarazi Nature Reserve (MNR).

Considering only its native species, the MNR harbours 60 species (81% of the entire uM ichthyofauna), which all are known from the Msb and only 52 from the Rsb (Figure 3). Further, among the endemic species of the uM, eight are known from the MNR (57% of all endemic species of the uM) (Tables 1 and A1). The other six endemic species known from the uM, but presently outside the current boundaries of the MNR (Appendix A: Figure A4), are reported only from the affluent rivers of the uM (Table 2). These indeed harbour distinct habitats, such as rapids, rocky areas, and falls, as well as clearer water environments, all of which are lacking in the main course of the uM and in the nearby confluences of those affluents [45]. The endemic species missing within the borders of the MNR are: (i) *Chiloglanis* sp. 'musasae' reported only from the Muyovozi and Ruru rivers (both right bank affluents of the Rumpungwe); (ii) *Clariallabes mutsindoziensis* reported only from the Mutsindozi River (a left bank affluent of the uM); (iii) *Clariallabes* sp. 'nyaruhandazi' reported from the Rukoziri, Kinwa, Mukazye, and Rumpungwe rivers (all left bank

affluents of uM) and the Nyarugunga and Ruru rivers (both right bank affluents of the Rumpungwe); (iv) *Enteromius* sp. 'ascutelatus' [41] reported only from Muyovozi and Kinwa rivers (both left bank affluents of the uM); (v) *Mastacembelus* sp. 'devosi' reported from the Muyovozi, Rumpungwe, and Ruru rivers (all left bank affluents of the uM); and (vi) *Orthochromis mazimeroensis* De Vos and Seegers, 1998 reported from the Mazimero and Inankanka rivers (both left bank affluents of uM) (Figure A4). Among these endemic species, *Clariallabes* sp. 'nyaruhandazi', *Chiloglanis* sp. 'musasae' and *Mastacembelus* sp. 'devosi' are reported in both subbasins of the uM, which suggests, at least for these, a wider distribution in this part of the Malagarazi Basin.

Among the 60 non-endemic native species of the uM, eight are confined to the left bank affluents of the uM Basin in Burundi, five are located nationally, i.e., in Burundi, only known from the uM (Appendix A: Figure A5): *Amphilius pedunculus* Thomson and Page, 2015, *Amphilius* sp. 'mutsindozi', *C. kazumbei*, *Enteromius pseudotoppini* (Seegers, 1996), and *Zaireichthys* aff. *rotundiceps*, with the last two species being rare in the uM (i.e., only known from the Mutsindozi and Mukazye rivers, and from the Mutsindozi River, respectively). The remaining three species, i.e., *C. liocephalus*, *Enteromius pellegrini* (Poll, 1939), and *Labeobarbus somereni* (Boulenger, 1911), while also showing a restricted presence in the affluents rivers of the uM, are present in many affluents of the uM (Table A1) and also in some other river basins of Burundi [2,14].

4.2. Ichthyological Similarities within the Upper Malagarazi (uM) Basin in Burundi

The degree of similarity (J) has been studied between the two main subbasins of the uM (Table 2), i.e., (i) the main course of the Malagarazi (Mmc), with its left bank affluent rivers (Maff), and (ii) the main course of Rumpungwe (Rmc), with its right bank affluent rivers (Raff), and (iii) the MNR. It shows that the similarity is high between the main course of both these two subbasins (J = 0.74) and between the affluents of both as well (J = 0.70). However, a lower similarity was observed between the main courses of both subbasins and their affluents (Table 2: J = 0.57 for the Msb and J = 0.65 for the Rsb). Further, the same holds true when comparing Mmc with Raff, the affluents of the other subbasin (J = 0.58), and Rmc with Maff, the affluents of the Malagarazi (J = 0.56). Therefore, these results suggest that the ichthyofauna of the main courses of both subbasins are quite different from their affluents.

In addition, it shows that the similarity is (quite) high between Mmc and MNR (J = 0.97) and also between Rmc and the MNR (J = 0.77) (Table 2). However, there is a lower similarity between Maff and the MNR (J = 0.64) and also between Raff and the MNR (J = 0.56). Further, the habitats of the main course are similar and are mainly composed of permanent flooded areas, waters associated with *Cyperus papyrus* vegetation and gallery forests, and with slow-flowing waters with a muddy, sand, gravel, and sometimes stony substrate [1,2,9,78]. As such, the present results also show that the affluent rivers of both subbasins harbour a quite distinct ichthyofauna compared to that of their main course. Indeed, the habitats of the affluent rivers are mainly constituted by, sometimes, temporally flooded areas with associated grass strips and the presence of rapids, as well as falls limiting free species dispersal, and with sand, gravel, stony, or rocky substrate [1,2,9,78].

Otherwise, the high similarity (J = 0.81) (Table 3) between the uM as a whole and the MNR reveals the importance of the latter as a Protected Area (PA) for the ichthyofauna of the uM. However, the absence of 14 species (19%) within the borders of the MNR reveals that about one-fifth of the known species is not, based on its current delimitation, included in this unique PA for the uM. Furthermore, this seems also to indicate that some freshwater habitats available for these species in the affluent rivers are presently lacking within the current borders of the MNR. In terms of protection issues, these results confirm that distribution data and regional species status assessments are important and needed to enable a more well-informed and efficient protection of the species concerned [39,79,80].

Indeed, among these 14 species absent from the MNR, six are strictly endemic to the uM (Figure A4), five others are only known from the uM part of the Basin as far as Burundi is concerned (Figure A5), and three, i.e., *C. liocephalus*, *E. pellegrini*, and *L. somereni*, are

shared with the Rusizi Basin in Burundi itself and also known from the RusNP [2,14]. In addition, one of the latter three, i.e., *C. liocephalus*, is also shared with the Ruvubu Basin and also known from the RuvNP (Table A1) [2,13]. Therefore, the protection of these first 11 uM species, only known from the uM, should be a priority and can be enhanced, for instance, by extending the current borders of the MNR. Thus, to optimise the protection of the uM ichthyofauna as a whole, it is necessary, as far as possible, to also include within the borders of the MNR some stretches of its affluent rivers. In addition, non-endemic species, known only from the uM for Burundi, could help define the MNR by including extra stretches where they are currently present. These species are also known from: for *A. pedunculus,* the Malagarazi Basin as a whole, the Luiche Basin, the Lake Rukwa Basin, and the Upper Great Ruaha Basin, all in Tanzania [81]; for *C. kazumbei*, the Malagarazi Basin as a whole and Luiche Basin in Tanzania [65]; for *E. pseudotoppini*, the Rungwa and Aswa basins in Tanzania [37]; and the two other species, still under study, i.e., for *Z.* aff. *rotundiceps* assigned to a valid species reported from the Rufiji Basin and Lake Rukwa Basin, both in Tanzania [63], and for *Amphilius* sp. 'mutsindozi', probably known from the Malagarazi Basin as a whole.

4.3. Ichthyological Similarities with the Surrounding Basins of Burundi

The uM only covers a fairly small part of the entire Malagarazi Basin (4%; i.e., 5439 km^2 versus 131,572 km^2) [82]. Nevertheless, this studied part of the uM presents a rather high degree of similarity (J = 0.7) regarding its ichthyofauna with that of the Malagarazi Basin as a whole (see Table 3). The important species diversity documented for the uM could be due, firstly, to the wide range of available habitats, plus a wide variety of substrate types (see point 4.2.) [1,2,9,78]. Furthermore, the disparate distribution of these habitats and substrate diversity could also further enhance the non-homogeneous distribution of the fish species occurring in the uM. Thus, the protection of the fish diversity of the uM, through its PA, i.e., MNR, is not only important for the protection of the fish diversity of the uM but also for the protection of the fish diversity of the Malagarazi Basin as a whole because the uM harbours about 67% of all species known from the Malagarazi Basin (Table 3).

However, the rest of the Malagarazi Basin remains largely underexplored [1]. Indeed, the latest fish checklist for the entire Malagarazi Basin is that by De Vos et al. [1], who reported a total of 108 species. Among these species, 63 species (58%) were reported to occur in the uM [2]. Additional recent field expeditions (A.B., 2013–2022), with a further study of historical collections of the uM and a review of the available literature, have resulted in an updated list totalling 74 species (67%). Indeed, among 11 new species for the uM, five are new records for the entire Malagarazi Basin, i.e., *Labeo* sp. 'kumana' and *Clariallabes* sp. 'nyaruhandazi', both currently endemic species for the uM only, and *Synondontis melanostictus* Boulenger, 1906; *S.* aff. *nigromaculatus* and *C.* cf. *theodorae*, although the last of the three species generally with a wider distribution in the uM. Among the two introduced species currently identified from the uM, *O. leucostictus* is here also reported for the first time as introduced into the Malagarazi Basin as a whole, while the *O. niloticus* was already known to occur in the Lower Malagarazi Basin [1].

Furthermore, the current results for the uM suggest that the last published checklist on the fishes of the Malagarazi Basin, established by De Vos et al. [1], is, particularly for its Tanzanian section, partially incomplete and outdated. Indeed, some areas might still require (further) exploration, e.g., the headwaters of affluent rivers of the Malagarazi Basin in Tanzania and also, in particular, the stretches of affluent rivers situated above some major falls. Indeed, as also found in the uM, the distribution of fish species along a river depends on its altitude gradient [57,83,84] and the presence of different habitats along its main course [85]. Thus, in view of this, it is certainly recommended to (better) sample these headwaters.

In terms of shared inter-basin (Appendix A: Figure A6) species diversity in Burundi, 22 out of the 74 species (29%) reported for the uM are also present in the Rusizi Basin [14] (Figure 4a). The low similarity between the uM and the Rusizi Basin (J = 0.2) is somewhat

surprising as both are part of the Lake Tanganyika (LT) Basin, which is part of the Congo Basin s.l. However, in terms of hydrological subbasins, the uM, i.e., the headwater stream and affluent rivers of the Malagarazi Basin in Burundi have ecological characteristics, which are very different from those of LT itself and may thus constitute a natural barrier between these two (sub)basins, i.e., the Rusizi and the Malagarazi. Indeed, the uM conductivity (cond.) < 150 µS/cm and pH ± 7 are showing lower values [45] (versus higher values, cond. < 600 µS/cm and pH ± 9 in Rusizi River [86]; and cond. ±650 µS/cm and pH ± 9 in LT [87]). Moreover, the Malagarazi is an eastern affluent of the LT, while the Rusizi is the northern affluent of the LT. In addition, the Mirwa escarpment, part of the southern section of the Congo–Nile Ridge, a mountain range located along the LT and on the southwest border of Burundi, isolates both the headwater streams from the uM Basin and those from the left bank of the Rusizi Basin. Furthermore, this mountainous area also separates these two basins from the small Burundian affluents of the LT, whose fauna is largely unknown and probably much less diverse given their much smaller surface areas [2].

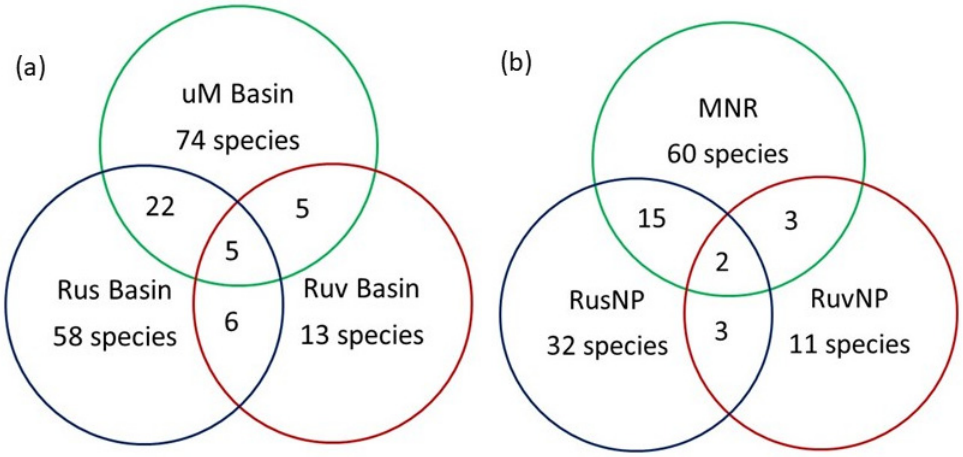

Figure 4. Shared and unique fish species of (**a**) the three main basins of Burundi: uM, Upper Malagarazi; Rus, Rusizi; and Ruv, Ruvubu; and (**b**) their main protected area: MNR, Malagarazi Nature Reserve; RusNP, Rusizi National Park; and RuvNP, Ruvubu National Park.

Moreover, only five (6%) out of the 74 species known from the uM [2,13] are present in the Ruvubu Basin (Figure 4a). The low similarity between the uM and Ruvubu Basin (J = 0.1), a right bank affluent of the Kagera Basin (Rwanda) (Figure A6), could be explained by: (i) the fact that Ruvubu and uM basins are also separated by the Congo–Nile Ridge, i.e., the Birime Mountain chain, situated in the southeast of Burundi, and with the Malagarazi Basin being part of the Congo Basin s.l., while the Ruvubu Basin is part of to the Nile Basin [1,2]; (ii) the fact that the Ruvubu Basin, in Burundi, is less explored in terms of fish diversity [2], making the list of fish species currently known from the Ruvubu Basin most probably not exhaustive, although it is already known to be species-poor [2,13,88]; and (iii) the presence of natural barriers, i.e., rapid areas found along the downstream stretch of the Ruvubu River and the Rusumo Falls (about 30 m height [89]) found near the confluence of the Ruvubu with the Kagera River (Tanzania) (Figure A6), which certainly blocks upstream fish migrations to the headwaters [88,89] for most species. Nevertheless, the shared fish species diversity (see [1,2]) can be explained by the hypothesis that the Upper and Middle Malagarazi would have been once connected to the Upper Nile Basin via Lake Victoria (effluent of Kagera River) before the uplift of the highlands (around 20 My ago) and the genesis of the endorheic trenches and basins of the East Africa Rift, including that of LT (around 12 My) [1,4,5,90,91].

In terms of surface area, the MNR is the smallest of the three major PAs for which their ichthyofauna has at least been somehow studied [MNR: 8371 ha; Rusizi National Park (RusNP): 10,673 ha; Ruvubu National Park (RuvNP): 50,800 ha; see [11]]. Nevertheless, the MNR is, without doubt, the most important among the PAs of Burundi in terms of its

potential for ichthyofaunal protection as it harbours, by far, the highest species diversity of all three. For example, the RusNP is drained by the Rusizi River, the outlet from Lake Kivu to Lake Tanganyika. It harbours a total of 32 species, while a total of 58 species are currently known from the entire Rusizi Basin [14]. Furthermore, it was noted that the RusNP does not host the only endemic species currently known from the basin, i.e., *Chiloglanis ruziziensis* De Vos, 1993, neither *Amphilius* species, such as *A.* cf. *uranoscopus* (Pfeffer, 1889) and *A. kivuensis* Pellegrin, 1933 [14]. Hence, the RusNP also illustrates a recurrent problem of the optimal delimitation of a PA with regard to the protection of the integral ichthyofauna of a basin drained.

Furthermore, the RuvNP includes 12 of the 13 species known from the Ruvubu Basin as a whole [2,13]. As such, it harbours all three endemic species of the Ruvubu Basin, i.e., *Labeobarbus acuticeps* (Matthes, 1959), *L. ruandae* (Pappenheim, 1914), and *Synodontis ruandae* Matthes, 1959. Nevertheless, despite its much larger surface area, i.e., about six times larger than the MNR, its total number of species (13) is only 21% of the fish species diversity protected by the MNR (60).

The poor faunal similarities of the MNR with both other PAs, i.e., J = 0.2 with RusNP and J = 0.1 with RuvNP in Burundi, illustrates that there are very few species shared between the MNR and both these parks (Figure 4b). As a result, among the 60 fish species present in the MNR, only 15 (25%) are shared with RusNP, and five (8%) are shared with RuvNP (Figure 4b). Furthermore, only two species (3%) are shared between these three PAs (Figure 4b). These low similarities could be explained by the fact that the uM with its PA, the MNR, seems to be isolated from the Rusizi Basin with its PA, the RusNP, by LT and its small affluents rivers, and from the Ruvubu Basin with its PA, the RuvNP, by the Congo–Nile Ridge. Therefore, in the interest of protecting the fish fauna of the uM, and of Burundi as a whole, the legal establishment of the MNR as a PA should be a national and international priority. This is also a strong point regarding the current delimitation of the PAs in Burundi because they all protect a very distinct part of the overall fish species diversity present in the basins draining the country. However, in addition, a revision of the under implementation MNR delimitation is also necessary. Indeed, the MNR should further integrate at least some of the known localities of (i) all known endemic species of the uM and, also, of (ii) all native species only known to occur in the uM when it concerns Burundi.

4.4. Introduced Species in the Upper Malagarazi (uM) Basin in Burundi

Two introduced species, *O. niloticus* and *O. leucosticus*, were also reported for the first time (Tables 1 and A1). According to MEEATU [92] and interviews with locals (A.B., pers. information, 2013–2022), in particular with fish farmers, based on their knowledge, a national association aiming to develop fish farming in the region, i.e., action for economic development focused on integrated aquaculture (Association pour le Développement Economique axé sur l'Aquaculture Intégrée: ADECA), has implanted, since 2013, several fish farms with *O. niloticus* in all three communes of the uM (Figure 2) to reactivate fish farming as suggested by a national strategy and a biodiversity action plan (2013–2020) of Burundi [93]. Subsequently, in 2016, the habitats, such as the main course of the uM River and some of its swamps and fish ponds around (Giharo Town, Rutana Province, and Koyogoro Town, Makamba Province), and also the Rumpungwe River (Gisuru and Kinyinya towns, both in the Ruyigi Province) (Figure 1), have been (re)stocked with ~60,000 fingerlings of *O. niloticus* [94]. Therefore, both the ADECA and the national program for food security and rural development of the Imbo (Rusizi Plain) and Moso (Malagarazi Plain) regions in Burundi (PNSADR-IM) were coached by the national center aiming to develop Aquaculture and Artisanal fisheries (Centre National de Développement de l'Aquaculture et de la Pêche Artisanale: CNDAPA) by providing fingerlings and help in stocking ([94], CNDAPA, pers. comm., 2022). For the production of fingerlings, the CNDAPA used spawners from Lake Rweru (Kagera Basin: northern Burundi) (CNDAPA, pers. comm., 2022), where these species had originally been introduced from Lake Edward in 1935 [2,95].

During recent samplings (2013–2022), *O. niloticus* was collected: (i) in the main course of the uM River, at Mutongotongo and Buga villages; (ii) in the Mutsindozi River, a left bank affluent of the uM; and (iii) in the Nyarugunga River, a right bank affluent of the Rumpungwe, at about 500 m from the nearest fish ponds situated at Rusengo village. Instead, *O. leucostictus* was only collected in the Mazimero and Muyovozi rivers, both left bank affluents of the uM. In addition, for both introduced species, only *O. niloticus* is currently reported from the MNR (Tables 1 and A1).

4.5. Anthropogenic Threats to the Upper Malagarazi (uM) Basin in Burundi and to the MNR

One of the most effective approaches to ensure actions to protect and limit the loss of fish biodiversity is to also identify the anthropogenic threats to it [79,96]. This allows for (i) the identification of fish biodiversity hotspots, being areas, i.e., a basin when dealing with fish, not only rich in species diversity but also relatively pristine or less threatened by these anthropogenic impacts [8,97], (ii) the establishment of priority areas for protection, and (iii) the aim to objectively try to reduce these threats by strengthening the protection status of identified fish biodiversity hotspots [8].

The uM is currently one of the most threatened (aquatic) ecosystems in Burundi due to the recent human population increase in the basin [2]. However, before 1980, this basin was among the less disturbed ones in the country. This was because it was uninhabitable due to the presence of schistosomiasis and malaria [98], for which, at that time, no effective cures were available. The main observed causes affecting and threatening the fish diversity of the uM and its aquatic ecosystems in which it thrives are (A.B., pers. obs. 2013–2022): (i) the use of destructive and/or illegal fishing practices comprising an ichthyotoxin named 'Ubuhunwa' in the Kirundi local language [41,45]; and (ii) the excessive demand for land for agriculture, either on a non-industrial or industrial scale [see Société Sucrière de Moso, Burundi (SOSUMO) sugar cane factory], but generalised throughout the basin. Indeed, apart from the ~5800 ha (already including about ~2800 ha of marshy area) exploited by the sugar refinery SOSUMO, established since the 1980s in the uM (Bukemba Village, Rutana Province) (Figure 5a) (A.B., pers. obs. 2013–2022) and some minor areas exploited for the cultivation of food crops (beans, cassava, peanuts, maize, soy sorghum, etc.) (see Figure 5b,c) (A.B., pers. obs. 2013–2022), ~1470 ha of marshy areas are already in use for rice cultivation [94,99]. In this context, it is important to highlight that the entire uM marshes only cover an estimated area of about 14,000 ha [78], of which, at present, more than 30% has already been converted into agricultural land for the production of all kinds of human food products (see above). In addition, this conversion also includes the installation of dams (Figure 5d) (A.B., pers. obs. 2013–2022) and canals for a more appropriate irrigation of these lands. Hence, all of these human activities together lead to the loss and/or modification of fish habitats by: (a) the drying up of natural marshes, in the case of sugar cane food crop production (Figure 5e) (A.B., pers. obs. 2013–2022), except for rice, which instead needs permanent flooding of the land; (b) the destruction or modification of the natural vegetation of the river banks for agriculture; (c) the increase of the siltation and turbidity of the rivers themselves and, as a result, reduces the capacity for self-purification [8,78]; and (d) the modification of the hydrological regime of some affluent rivers as a result of dam building, i.e., resulting in the reduction of the stream flow, and/or channelisation, i.e., resulting in the increase of the stream flow. Furthermore, the construction of dams also (e) constitutes an obstacle to upstream and downstream movement of, at least, migratory fish species such as *Labeo*, *Labeobarbus*, and *Clarias*, which often move upstream in the small affluents or marshes during the breeding season or feeding and/or refuge migrations [100–102].

Furthermore, (iii) the waste discharges of the SOSUMO, such as its untreated wastewaters, and the added agricultural inputs, such as chemical fertilizers, pesticides, and herbicides, used in the sugar cane plantations, which must be added to those used by the rice farmers, run directly into the uM River (Figure 5f) (A.B., pers. obs. 2013–2022). All of this is contributing to the pollution of the rivers concerned by reducing their dissolved oxygen levels and by changing other physicochemical parameters, such as their conductivity, pH,

etc. as well [45]. In addition, the elevation of the left bank of the main course of the uM itself, which is used to obtain dry land for the SOSUMO's sugar cane plantations, leads to (a) the reduction of the spawning grounds existing in the marshes or in gallery forest due to the destruction of the natural river banks with their gallery forest (Figure 5g) (A.B., pers. obs. 2013–2022) and (b) the drying up of the marshes, being ideal rainy-season spawning ground, due to their conversion into sugar cane fields.

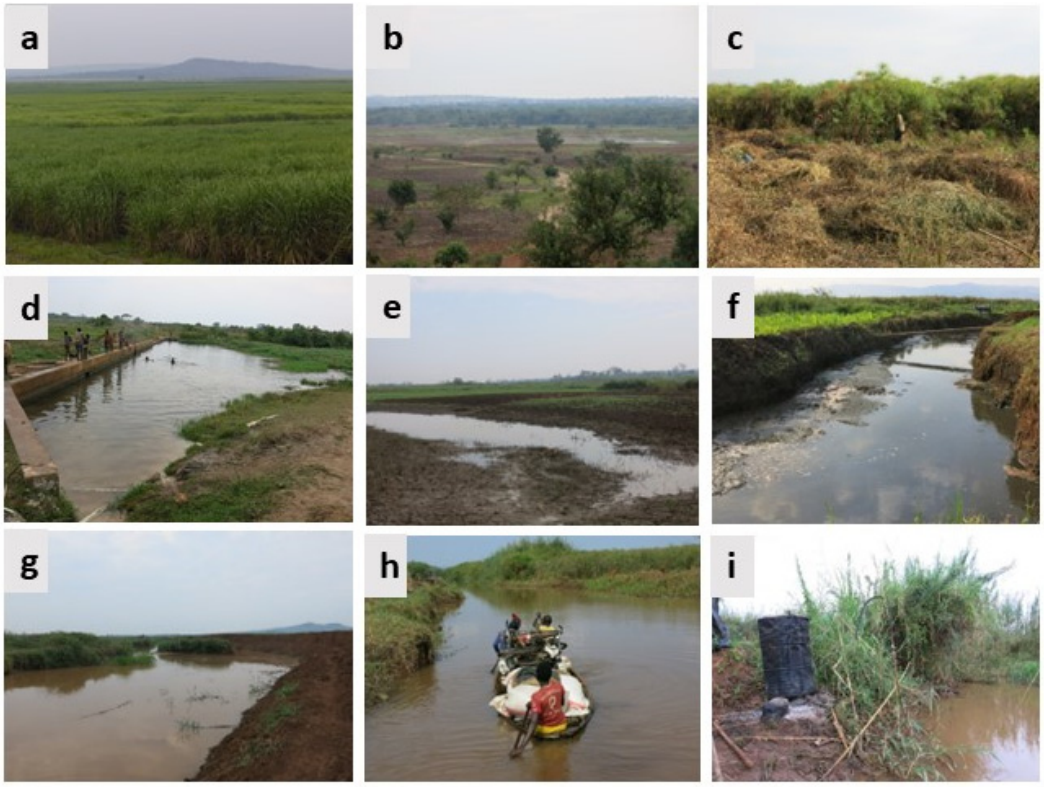

Figure 5. Photographic overview of some anthropogenic impacts documented for the upper Malagarazi (uM) Basin in Burundi (see main text for more details): (**a**). Sugar cane plantation of the SOSUMO company (30°04′ E 3°59′ S, 19 October 2022); (**b**). Yield of foods crops in preparation, Mutwana Village (30°17′59.7″ E 3°50′57.6″ S) (10 October 2017); (**c**). Clearing of the *Cyperus* vegetation for agriculture purposes, Rwabira Village (30°12′53.9″ E 3°59′30.0″ S) (07 July 2017); (**d**). Irrigation dam installed on the Mazimero River, Nkanka Village (30°11′45.3″ E 3°53′04.0″ S) (20 August 2021); (**e**). Drying up of natural marshes for agriculture at Sesa Village (30°24′29.0″ E 3°46′22.8″ S) (22 August 2022); (**f**). Wastewater channel from the SOSUMO company, containing molasses, running to the upper Malagarazi River, Rwabira Village (30°12′53.9″ E 3°59′30.0″ S) (8 October 2017); (**g**). Upheaval of the left bank (right-hand side of the photograph) of the upper Malagarazi River near SOSUMO, Mutongotongo Village (30°12′33.4″ E 4°02′45.4″ S) (25 February 2016); (**h**). Human transportation by pirogue across the uM River, Rwabira Village (30°12′53.9″ E 3°59′30.0″ S) (7 July 2017); and (**i**). Pollution of the uM River by molasses from the traditional manufacturers of molasses-based rum at Rwabira Village (30°12′53.9″ E 3°59′30.0″ S) (7 July 2017). Except for photograph (**d**) taken outside the MNR, all other photographs were taken within the borders of the MNR.

The (iv) transportation of humans and their goods, such as food products, plastic, and iron drinking bottles, from and towards Tanzania through the uM by using canoes has become a common practice (Figure 5h) (A.B., pers. obs. 2013–2022). Currently, over eight settlements, e.g., Buga, Mutongotongo, Rwabira, Gatonga, Muvumu, Mutwana, Kumana, and Sesa, were identified in the region covered by the MNR, which has resulted in a permanent presence of humans within the current border of the MNR as under implementation. This has led to an increase in all impacts resulting from human occupation and, in particular, deforestation, due to the need for firewood and pollution, through

the waste water. Moreover, it has allowed ill-intentioned people to more easily hide themselves in the area while manufacturing prohibited beverages (Figure 5i) (A.B., pers. obs. 2013–2022), especially traditional molasses rum, such as 'Igongo' in the Kirundi local language, with their waste products being directly discharged in the uM River and thus further contributing to a degradation of its water quality [see above (iii)].

Lastly, the (v) introduction of alien species, such as *O. niloticus* and *O. leucostictus*, was documented for the first time for the uM. Both these species have been shown to be invasive and capable of disrupting the food chain of native species with the same diet, mainly cichlids [103–105]. Furthermore, these species might also influence in changing the genetic setup of natural populations of some other *Oreochromis* species due to hybridisation [105,106]. Finally, they may also cause the spread of exogenous parasites amongst the native fish species, as illustrated for some Platyhelminthes spp. [107].

4.6. IUCN Status and Protection of Ichthyofauna of the Upper Malagarazi (uM) Basin in Burundi

Referring to the IUCN Red List [27] (Table A1), the uM harbours: (i) 47 species (64% of 74 species) identified as Least Concern (LC); (ii) two species (3%) as Vulnerable (VU), i.e., *O. malagaraziensis* and *E. pseudotoppini*; (iii) three species (4%) identified as Endangered (EN), i.e., *C. mutsindoziensis*, *O. mazimeroensis*, and *O. mosoensis*; and (iv) one species (1%) as Critically Endangered (CR), i.e., *Orthochromis uvinzae*. The other species, amounting to about one-third of the known species diversity (21 species: 28%), has not been successfully assessed, because (i) there is a lack of adequate information on abundance and/or distribution, or, instead, (ii) it has not yet been assessed, for several reasons (for a detailed argumentation, see Supplementary Materials Text S2: IUCN Red List status 1; see also [108]). Therefore, the presence of a bit more than one-quarter of the species with a non-evaluated, or inefficiently evaluated, conservation status is indicative of the urgent need for detailed studies to provide more accurate assessments of those species conservation statuses [109].

Of the 14 species currently known to be endemic to the uM (Tables 1 and A1), one (7%) is LC, one (7%) is VU, three (21%) are EN, and one (7%) is CR. Among these evaluated endemic species, four (29%) belong to the genus *Orthochromis*. The remaining eight endemic species of the uM have not been successfully assessed (DD) or not at all evaluated (NE) (for a detailed argumentation, see Supplementary Materials Text S2: IUCN Red List status 2). There is, therefore, an urgent need to formally describe several species from the uM and fill knowledge gaps on the distribution, abundance, and ecology of all recognised species [108].

Furthermore, for most, if not all, African PAs, as currently known and delimited, the ichthyological species richness of the basin(s) and/or region they cover was not taken into consideration when drafting their delimitations [24,28,57]. As such, the present checklist of the uM should serve as a sound source to support (i) the finalisation of the process to fully legalise the MNR by stressing its importance with regard to the conservation/protection of the ichthyofauna of the uM, while also (ii) underlining the need to protect all endemic species, as well as those only presents in the (lower and/or upper) affluents of the uM, and those identified as vulnerable, or even more precarious, for the uM, according to their IUCN Red List assessments. For the latter, adjustments to the delimitation of the current borders of the MNR are certainly needed. Indeed, excluding Lake Tanganyika, the uM has already been identified as the hotspot for riverine fish species diversity in Burundi [2]. However, the current delimitation of the MNR was proposed primarily considering the protection of birds and hippopotamuses [110]. This explains why, at least for fish species diversity protection, the inclusion of the lower parts of some of the left bank affluents of the uM, such as, from upstream (southeast) to downstream (northwest), the Mutsindozi, Muyovozi, Kinwa, Mazimero, and Mukazye rivers (Figures 6 and A4), is needed. Indeed, these will cover the localities, i.e., habitats of nine species (82% of 11 species) currently not included in any of the PAs of Burundi, i.e., *A. pedunculus*, *Amphilius* sp. 'mutsindozi', *C. kazumbei*, *Chiloglanis* sp. 'musasae', *C. mutsindoziensis*, *Clariallabes* sp. 'nyaruhandazi', *E. pseudotoppini*, *O. mazimeroensis*, and *Z.* aff. *rotundiceps*. Furthermore, these adjustments of the MNR will

allow the protection of (i) other species known in these rivers (Table A2) and (ii) the cultural traditions of the local human populations, who used the upper reaches of the Mazimero Basin as a sacred site for ritual practices (A.B., pers. obs. 2022). As a result, to enable more effective protection of all endemic species of the uM, an increased surface area for the MNR of about 8400 ha (=84 km²) to about 15,400 ha (=154 km²) was proposed (for a detailed argumentation, see Supplementary Materials Text S2: Area of new proposed limits of the MNR; see also [79,111]). This will also imply strict enforcement, in the area surrounding the MNR, of Article 5 of the water code in Burundi (Law N°1/02 of 26 March 2012), which proposes a riparian buffer zone of 25 m on each river bank, counting from the flood limits of the main affluent rivers of the LT (i.e., the Malagarazi River itself), and 5 m for each affluent of these main rivers. This should contribute to the delimitation of a new minimum surface area, which will be more effective for the protection of its ichthyofauna [112]. However, in order to maximise the protection of all fish species already known to occur in the uM, this law should be adapted for the affluents of the uM by increasing the proposed buffer zone from 5 m to 10 m for the direct affluents of the uM and maintaining a 5 m buffer zone only for its sub-affluents. Indeed, these buffer zones protecting the riparian galleries along the rivers will (i) allow for better protection of pristine aquatic habitats suitable for fish by, amongst others, limiting siltation through erosion and (ii) also better preserve the terrestrial invertebrate fauna, which is known to be an important source of food for the fish species inhabiting those (affluent) rivers [113,114]. To strengthen this protection, the strict application of Articles 36–41 (Law N°1/16 of 30 November, 2016 on the organisation of fisheries and aquaculture in Burundi) should also be enforced, as these prohibit the use of destructive fishing techniques, such as the use of ichthyotoxins and mosquito nets.

In addition, the distribution of the two remaining species (18% of 11 species), i.e., *Enteromius* sp. 'ascutelatus' [41] and *Mastacembelus* sp. 'devosi', is currently not covered by the MNR, with the former species having a very restricted distribution and, therefore, also requiring more attention for its effective protection. Indeed, recent sampling efforts only confirm its presence in the upper stretches of one of the uM left bank affluents, i.e., the upper Muyovozi River (Figure 6, n° 4). Unfortunately, any further extension of the MNR, including the upper stretches of the Muyovozi River, is not realistic, as these are located more than 30 km from the nearest current border of the MNR. Likewise, the closest sample point of *M*. sp. 'devosi' to the MNR is located at the end of its upper stretches on Muyovozi River (Figure 6, n°4). Therefore, to enable more effective protection of both endemic species, it is important to envision the creation of a new protected area for the upper stretches of Muyovozi, here referred to as Muyovozi Nature Reserve (MuNR) (Figure 6). Furthermore, other species could be protected by the MuNR as well (for a detailed argumentation, see Supplementary Materials Text S2: Importance of the MuNR; see also [115–117]).

Thus, new surveys including animals and plants, both aquatic and terrestrial, should be organised in the subbasin and its upstream surface area covered by the envisioned MuNR, as soon as possible, in order to allow for a more exhaustive overview of the species diversity that this new PA could protect. Therefore, based on the IUCN categories of PAs [118], the Law n°1/10 of 30 May, 2011, establishing the creation of PAs in Burundi, this newly envisioned PA should have the status of a Nature Reserve (NR). Indeed, a NR allows for the protection of areas with an ecological, biodiversity, and/or human activities interest, which is touristic in the latter case (see Law n°1/10). Nevertheless, other PAs known from Burundi exist as: (i) "Parks", created to protect large areas containing several ecosystems and human interests, i.e., scientific, educational, cultural, and recreational; (ii) "Landscapes", created to protect areas with considerable traditional interest; and (iii) "Natural Monuments", created for the protection of natural elements, and especially those that are also of cultural importance.

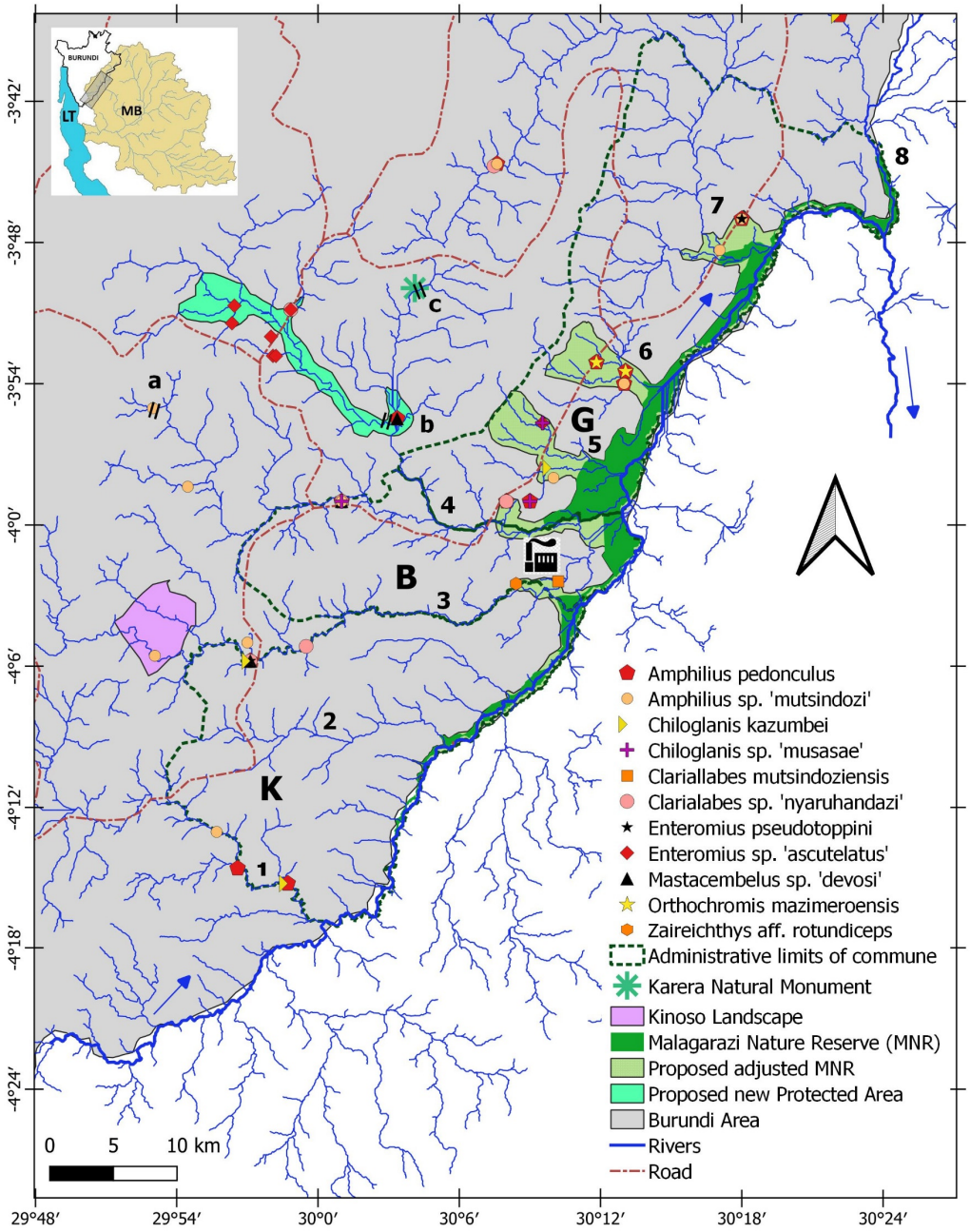

Figure 6. Current and suggested adjustments to the delimitations of the MNR and of the proposed new protected area (PA), i.e., the Muyovozi Nature Reserve (MuNR), taking into consideration the protection of the entire currently known ichthyofaunal species diversity of the upper Malagarazi (uM). Capital letters refer to the administrative communes, which are partially covered by the delimitation of the MNR (from up- to downstream): K. Kayogoro; B. Bukemba; G. Giharo. The blue arrows indicate the direction of the water flow. Names of the major affluent rivers of the uM (from up- to downstream): 1. Rukoziri; 2. Nyakabanda; 3. Mutsindozi; 4. Muyovozi; 5. Kinwa; 6. Mazimero; 7. Mukazye; 8. Rumpungwe. Double lines indicate main falls: a. Cikinga Falls (Musasa River, right bank affluent of Muyovozi River); b. Nyaganza Falls (Muyovozi River); c. Karera Falls (Karera River, left bank affluent of Muyovozi River). . SOSUMO factory.

Hence, an adjusted and extended delimitation of the Malagarazi Nature Reserve (MNR), together with the envision of a Muyovozi Nature Reserve (MuNR), would contribute to the implementation of Burundi's national strategies and action plans on biodiversity from 2013–2020 [93]. Indeed, both these PAs would contribute, according to the

objective 11 of the third strategic axis of the action plans for Burundi (see [93]), to the integration into a PA network of 10% of the country's surface area (for a detailed argumentation, see Supplementary Materials Text S2: Overview of the protected area of Burundi). This would bring the total protected surface area for the country from 5.6 to 6.1%, which nevertheless remains well below the envisioned 10%.

We believe that the current work on the ichthyofauna of the uM has brought together the elements that underscore the importance of fully implementing the status of the MNR as a true PA, at least for fish. Furthermore, we also hope to have provided sufficient evidence to highlight the importance and necessity of adjusting its current delimitation based on our updated knowledge of the ichthyofauna of the uM. Finally, the envisioning of an additional PA is unavoidable for fish protection, as well as for the protection of its flora and an additional natural monument. As such, we hope that our current work can provide the much-needed information on which to base better-informed protection of the ichthyofauna of the uM, in particular, and also of Burundi, in general, and thus might further incite all parties involved, i.e., politicians and conservationists alike, to achieve the essential changes.

5. Conclusions

With 74 native species reported, the diversity of the fish fauna of the upper Malagarazi (uM) represents about 67% of the fish species diversity of the entire Malagarazi Basin, and about 75% of the riverine fish species diversity of Burundi. Furthermore, 14 of these species (18%) are endemic to the uM. Furthermore, nine of these species, among which five are endemic, are still awaiting formal description. In addition, four other species, clearly identified as distinct, still have an uncertain identification. Hence, an integrative approach, including molecular data, should be used to further explore these cases in particular.

Among these native species, 60 (81%), including eight endemics (11%), are reported from the MNR. Instead, the remaining 14 species, including six endemics, and five with their distribution limited to the uM when considering the distribution of fish in Burundi, are only known from outside the current boundaries of the MNR in Burundi, and thus confined to the uM affluents rivers.

Therefore, for an effective protection of the fish species diversity of the uM, as a whole, this study proposes: (i) the readjustment of the current limits of the MNR; and (ii) the need to also support the creation of a new protected area. As such, we hope to have provided enough evidence to underscore the importance of these propositions in envisioning a more sustainable future for the uM's ichthyofauna.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d16070417/s1, Figure S1: Examples of some fishing methods used of the upper Malagarazi (uM) in Burundi; Table S1: Sampling localities in the upper Malagarazi Basin for the years 2013–2022; Text S1: Results: Details on *3.4. Taxonomic problems: an overview*; Text S2: Discussion: Details on *4.6. IUCN and protection of ichthyofauna of the upper Malagarazi (uM) Basin in Burundi*.

Author Contributions: A.B. and G.B. were responsible for the fieldwork and the preliminary fish identifications. A.B., G.B., T.K., and E.V. participated in the implementation of the methodological approach and design of the study and wrote jointly the first and subsequent revised versions of the manuscript. L.M.d.C. participated in the implementation of the design of the study and wrote jointly with other authors the subsequent revised versions of the manuscript. D.R.M. participated in fieldwork and wrote jointly with other authors the text of the Cyprinidae, C.M.M. wrote jointly with other authors the text of the Mormyridae, and E.A. wrote jointly with other authors the text of the Amphiliidae. E.V. and G.B. supervised the overall work. All authors contributed to useful discussions, read and revised the manuscript, and approved its final version. Finally, All authors have read and agreed to the published version of the manuscript.

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framework agreement between the RMCA and the Directorate-General for Development Cooperation and Humanitarian Aid (DGD). In addition, the present study was completed thanks to four study visits (2018, 2019, 2021, and 2023) of the first author to the RMCA, all within the framework of his master's degree and beyond, for the last study visit. These study visits were funded through the RMCA ABIC program (2018) and the Mbisa Congo I and II projects. The first one was also funded through a framework agreement between the RMCA and the DGD. Finally, the contribution of L.M.C. (2022–present) was also supported by the Mbisa Congo II project.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Some data generated during this study are available from the first author upon reasonable request.

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

Appendix A

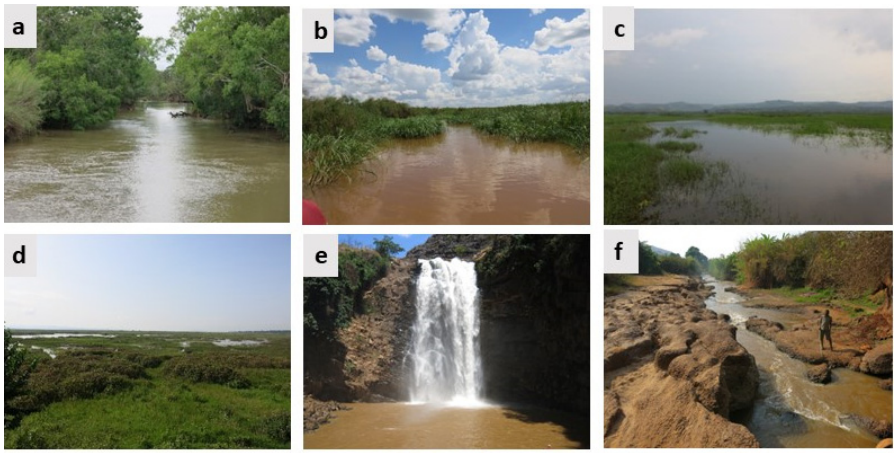

Figure A1. *Cont*.

Figure A1. Examples of available aquatic habitats of the upper Malagarazi (uM) in Burundi: (**a**). uM River, Kumana Village (3°46′39.1″ S 30°21′29.7″ E) (13 October 2017); (**b**). uM River, Rwabira Village (3°59′24.3″ S 30°12′51.4″ E) (16 February 2018); (**c**). Temporary swamp (rainy season) close to the uM River, Muvumu Village (3°53′05.7″ S 30°15′18.2″ E) (9 February 2018); (**d**). Permanent marshes near the mouth of the Muyovozi River (left bank affluent of uM), Gatonga Village (3°55′58.8″ S 30°12′46.4″ E) (17 January 2017); (**e**). Nyaganza I Falls on the Muyovozi River (left bank affluent of uM), near Kibinzi Village (3°55′35.3″ S 30°03′21.6″ E) (23 August 2021); (**f**). Musasa River, right bank affluent of Muyovozi River, Murama Village (3°59′43.3″ S 30°04′16.6″ E) (19 August 2021); (**g**). Mutsindozi River (left bank affluent of uM), Kibimba Village (4°05′49.6″ S 29°54′34.0″ E) (29 November 2018); (**h**). Mazimero River (left bank affluent of uM), Nkanka Village, upstream of the Gihofi–Rubaho Road (3°53′02.8″ S 30°11′56.2″ E) (20 January 2017); (**i**). Muyovozi River, left bank affluent of uM River, Ramvya village (3°50′41.1″ S 29°56′26.7″ E) (10 November 2019). Note that (**a**–**d**) are the photos taken within the MNR, while (**e**–**i**) were taken out of the limit of the MNR.

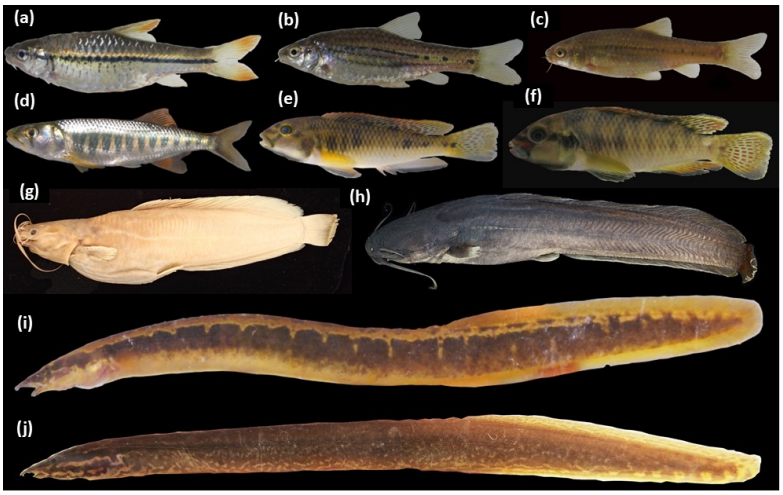

Figure A2. Photographs (lateral view) of some representatives of the endemic species of the ichthyofauna of upper Malagarazi (uM) Basin: (**a**). *Enteromius devosi*, from the Munywero River (a right bank affluent of Rumpungwe), Munywero Village (3°46′23.0″ S 30°24′28.7″ E) (1 February 2018); (**b**). *E. quadrilineatus* from the Nyarugunga River (a right bank affluent of Rumpungwe), Migende village (3°25′54.6″ S 30°25′31.4″ E) (3 December 2018); (**c**). *Enteromius* sp. 'ascutelatus', from the Nyanknde River (a right bank affluent of Muyovozi River, uM), Nyankende Village (3°52′49.0″ S 29°58′05.1″ E) (9 November 2019); (**d**). *Opsardium splendens*, from the Mutsindozi River (a left bank affluent of Malagarazi), Kinoso Village (4°05′33.6″ S 29°53′04.0″ E) (17 October 2022); (**e**). *Orthochromis malagaraziensis*, from the Nyamabuye River (= upper stretches of the Mukazye River), Giheta Village (3°44′45.5″ S 30°07′28.0″ E) (23 July 2022); (**f**). *Orthochromis mazimeroensis*, from the Mazimero River, Nkaka Village (3°53′04.0″ S 30°11′45.3″ E) (20 August 2021); (**g**). *Clariallabes mutsindoziensis* (preserved specimen), from the Mutsindozi River, Gihofi Village, near its mouth with uM River (locality situated between 4°02′–4°04′ S 30°09′–30°11′ E) (11 August 1993); (**h**). *Clariallabes* sp. 'nyaruhandazi', from the Mutsindozi River (a left bank affluent of the Malagarazi), Kabizi Village (4°05′19.4″ S 29°59′19.2″ E) (1 December 2018); (**i**). *Mastacembelus* sp. 'devosi', from the Nyagatwenzi River (a right bank affluent of Rukoziri), Gikurazi Village (4°12′08.0″ S 29°49′15.6″ E) (15 October 2022); and (**j**). *Mastacembelus* sp. 'malagarazi', from the Mazimero River (a left bank affluent of Malagarazi), Nkanka Village (3°53′04.0″ S 30°11′45.3″ E) (20 August 2021).

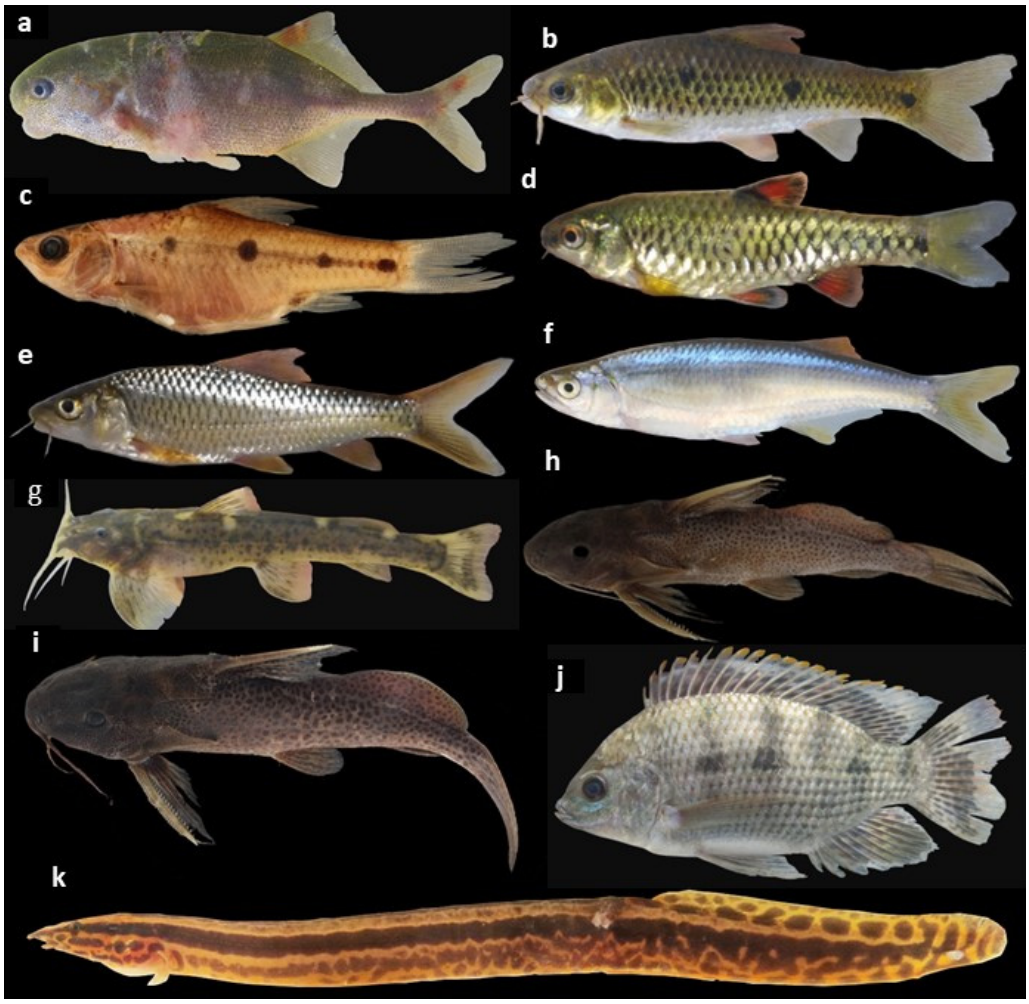

Figure A3. Photographs (lateral view) of some representatives of case studies of the species of the ichthyofauna of upper Malagarazi (uM) Basin in Burundi: (**a**). *Cyphomyrus discorhynchus*, from the Malagarazi River, Buga Village (4°06′10.9″ S 30°09′51.4″ E) (15 November 2019); (**b**). *Enteromius pellegrini*, from the Nyakayi River (= upper stretches of the Karera River, a left bank affluent of Muyovozi), Karera Village (3°49′48.8″ S 30°04′47.4″ E) (25 July 2022); (**c**). *Enteromius* sp. 'rugoma' (preserved specimen), from the Mugombwe River (a right affluent of Rukoziri), Gasaka Village (4°13′19.7″ S 29°47′53.9″ E) (15 October 2022); (**d**). *Enteromius* sp. 'nyamabuye', from the uM River, Butezi Village (3°55′01″ S 30°15′22″ E) (13 December 2008); (**e**). *Labeobarbus somereni*, from the Mutsindozi River (a left bank affluent of uM), Kinoso Village (4°05′33.6″ S 29°53′04.0″ E) (17 October 2022); (**f**). *Chelaethiops congicus*, from the Nyamabuye River (upper stretches of the Mukazye River, a left bank affluent of uM), Giheta Village (3°44′45.5″ S 30°07′28.0″) (23 July 2022); (**g**). *Amphilius* sp. 'mutsindozi', from the Nyamabuye River (a left bank affluent of the uM), Giheta Village (3°44′45.5″ S 30°07′28.0″ E) (23 July 2022); (**h**). *Synodontis melanostictus* (preserved specimen), from the Rumpungwe River, Sesa Village (3°46′14.8″ S 30°24′30.6″ E) (19 July 2011); (**i**). *Synodontis* aff. *nigromaculatus* (preserved specimen), from the uM River, Mutwana Village (3°51′25.2″ S 30°17′53.5″ E) (30 July 2009); (**j**). *Oreochromis upembae*, from the Rumpungwe River, Sesa Village (3°46′15.4″ S 30°24′30.6″ E) (22 August 2021); and (**k**). *Mastacembelus frenatus*, from the uM River, Rwabira Village, (3°59′19.0″ S 30°12′54.0″ E) (7 July 2017).

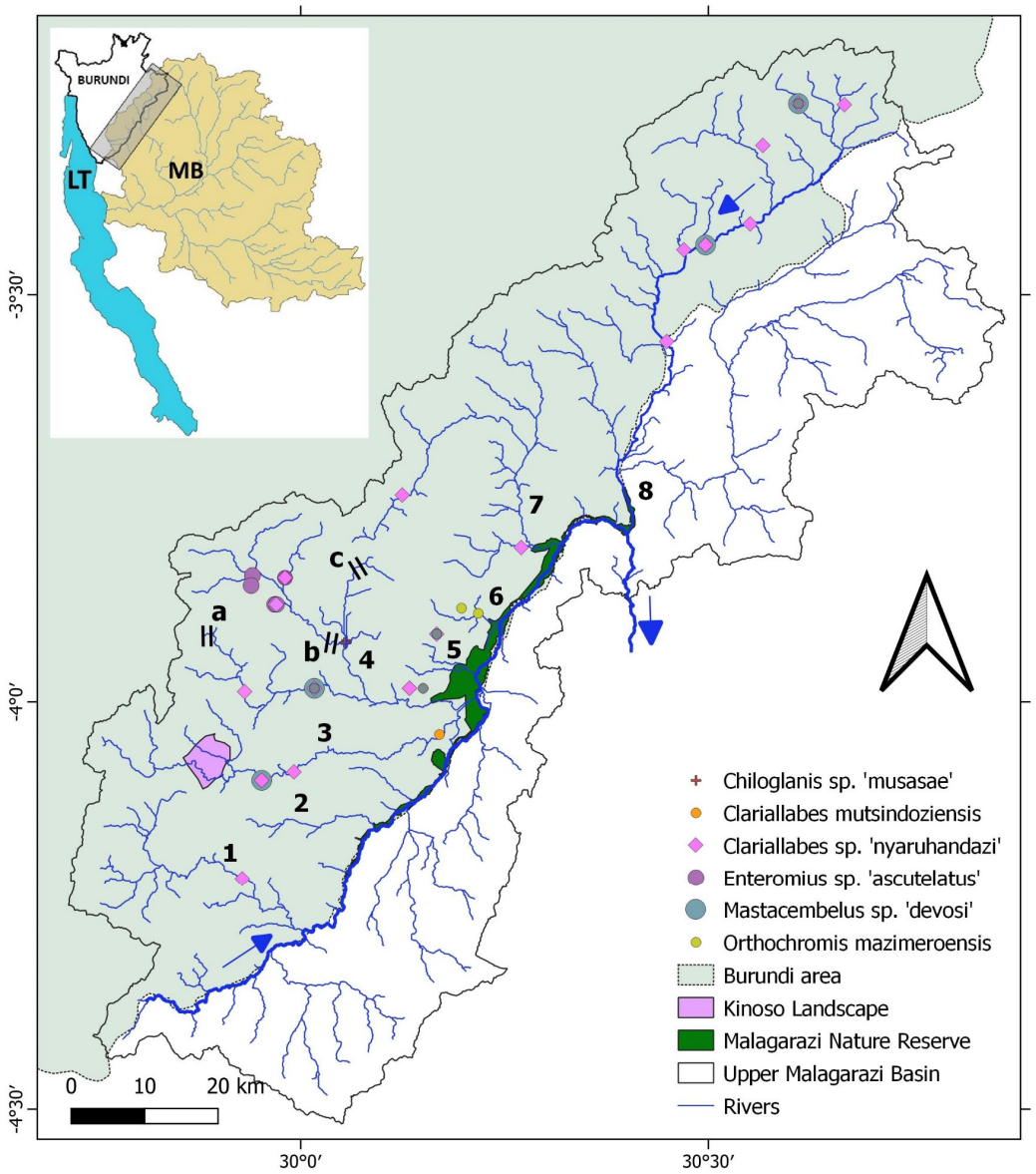

Figure A4. Distribution of the six endemic fish species of the upper Malagarazi (uM) Basin in Burundi, which are only reported from outside the actual borders of the Malagarazi Nature Reserve (MNR). Double bars indicate major falls: a. Cikinga Falls (Musasa River, right bank affluent of the Muyovozi River); b. Nyaganza Falls (Muyovozi River); and c. Karera Falls (Karera River, left bank affluent of the Muyovozi River). LT, Lake Tanganyika; MB, Malagarazi Basin. The blue arrows indicate the flow direction of the water in the rivers of the uM. Names of the major affluent rivers of the uM (from upstream to downstream): 1. Rukoziri, 2. Nyakabanda, 3. Mutsindozi, 4. Muyovozi, 5. Kinwa, 6. Mazimero, 7. Mukazye, and 8. Rumpungwe.

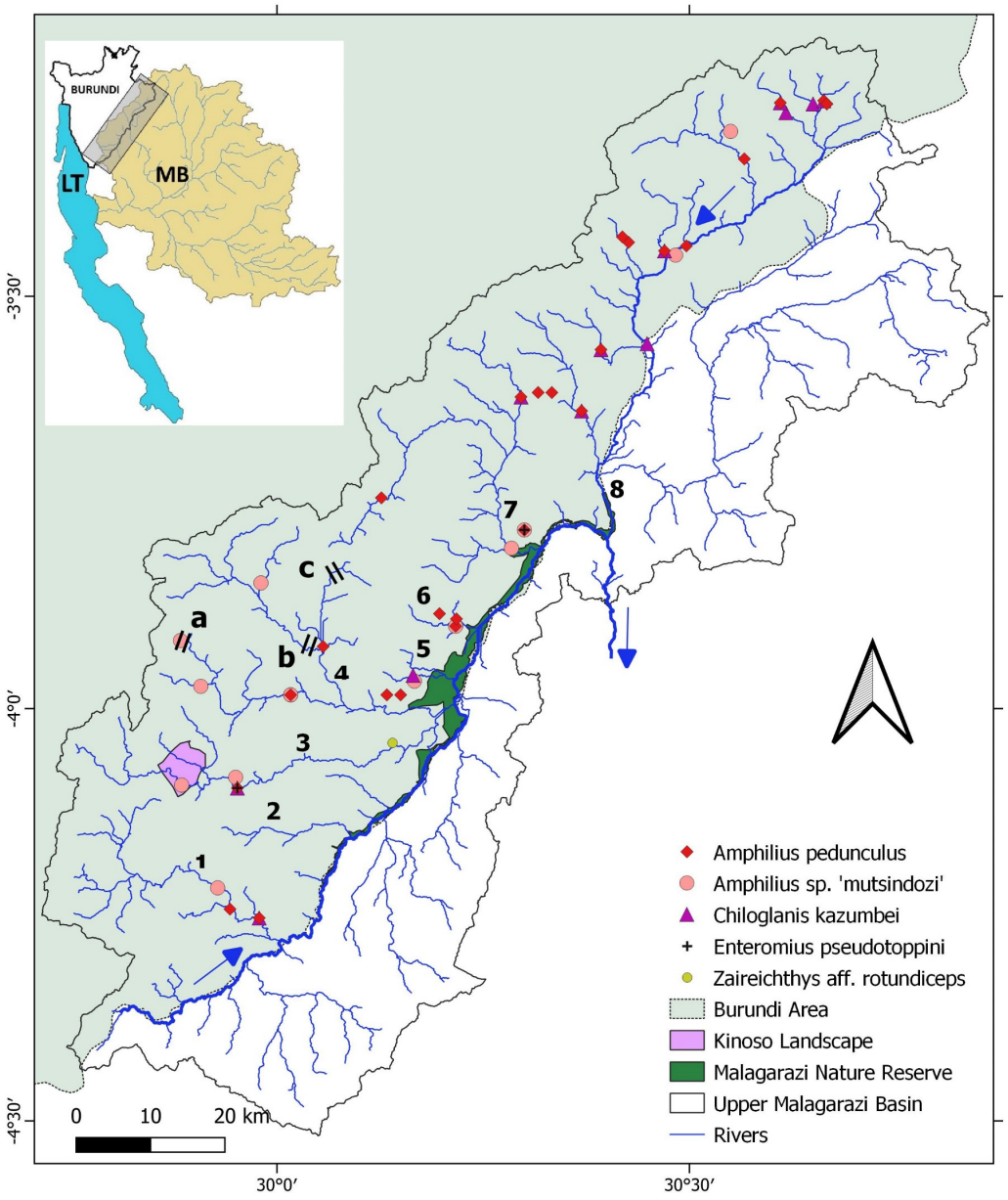

Figure A5. Distribution of five native species of Burundi reported only from the upper Malagarazi (uM) but from outside the actual borders of the MNR only. Double bars indicate major falls: a. Cikinga Falls (Musasa River, right bank affluent of the Muyovozi River); b. Nyaganza Falls (Muyovozi River); and c. Karera Falls (Karera River, left bank affluent of the Muyovozi River). LT, Lake Tanganyika; MB, Malagarazi Basin. The blue arrows indicate the flow direction of the water in the uM. Names of the major affluent rivers of the uM (from upstream to downstream): 1. Rukoziri, 2. Nyakabanda, 3. Mutsindozi, 4. Muyovozi, 5. Kinwa, 6. Mazimero, 7. Mukazye, and 8. Rumpungwe.

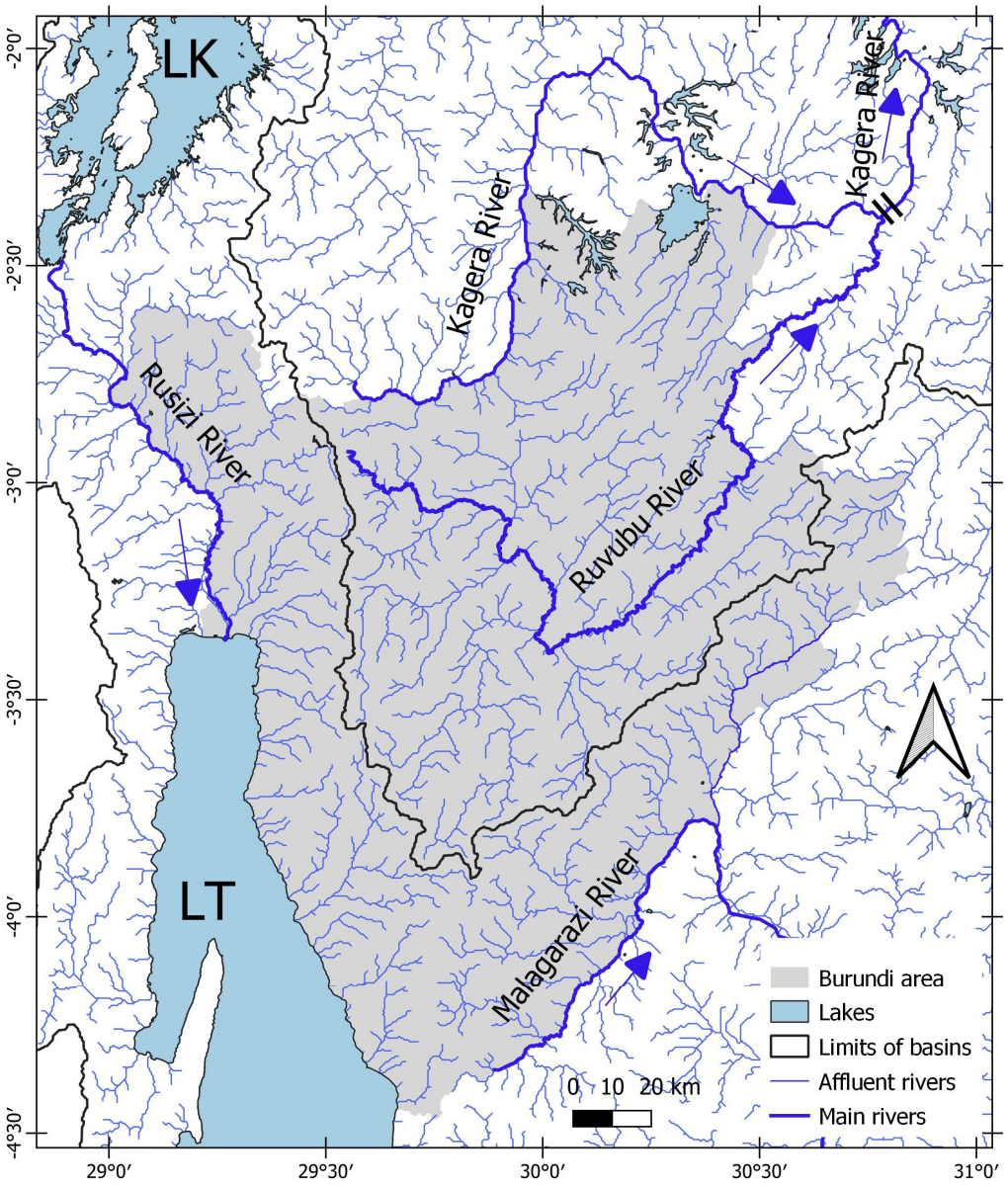

Figure A6. The main hydrographic basins of Burundi. Double bars on Kagera River indicate Rusumo Falls. LK, Lake Kivu; LT, Lake Tanganyika. The blue arrows indicate the direction of the water flow.

Appendix B

Table A1. List of the fish species (scientific names followed by local names in braces), first for the upper Malagarazi basin (uM) in Burundi as a whole, then for the two sub-basins of the uM Basin, being the uM River itself (sb Malagarazi), and the Rumpungwe River (sb Rumpungwe), its major leftbank affluent, and then for the Malagarazi Nature Reserve (MNR). Furthermore, IUCN status, neighbouring PAs of Burundi, collections, and literature were noted. The two sub-basins include a main course (mc) and their affluent rivers (affl.). Distribution of the different species in the uM basin: +, present; -, absent; +e, endemic; and +i, introduced. IUCN status: NE, not evaluated; DD, data deficient; LC, least concern; NT, near threatened; VU, vulnerable; and CR, critically endangered. Two PAs close to the MNR in Burundi whose ichthyofauna has been studied, the Rusizi National Park (RusNP) [14] and the Ruvubu National Park (RuvNP) [13] for comparisons. The numbers between brackets for each family are the number of species found in each family, firstly for the uM as a whole, and secondly for the MNR. Collections indicated where the specimens are housed, and the literature indicated the references used.

Species	uM	Malagarazi sb		Rumpungwe sb		MNR	IUCN Status	PAs		Collections	Literature
		mc	affl.	mc	affl.			RusNP	RuvNP		
Mormyridae (8/8)											
Cyphomyrus discorhynchus (Peters, 1852) [Fonogo, Igitifu]	+	+	+	+	+	+	LC	+	-	MRAC	[1,2]
Gnathonemus longibarbis (Hilgendorf, 1888) [Gisoma, Insomarukunga, Indomodomo]	+	+	+	+	+	+	LC	-	-	MRAC	[1,2]
Marcusenius macrolepidotus (Peters, 1852) [Igitifu]	+	+	+	+	+	+	LC	-	-	MRAC	[1,2]
Marcusenius stanleyanus (Boulenger, 1897) [Igitifu]	+	+	-	+	-	+	LC	-	-	MRAC	[1,2]
Mormyrus anguilloides (Linnaeus, 1758) [Ikimongo]	+	+	-	+	-	+	LC	-	-	MRAC	[1,2]
Mormyrus longirostris Peters, 1852 [Icembe]	+	+	-	+	-	+	LC	-	-	MRAC	[1,2]
Petrocephalus catostoma (Günther, 1866) [Rumete, Ubutifu]	+	+	+	+	+	+	LC	-	-	MRAC	[1,2]
Pollimyrus nigricans (Boulenger, 1906) [Rumete, Ubutifu]	+	+	+	+	+	+	LC	+	+	MRAC	[1,2]
Cyprinidae (21/17)											

Table A1. *Cont.*

Species	uM	Malagarazi sb		Rumpungwe sb		MNR	IUCN Status	PAs		Collections	Literature
		mc	affl.	mc	affl.			RusNP	RuvNP		
Enteromius devosi (Banyankimbona, Vreven and Snoeks, 2012) [Umubuti]	+e	-	+e	+e	+e	+e	NE	-	-	MRAC	[119]
Enteromius innocens (Pfeffer, 1896) [Umubuti]	+	+	+	+	+	+	LC	+	-	MRAC	[1,2]
Enteromius lineomaculatus (Boulenger, 1903) [Umubuti]	+	+	+	+	+	+	LC	+	-	MRAC	[1,2]
Enteromius luikae (Ricardo, 1939) [Umubuti]	+	+	+	+	+	+	LC	-	-	MRAC	[1,2]
Enteromius oligogrammus (David, 1937) [Umubuti]	+	+	+	+	+	+	LC	-	-	MRAC	[1,2,12]
Enteromius paludinosus (Peters, 1852) [Umubuti]	+	+	+	+	+	+	LC	-	-	MRAC	[2,12]
Enteromius pellegrini (Poll, 1939) [Umubuti]	+	+	+	-	+	-	LC	+	-	MRAC	[2,12]
Enteromius pseudotoppini (Seegers, 1996) [Umubuti]	+	-	+	-	-	-	VU	-	-	MRAC	[2]
Enteromius quadrilineatus (David, 1937) [Umubuti]	+e	+e	+e	+e	+e	+e	NE	-	-	MRAC	[1,2,12]
Enteromius radiatus (Peters, 1853) [Umubuti]	+	+	-	+	+	+	LC	-	-	MRAC	[1,2]
Enteromius sp. 'ascutelatus' [Umubuti]	+e	-	+ e	-	-	-	NE	-	-	MRAC	[2,45]
Enteromius sp. 'nyamabuye' [Umubuti]	+	+	+	+	+	+	NE	-	-	MRAC	-
Enteromius sp. 'rugoma' [Umubuti]	+	+	+	+	+	+	NE	-	+	MRAC	-
Labeo altivelis Peters, 1852 [Ikirugwe rubere]	+	+	-	+	-	+	LC	-	-	MRAC	[1,2,12, 53]
Labeo cylindricus Peters, 1852 [Ikirugwe]	+	+	+	+	+	+	LC	+	-	MRAC	[1,2]
Labeo dhonti Boulenger, 1920 [Ikirugwe, Imbinda]	+	+	+	-	-	+	LC	-	-	MRAC	[1,2]

Table A1. *Cont.*

Species	uM	Malagarazi sb		Rumpungwe sb		MNR	IUCN Status	PAs		Collections	Literature
		mc	affl.	mc	affl.			RusNP	RuvNP		
Labeo fuelleborni Hilgendorf and Pappenheim, 1903 [Ikirugwe, Imbinda]	+	+	+	+	+	+	DD	-	-	MRAC	[1,2,12]
Labeo parvus Boulenger, 1902 [Ikirugwe, Imbinda]	+	+	-	+	+	+	LC	-	-	MRAC	[1,2]
Labeo sp. 'kumana' [Ikirugwe]	+	+	+	-	-	+	NE	-	-	MRAC	[2,45]
Labeobarbus cf. *macrolepis* (Pfeffer, 1889) [Igihira]	+	+	+	+	-	+	NE	-	-	MRAC	[1,2]
Labeobarbus somereni (Boulenger, 1911) [Igihira]	+	-	+	-	-	-	LC	+	-	MRAC	[2,12,49]
Danionidae (2/2)											
Opsaridium splendens Taverne and De Vos, 1997 [Umukirambaya, Umusurakwezi, Inyamukubo]	+e	+e	+e	+e	+e	+e	DD	-	-	MRAC	[1,2]
Chelaethiops congicus (Nichols and Griscom, 1917) [Umurangara]	+	+	+	-	+	+	LC	-	-	MRAC	[1,2]
Citharinidae (1/1)											
Citharinus gibbosus Boulenger, 1899 [Ikibazwa]	+	+	-	+	-	+	LC	-	-	MRAC	[1,2]
Distichodontidae (1/1)											
Distichodus maculatus Boulenger, 1898 [Inkaragata]	+	+	+	-	-	+	LC	-	-	MRAC	[1,2]
Alestidae (5/5)											
Alestes macrophthalmus Günther, 1867 [Imanzi]	+	+	+	-	-	+	LC	+	-	MRAC	[1,2]
Brachyalestes imberi (Peters, 1852) [Imere, Isoga]	+	+	+	+	+	+	LC	+	-	MRAC	[1,2,12]
Brachyalestes sadleri (Boulenger, 1906) [Imere Isoga]	+	+	+	+	+	+	LC	-	-	MRAC	[1,2]

Table A1. *Cont.*

Species	uM	Malagarazi sb		Rumpungwe sb		MNR	IUCN Status	PAs		Collections	Literature
		mc	affl.	mc	affl.			RusNP	RuvNP		
Hydrocynus vittatus Castelnau, 1861 [Imanda]	+	+	-	+	-	+	LC	-	-	MRAC	[1,2]
Micralestes stormsi Boulenger, 1902 [Akanwarumogi, Imbaragu]	+	+	+	+	-	+	LC	+	-	MRAC	[1,2]
Clariidae (7/4)											
Clariallabes mutsindoziensis Taverne and De Vos, 1998 [Inyabuhiri, Ikambare]	+e	-	+e	-	-	-	EN	-	-	MRAC	[2,72]
Clariallabes sp. 'nyaruhandazi' [Inyabuhiri, Ikambare]	+e	-	+e	-	+e	-	NE	-	-	MRAC	[2,45]
Clarias aff. *theodorae* Weber, 1897 [Umwumbiri, Inyabuhiri]	+	+	+	+	+	+	NE	-	-	MRAC	[2,45]
Clarias gariepinus (Burchell, 1822) [Ineke, Ikambale]	+	+	+	+	+	+	LC	+	+	MRAC	[2,6,120]
Clarias hilli Fowler, 1936 [Umwumbiri, Inyabuhiri]	+	+	+	-	+	+	LC	-	-	MRAC	[1,2]
Clarias liocephalus Boulenger, 1898 [Icumbugutwi, Ikambale]	+	-	+	-	+	-	LC	+	+	MRAC	[1,2]
Heterobranchus longifilis Valenciennes, 1840 [Imbera]	+	+	-	+	-	+	LC	-	-	MRAC	[1,2]
Amphiliidae (3/0)											
Amphilius pedunculus Thomson and Page, 2015 [Kavungwe, Ijogo, Imoto, Inemberi, Inyegeyege]	+	-	+	+	+	-	NE	-	-	MRAC	[81]
Amphilius sp. 'mutsindozi' [Kavungwe, Ijogo, Imoto, Inemberi, Inyegeyege]	+	-	+	+	+	-	NE	-	-	MRAC	-
Zaireichthys aff. *rotundiceps* (Hilgendorff, 1905) [unknown local name]	+	-	+	-	-	-	NE	-	-	MRAC	[1,2,121]

Table A1. *Cont.*

Species	uM	Malagarazi sb		Rumpungwe sb		MNR	IUCN Status	PAs		Collections	Literature
		mc	affl.	mc	affl.			RusNP	RuvNP		
Malapteruridae (1/1)											
Malapterurus tanganyikaensis Roberts, 2000 [Inyika]	+	+	-	+	-	+	NE	-	-	MRAC	[2]
Mochokidae (6/4)											
Chiloglanis kazumbei Friel and Vigliotta, 2011 [Imenamabuye]	+	-	+	+	+	-	NE	-	-	AMNH, CU, MRAC, SAIAB	[2,65]
Chiloglanis sp. 'musasae' [Imenamabuye]	+e	-	+e	-	+e	-	NE	-	-	MRAC	[2,45,65]
Synodontis afrofischeri Hilgendorf, 1888 [Igogo, Ijwegeri]	+	+	+	+	+	+	LC	-	-	MRAC	[1,2,122]
Synodontis aff. *nigromaculatus* Boulenger, 1905 [Igogo]	+	+	-	-	-	+	NE	-	-	MRAC	[2,45]
Synodontis melanostictus Boulenger, 1906 [Igogo]	+	+	-	+	-	+	NE	-	-	MRAC	[2,66]
Synodontis victoriae Boulenger, 1906 [Igogo, Ijwegeri]	+	+	+	+	+	+	LC	-	-	MRAC	[1,2,122]
Schilbeidae (1/1)											
Schilbe intermedius Rüppell, 1832 [Umurembe, Umuhwinyiza]	+	+	+	+	-	+	LC	-	+	MRAC	[1,2]
Mastacembelidae (3/2)											
Mastacembelus frenatus Boulenger, 1901 [Umweko, Umurombo]	+	+	+	+	+	+	LC	+	+	MRAC	[1,2,35]
Mastacembelus sp. 'devosi' [Umweko, Umurombo]	+e	-	+e	+e	+e	-	NE	-	-	MRAC	[2,35,45]
Mastacembelus sp. 'malagarazi' [Umweko, Umurombo]	+e	+e	+e	-	+e	+e	NE	-	-	MRAC	[2,35,45]

Table A1. *Cont.*

Species	uM	Malagarazi sb		Rumpungwe sb		MNR	IUCN Status	PAs		Collections	Literature
		mc	affl.	mc	affl.			RusNP	RuvNP		
Anabantidae (1/1)											
Ctenopoma muriei (Boulenger, 1906) [Agakumu k'ababumvyi, Gitunanati]	+	+	+	+	+	+	LC	+	-	MRAC	[1,2]
Cichlidae (13/12)											
Astatoreochromis straeleni (Poll, 1944) [Ifuro, Ipara]	+	+	+	+	+	+	LC	+	-	MRAC	[1,123]
Astatotilapia burtoni (Günther, 1894) [Ifuro, Ipara]	+	+	+	+	-	+	LC	+	-	MRAC	[2]
Astatotilapia stappersii (Poll, 1943) [Ifuro, Ipara]	+	+	+	+	+	+	LC	+	-	MRAC	[2]
Coptodon rendalli (Boulenger, 1897) [Ingege, Intaba]	+	+	+	-	-	+	LC	-	-	MRAC	[1,2]
Haplochromis paludinosus (Greenwood, 1980) [Ifuro, Ipara]	+e	+e	+e	+e	+e	+e	LC	-	-	MRAC	[2]
Oreochromis leucostictus (Trewavas, 1933) [Ingege, Intaba]	+i	-	+i	-	-	-	LC	+i	-	MRAC	[31]
Oreochromis niloticus (Linnaeus, 1758) [Ingege, Intaba]	+i	+i	+i	-	+i	+i	LC	+i	-	MRAC	[31]
Oreochromis upembae (Thys van den Audenaerde, 1964) [Ingege, Intaba]	+	+	+	+	+	+	LC	-	-	MRAC	[1,2,31, 124]
Orthochromis malagaraziensis (David, 1937) [Isaburongo]	+e	+e	+e	+e	+e	+e	VU	-	-	MRAC	[1,2,12, 72]
Orthochromis mazimeroensis De Vos and Seegers, 1998 [Isaburongo]	+e	-	+e	-	-	-	EN	-	-	MRAC	[1,2,124]
Orthochromis mosoensis De Vos and Seegers, 1998 [Isaburongo]	+e	+e	+e	+e	+e	+e	EN	-	-	MRAC	[1,2,124]

Table A1. *Cont.*

Species	uM	Malagarazi sb		Rumpungwe sb		MNR	IUCN Status	PAs		Collections	Literature
		mc	affl.	mc	affl.			RusNP	RuvNP		
Orthochromis uvinzae De Vos and Seegers, 1998 [Isaburongo]	+e	+e	+e	-	-	+e	CR	-	-	MRAC	[1,2,124]
Pseudocrenilabrus multicolor (Schöller, 1903) [Kabaya, Ipara Ifuro]	+	+	+	+	+	+	LC	-	-		[1,2]
Procatopodidae (2/2)											
'*Lacustricola*' *centralis* (Seegers, 1996) [Agatambirabavomyi, Agasembe]	+	+	+	+	+	+	LC	-	-	MRAC	[1,2,37]
Micropanchax fuelleborni (Ahl, 1924) [Agatambirabavomyi, Agasembe]	+	+	+	-	-	+	LC	-	-	MRAC	[2,37,45]
Protopteridae (1/1)											
Protopterus aethiopicus Heckel, 1851 [Kamongo, Mamba, Kambali-mamba]	+	+	-	+	-	+	LC	+	-	MRAC	[1,2,12]
Summary											
Introduced species (i)	**2**	1	2	0	1	1		2	2		
Native species	**74**	60	60	52	46	60		18			
Endemic species (e)	14	8	14	7	10	8					
Species per basin/sub-basin	**76**	**76**		**61**				**20**	**6**		
Endemic species per basin/sub-basin	**14**	**14**		**10**							
Shared Species between MNR and the basin and different sub-basin	**60**	**60**		**52**				**15**	**5**		

Table A2. List of the fish species available in main affluent rivers of Malagarazi. The Muyovozi River was subdivided into two stretches, i.e., Muyovozi stretches (Muy str) corresponding to the main course and its affluents, except Musasa River, and Musasa stretches (Mus str) corresponding to the Musasa River, a main affluent of Muyovozi. *: contribution of protection of which affluent river with new delimitation.

Species	Rukoziri	Mutsindozi	Muyovozi			Kinwa	Mazimero	Mukazye
			Muy str	Mus str	Total			
Mormyriidae								
Cyphomyrus discorhynchus	+	-	+	-	+	-	-	+
Gnathonemus longibarbis	+	-	+	-	+	+	-	+
Marcusenius macrolepidatus	+	-	-	-	-	+	+	+
Petrocephalus catastoma	+	-	-	-	-	-	+	+
Pollimyrus nigricans	+	-	-	-	-	+	-	-
Cyprinidae								
Enteromius devosi	+	+	+	+	+	-	+	-
Barbus innocens	+	+	+	-	+		-	+
Enteromius lineomaculatus	+	+	+	+	+	+	-	+
Barbus luikae	-	+	+	-	+		-	+
Enteromius paludinosus	+	+	+	+	+	+	+	+
Enteromius pellegrini	+	+	+	+	+	+	-	-
Enteromius oligogramus	+	+	-	+	+	+	+	+
Enteromius pseudotoppini	-	+	-	-	-	-	-	+ *
Enteromius sp. 'ascutelatus'	-	-	+ *	-	+	+	-	-
Enteromius sp. 'nyamabuye'	-	+	-	-	-	-	-	+
Enteromius sp. 'rugoma'	+	+	-	-	-	+	-	+
Enteromius quadrilneatus	+	+	+	+	+	-	+	+
Labeo cylindricus	+	+	+	-	+	+	-	-
Labeo fuelleborni	-	-	+	+	+	-	-	+
Labeo parvus	-	-	+	-	+	-	+	-
Labeobarbus cf. *macroleptadus*	-	+	+	+	+	-	-	-
Labeobarbus somereni	-	+	+	+	+	-	-	-
Danionidae								
Chelaethiops congicus	+	+	+	+	+	+	-	+
Opsaridium splendens	-	+	+	+	+	-	-	+
Alestidae								
Alestes macrophthalmus	-	-	-	+	+	-	-	-
Brachyalestes imberi	+	-	-	-	-	-	-	+
Clariidae								
Clariallabes mutsindoziensis	-	+ *	-	-	-	-	-	-
Clariallabes sp. 'nyaruhandazi'	+	+	+ *	+	+	+	+	-
Clarias aff. *theodorae*	-	-	+	-	+		+	-
Clarias hilli	+	-	-	+	+		-	-
Clarias liocephalus	+	-	-	+	+	+	+	-
Clarias gariepinus	+	-	+	+	+	-	-	-
Amphiliidae								
Amphilius pedunculus	+	+	+	+	+	+	+ *	+ *
Amphilius sp. 'mutsindozi'	+	+	-	+	-	-	+ *	+ *
Zairechthys aff. *rotundiceps*	-	+ *	-	-	-	-	-	-

Table A2. *Cont.*

Species	Rukoziri	Mutsindozi	Muyovozi			Kinwa	Mazimero	Mukazye
			Muy str	Mus str	Total			
Mochokidae								
Chiloglanis kazumbei	-	+	-	-	-	+ *	-	-
Chiloglanis sp. 'musase'	-	-	-	+	+	+ *		-
Synodontis afrofisheri	-	-	-	-	-	-	-	+
Synodontis victoriae	-	+	+	-	+	-	-	+
Mastacembelidae								
Mastacembelus frenatus	-	+	-	-	+	+	+	+
Mastacembelus sp. 'devosi'	-	+	+ *	-	+		+	-
Mastacembelus sp. 'malagarasi'	-	-	-	-	-	+	-	-
Anabantidae								
Ctenopoma muriei	-	-	-	-	-	+	+	-
Cichlidae								
Astatoreochromis straeleni	-	-	-	-	-	+	+	-
Astatotilapia burtoni	-	-	-	-	-		+	-
Astatotilapia stappersii	-	-	+	-	+		+	-
Haplochromis paludinosus	-	+			+	+	+	+
Coptodon rendalli	-	-	-	-	-	+	+	-
Oreochromis upembae	-	-	+	+	-	-	+	-
Orthochromis malagarasiensis	+	+	+	-	+	-	-	-
Orthochromis mazimeroensis	-	-	-	-	-	-	+ *	-
Orthochromis mosoensis	-	+	-	+	+	+	-	+
Procatopodidae								
'Lacustricola' centralis	-	-	-	-	-	-	+	-
Micropanchax fluelleborni	-	-	+	-	+	+	-	+
Protopteriidae								
Protopterus aethiopicus	-	-	-	-	-	-	+	-
Total	23	28	27	21	34	14	24	25

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