African Fish Biodiversity, FishBase and Fishculture

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Summary

At present, about 28 600 fish species are considered valid, whilst the total number is estimated at 30 000 to 35 000. For Africa, about 3 000 valid fresh- and brackish water species are currently recognized. Conserving the biodiversity of these fishes and at the same time managing their exploitation in a sustainable way is a difficult exercise.

In sub-Saharan Africa, the importance of aquaculture is not very high. Nonetheless, 18 different species are used commercially, of which six have a non-African origin.

Documenting and characterizing the ichthyodiversity is vital for conservation and sustainable development purposes. The presence of a large collection, a specialised library and a considerable know-how in the Africa Museum has led to various revisions, checklists, species (re)descriptions and regional guides. All the information on African fishes is currently being entered in FishBase, a huge freely accessible database with information on the taxonomy, ecology and various other aspects of the biology of fishes, based on scientific publications and reviewed by specialists. FishBase also includes high quality tools for applied research on fishes, such as a disease wizard, biogeography tools, trophic pyramids, and the species invasiveness tool.

Résumé

Biodiversité des poissons africains, Fishbase et pisciculture

A l'heure actuelle, environ 28 600 espèces de poissons sont considérées comme valides, tandis que le nombre total est estimé de 30 000 à 35 000. Pour l'Afrique, environ 3 000 espèces valides d'eaux douces et saumâtres sont actuellement décrites. Conserver la biodiversité de ces poissons et en même temps contrôler leur exploitation d'une manière durable est un exercice difficile.

L'importance de l'aquaculture en Afrique sub-saharienne n'est pas très élevée. Néanmoins, 18 espèces différentes sont exploitées commercialement, dont six ont une origine non-africaine. Documenter et caractériser l'ichtyodiversité est essentiel pour la conservation et le développement durable. La présence d'une collection importante, d'une bibliothèque spécialisée et d'une expertise considérable dans le Musée Royal de l'Afrique Centrale a mené à des révisions diverses, des catalogues, des (re)descriptions d'espèces et des guides faunistiques. Actuellement, toute l'information sur les poissons africains est encodée dans FishBase, une base de données énorme. Elle est accessible gratuitement et toute l'information sur la taxonomie, l'écologie et d'autres aspects divers de la biologie des poissons y est basée sur des publications scientifiques et est revue par des spécialistes. FishBase contient aussi des outils de haute qualité pour la recherche appliquée sur les poissons, tels qu'un générateur pathologique, des outils de biogéographie, des chaînes trophiques et un outil invahissant des espèces.

Fish diversity and fish production

The importance of biodiversity, which incorporates the diversity of genes, species and ecosystems, has moved to the forefront of the debate on sustainable development of natural resources. Much of this was triggered by the Convention of Biological Diversity (http://www.biodiv.org/convention/articles.asp).

With regard to the use of aquatic biodiversity, FAO is taking the lead in developing protocols and monitoring the status of the world's fisheries and aquaculture. A case in point here is the development of the FAO code of conduct for responsible fisheries, including aquaculture. The awareness of the importance of biodiversity within the economical sector is growing as well and some companies have adopted a biodiversity policy in which they express their reluctance of being involved in the transfer of fishes to regions where they can compromise the indigenous ichthyofauna.

The link between the natural fish diversity on the one hand and fisheries and aquaculture on the other is a strong one, though not easy to describe in simple

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terms. Evidently, the diversity of fishes used in aquaculture originates from the diversity of fishes inhabiting natural water bodies (see below for the situation in Africa). Aquaculture is growing at a production rate of about 10% per year; yet prices of the products are generally decreasing (1). Next to enhancing the production, the sector is also looking to enhance the quality of the products offered. In such cases, the genetic diversity of natural populations can be used. This is demonstrated in a comparative study within the GIFT programme, in which the growth performance of various strains of *Oreochromis niloticus* was tested in a variety of farm environments and in which the wild strains, with one exception, performed as well as or better than the farmed strains (7, 14).

Conversely, the diversity of cultured fish strains increasingly influences the diversity of fishes in their natural habitats in various ways such as the accidental release of non-native species (causing e.g. predation or competition for food and spawning areas, etc....), habitat modification, pollution (nutrients, antibiotics), the spread of diseases, contamination of natural gene pools, etc... but also the use of wild fish as ingredients for fish food.

Fisheries evidently alter the natural fish communities and their habitats, with overfishing causing the disappearance of a number of taxa as one of its most extreme forms of impact. Worldwide analyses of marine fisheries have revealed a consistent pattern with increasing fisheries pressures that can best be described as 'fishing down food webs' (13). In terms of biodiversity, this means that high trophic level taxa such as predators are especially vulnerable and most likely to disappear with increasing fishing pressure.

The interactions between fisheries activities and ichthyodiversity are difficult to document in tropical freshwater regions such as the large African lakes where a large part of fish production relies on a complicated multispecies fisheries. A case in point is the southern part of Lake Malawi where changes in species composition have been observed in the demersal fish communities and some species may have become locally extinct. Phenomena of these kinds are difficult to quantify if detailed baseline data on catch composition are lacking. Sound taxonomic data are a logic, fundamental requirement; however in reality they are often lacking.

Clearly, there is an area of tension between fish production (fisheries and aquaculture) and biodiversity conservation. Certainly in the tropics, the conflict between fish production and conservation of ichthyodiversity is a difficult one to resolve. Assuming that both work towards the same goal in making sure that fish stocks do not disappear is too simple an assumption. It is clear that certainly in poor regions in the tropics, where millions of people rely on fishes for animal proteins, fish production is of a higher priority than biodiversity conservation. And therefore, reconciling both is not an easy task.

The idea that a larger production of aquaculture will reduce the world's dependence on wild stocks of fish or, in other words, decrease the impact of fisheries on the diversity of fishes is somewhat dubious. It appears that in Africa where, because of the rapid human population growth, the shortage of inexpensive proteins will remain no matter how big aquaculture would be booming, this 'bonus' effect of aquaculture would be minor. In addition, aquaculture itself is not harmless to the environment the wild stocks live in (see above), and on its own exerts a significant pressure on the natural ichthyodiversity by using fishmeal and fishoil to feed not only high-priced predatory aquaculture species such as salmon and shrimps, but also herbivorous and omnivorous species.

Interesting to note is that for one specialised sector of aquaculture, ichthyodiversity is of prime importance and that is the aquarium fish trade. The trade in live marine animals in 2003 is estimated at US$ 200-330 million annually. The global market of live ornamental fish (marine and freshwater) between 1994 and 1998 fluctuated between US$ 169-207 million per year (5). One could almost say the higher the ichthyodiversity the better for this section. However also here adverse effects have to be noted such as the destruction of reef habitats by heavily invasive collecting means such as dynamite and cyanide.

Fish diversity in Africa

Fishes are representing a large part of all living vertebrates. They constitute more than half of the approximately 48 170 recognized living vertebrate species (12). Currently some 28 600 fish species are included in FishBase. Eschmeyer (8) estimates the number of valid species between 30 000 and 35 000. More new species will be described in the future when poorly sampled geographic areas are studied. Indeed, from the East African lakes, for example, several hundreds of endemic cichlids are to be described. A major step in the early knowledge on the biodiversity of the African freshwater fishes was the publication of the famous catalogues of African fishes by Boulenger (2). This was the first attempt to review all living freshwater fishes of Africa. Boulenger reported 1 425 species. In the Check-List of Freshwater Fishes of Africa (4) the number of species listed for Africa is 2 908.

In FishBase, the largest database on fishes (see below), the Ethiopian zoological realm, including sub-Saharan Africa and south-Arabia, but not north Africa), is currently represented by some 3 100 species. A major part of the fish fauna is endemic to the region (Table 1).

Table 1
The number of fish species in the Ethiopian zoogeographic realm

Endemic	3012					
Native but, not endemic	Total	In common with				
		Palearctic	Oriental	Australian	Nearctic	Neotropical
	49	19	40	32	3	3
Introduced	37					
Questionable	2					

Only about 1,5% is also distributed elsewhere. Thirty seven non-native species are currently present in the Ethiopian region. These fishes have been introduced mainly for aquaculture, mosquito control and angling.

A breakdown of the number of species encountered in the freshwaters of the other zoological realms immediately demonstrates that fish species numbers are much larger in the tropical areas than in the more temperate regions (Table 2).

Table 2
The number of freshwater species in the different zoological realms.
The high number of questionable species in the Oriental region is probably due to a larger number of vague localities without much detail, that still need to be checked.
Most likely, the number will decrease to a level which is comparable to the other zoological realms

	Ethiopian	Palearctic	Oriental	Australian	Nearctic	Neotropical
Total	3100	1477	2924	676	1103	4456
Endemic	3012	1253	2594	508	977	4303
Native	48	145	227	119	76	82
Introduced	37	76	53	45	46	71
Questionable	2	3	50	4	0	0
Extirpated	0	1	0	0	5	0

Important to note is also that tens of species have been introduced in all major realms; in certain areas this number amounts to more than one out of twenty species present.

Fish biodiversity studies in the Africa Museum

In many reports and statements, it is mentioned that documenting and characterizing biodiversity is a vital and basic step in order to assure its sustainable development and conservation. Never before in the human history the awareness of the importance to gain knowledge on this basic issue has been larger; yet the number of scientists working on this topic has never been so low (27) and there is a real fear that the expertise still available will get largely lost in the next generations. The role of Natural History Museums is critical in safeguarding this valuable knowledge and the necessary skills to expand it.

In the Royal Museum for Central Africa (Africa Museum), in Tervuren, there is a more than a century long tradition in biodiversity studies on African fresh- and brackish water fishes. The Museum curates by far the largest collections of African fresh- and brackish water fish species and also holds a unique specialised library focussed on the ichthyodiversity of Africa. Many taxonomic revisions of important fish groups have been made such as the tilapias (24, 25), the clariid catfishes (21, 22), the pelagic schilbeid catfishes (6), the species of the genus *Chrysichthys* (16, 17), the Mastacembelidae (26), and the endemic fishes of the large African Lakes region (15, 18, 19). The results of these systematic studies are included in the Check-List of Freshwater Fishes of Africa (CLOFFA). The four volumes of this checklist (4) represented a milestone in documenting the ichthyodiversity of the African fresh- and brackish waters and are used as the basis of various other initiatives such as FishBase (see below). The above mentioned revisions and checklists are just one form of results from the ichthyodiversity studies done at the Museum. Many other publications concern the (re)description of one or more problematic species or report on the morphology, anatomy, phylogeny and evolution of various taxa. Important are also the faunal guides such as the books on the West and the West-Central African freshwater fishes (11, 23), which resulted from the studies

and contributions of many international specialists on African fishes.

Currently five ichthyologists are working in the Africa Museum on various scientific research programmes and collaborate in a number of international projects. The units also receive many visitors and train Belgian and foreign students (the latter mainly from Africa) on a range of academic levels. All this knowledge does not stay in an ivory tower; on the contrary, an increasing effort is done to make the information and expertise widely available to a larger public. One of these efforts is FishBase.

FishBase, encyclopaedia and tool

The idea of a database on fishes was coined on several occasions in the past, but the concept of FishBase was developed and got shape from 1987 onwards mainly through the efforts of D. Pauly and R. Froese. Their initial idea was to create a database with the existing information on about 200 economically important fishes with the aim to include 2 500 species during its further growth. The development of FishBase was done at ICLARM (International Center for Living Aquatic Resources Management), currently the WorldFish Center. In 1990, the project was funded by the European Commission. Soon the decision was taken to include all finfish and in 1994 a first CD-ROM was produced. In 1996, the FishBase team received further special support by the European Union through the ACP Fisheries and Biodiversity Management Project. Indeed, the quickly expanding FishBase became an important tool in the transfer of information on fishes to the developing countries, including those in Africa.

The funding by the European Union continued until 1999. In order to assure the continuation of the programme, a FishBase Consortium was founded in 2000. It consisted of seven members, all more or less complementary in their specialisation: the WorldFish Center (Penang, Malaysia), the Food and Agriculture Organization of the United Nations (Rome, Italy), the Institut für Meereskunde an der Universität Kiel (Germany), the University of British Columbia – Fisheries Center (Vancouver, Canada), the Musée National d'Histoire Naturelle (Paris, France), the Naturhistoriska Riksmuseet (Stockholm, Sweden) and the Africa Museum (Tervuren, Belgium). An eighth member, the Aristotle University of Thessaloniki (Greece), joined the FishBase Consortium in 2004.

FishBase (www.fishbase.org) has now grown into a huge on-line encyclopaedia with information on 28 600 fish species and serves as an important tool for scientists. It contains a lot of information on taxonomy, biodiversity, ecology and life-history. Fish collections from more than 40 institutions can be consulted through FishBase. The main input of data is done by the FishBase team (WorldFish Center) in Los Baños, The Philippines. The Africa Museum started entering its fish collection data in 1997. Currently, within the FishBase Consortium, it is responsible for all data on African fresh- and brackish water fishes. The contribution of the Africa Museum is made possible through a framework agreement between the Africa Museum and the Belgian Development Cooperation. Indeed, the development of FishBase activities within the Museum, including the provision of high quality data on African fishes directly to the scientists and decision makers in Africa and the organisation of special training programmes, is a major instrument to directly assist in a better sustainable management of fisheries and aquaculture.

In the Museum, data input is done by RDE (Remote Data Entry), a system which enables the FishBase collaborators to make direct modifications via the Internet. New species are added and the information already available is checked. This is a slow and meticulous process that will take many years. The information entered is taken from scientific publications and is reviewed by scientists. This makes FishBase a high quality tool for scientists as well as a wider audience. FishBase also sets up species-level links to other databases such as Eschmeyer's Catalog of Fishes, the IUCN's Red List Data, LarvalBase, Genbank and various FAO databases on fisheries and aquaculture. Since the information in these is already on the internet, duplication of data is avoided. Some valuable tools, like identification keys, field guides, trophic pyramids and biodiversity maps, are built upon all this information (see below).

A FishBase CD-ROM (set) was produced every year between 1996 and 2000. The latest version (2004) comprises 5 CD's or one DVD. However, since 1998 FishBase is also freely accessible on the internet at www.fishbase.org. The internet version has the advantages of being accessible for everyone and is updated monthly. In addition, an interaction between the FishBase user and the team is possible. The use of FishBase increased rapidly, starting with some 10 000 hits in August 1998 and evolving to more than 12 million hits per month from about half a million users in May 2004 (Figure 1).

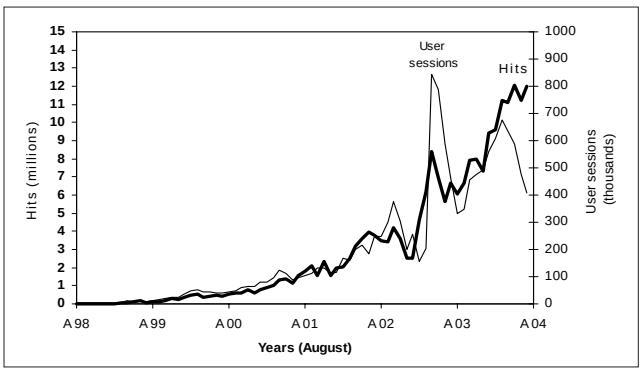

Figure 1: FishBase usage over time. Number of hits per month and user sessions per month in the period from 1 August 1998 to 1 August 2004.

Many of the users visit FishBase more than once per month. FishBase proved to be a successful project for scientists who are using FishBase intensively as a source for information on the biology of fishes (9). But still individuals are the main group of FishBase users, mostly using common names for searching information. Therefore, more than 204 600 common names are included, currently representing 386 languages in 17 scripts. The entire FishBase database is available in 13 different languages and 4 scripts.

Aquacultural fish diversity in Africa

Aquaculture currently accounts for more than 30% of the recorded fish production (20). However, doubt has been expressed about the reliability of the very high production figures reported from China (Froese, pers. comm.). About 210 finfish are currently farmed, but the majority of the production comes from a few carp, salmonid and tilapia species.

When it comes to genetic improvement and even levels of domestication, the aquaculture is far behind compared to the terrestrial agricultural sector, certainly in the tropical regions, and not in the least in Africa. Moreover, aquaculture has never been a great success in Africa compared to e.g. Asia, where more than fifteen times as much African tilapia is produced than in Africa itself. Though constantly growing, the contribution of Africa to the total world aquaculture production is less than 1% (20). And even then the north African region, and especially Egypt, provides over 80% of the production. In sub-Saharan Africa, the aquaculture production is low and aquaculture statistics are often not very accurate because of the relatively low economic profile of the sector and the lack of financial resources.

In FishBase, the information by country/island provides a choice between an FAO aquaculture list and a general aquaculture list. The FAO aquaculture list is based on aquaculture production statistics published by the FAO, while the general list is based on information entered in FishBase. In the latter a separation is made between species already used in aquaculture and species with a potential use in aquaculture.

Eighteen freshwater fish species are used in commercial aquaculture in sub-Saharan Africa (Table 3).

Six of them are introduced from outside the Ethiopian region for aquaculture. The most popular species used in aquaculture in Africa are *Oreochromis niloticus*, *Cyprinus carpio*, *Clarias gariepinus* and *Heterotis niloticus*. In addition, many other species, some of which, such as the clariid catfish *Heterobranchus longifilis*, are very promising (10). Hence, the number of African fish species used in commercial aquaculture will certainly rise in the future.

Oreochromis niloticus, which is often considered as the tropical aquatic equivalent of the chicken, is currently found in many areas in Africa outside its natural distribution. For instance, it has been found in coastal basins in Cameroon and the Republic of Congo, the Lower Congo River system and Lake Kariba (Brummett, pers. comm.; Mamonekene, pers. comm.; Snoeks,

Table 3
Species used in commercial aquaculture in African countries (* is for introduced species)

Species	Commercial aquaculture in:
1. *Carassius auratus auratus*	South Africa*
2. *Carassius carassius*	Ethiopia*
3. *Chrysichthys nigrodigitatus*	Ivory Coast / Nigeria
4. *Clarias anguillaris*	Burkina Faso
5. *Clarias gariepinus*	Cameroon / Central African Republic / Gabon* / Ghana / Guinea / Kenya / Lesotho / Malawi / Mali / Nigeria / Rwanda / South Africa / Swaziland / Tanzania / Zambia
6. *Cyprinus carpio carpio*	Cameroon* / Kenya* / Lesotho* / Madagascar* / Malawi* / Mozambique* / Nigeria* / Rwanda* / South Africa* / Swaziland* / Uganda* / Zambia*
7. *Esox lucius*	Uganda*
8. *Heterotis niloticus*	Central African Republic* / Congo Democratic Republic* / Republic of Congo* / Ivory Coast / Gabon* / Gambia / Madagascar* / Mali / Nigeria
9. *Lates niloticus*	Nigeria
10. *Oncorhynchus mykiss*	Kenya* / Lesotho* / Madagascar* / Réunion* / South Africa* / Zimbabwe*
11. *Oreochromis andersonii*	Zambia
12. *Oreochromis aureus*	Ivory Coast *
13. *Oreochromis macrochir*	Zambia
14. *Oreochromis mossambicus*	Malawi / Mozambique / South Africa / Swaziland / Zimbabwe
15. *Oreochromis niloticus niloticus*	Burkina Faso / Burundi* / Cameroon / Central African Republic* / Republic of Congo* / Gabon* / Ghana / Kenya* / Liberia / Mali / Niger / Rwanda* / Senegal / Sierra Leone / South Africa* / Sudan* / Tanzania* / Togo / Uganda / Zambia*
16. *Salmo trutta trutta*	Kenya*
17. *Tilapia rendalli*	Malawi / Tanzania / Zambia
18. *Tilapia zillii*	Uganda

pers. obs.). Obviously, it is competing in these areas with native taxa as it did in the Lake Victoria region where it was also introduced. Together with *Lates niloticus*, which was introduced for fisheries, it played a major role in outcompeting local tilapias (28).

Within this context, it is a pity that apparently, several well-meaning organisations lack the expertise and background knowledge to take into account the directives of the Convention on Biological Diversity or the FAO Code of Conduct for responsible fisheries (http://www.fao.org/DOCREP/005/v9878e/v9878e00.htm) when promoting this species for local aquaculture. A cautious approach is also advocated by the Nairobi Declaration (http://www.cta.int/pubs/nairobi/declaration.pdf), which resulted from a meeting on the conservation of aquatic biodiversity and use of genetically improved and alien species for aquaculture in Africa, held in 2002, which involved 45 scientists and policy-makers. Introduction of alien species can only be envisaged after all other options are carefully explored. Outside Africa, the situation in Florida is a case in point, where various non-native species such as the blue tilapia (*Oreochromis aureus*) have caused the loss of native fish species and vegetation (3).

FishBase tools

The information discussed above was extracted from FishBase for the use of this publication. FishBase offers also several interesting tools to ichthyologists, fisheries scientists and aquaculturists. These can not all be discussed within this paper. One example is the part on fish diseases. A list with all possible diseases, as found in the literature, is available for 723 species, including most of the economic important species. For every disease the nature of infection is given, as well as the locality where it was manifested. More details are available for 1 217 diseases; they include the symptoms, the type of infestation, the part of the body affected, the change in behaviour observed and a list of fish species reported infected. If available, pictures of the disease are included on the pictures page for the species. With FishBase it is also possible to make a diagnosis by following a key.

For each species, key information on life-history traits, such as reproduction, spawning period, egg development, larvae information and length at first maturity is available. Population dynamics parameters (growth, length-weight relationship and length-length relationship) are presented in tables and graphs. The life-history tool gives an overview of the most important data (maximum length, natural mortality, age at first maturity, fecundity, resilience,...); estimates of missing data are derived from default values. It is even possible to recalculate these traits based on the user's own dataset. In addition, a length-frequency wizard is present that helps to apply three basic biological considerations in deciding an appropriate fishing strategy, namely maturity, growth potential and fecundity.

For a lot of ecosystems, a trophic pyramid can be generated. These Lindeman pyramids are constructed from FishBase data, more precisely from the diet composition, predators, food items and food consumption tables of each species distributed in the ecosystem. The 'ecopath parameters' tool gives a list with all the species of an ecosystem and an indication of which tables contain already data and which not.

Regularly, new tools are being developed in FishBase, such as a tool for species invasiveness (Casal & Froese, pers. comm.). It will analyse the introduction and establishment of a species and then generate a risk assessment. Essential for this risk assessment tool are the history of the introduction, the establishment and invasion, data on the environment and the conditions of the source and recipient ecosystems. This assessment will result in a list of species which may become established in the wild in decreasing order of probable success of establishment.

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Literature

1. Bartley D., 1997, 2.3. Biodiversity and Genetics. pp. 50-54. *In:* FAO, Review of the state of world aquaculture. FAO Fisheries Circular 886 (Rev.1). FAO, Rome. 163 p.

2. Boulenger G.A., 1909, 1911, 1915, 1916, Catalogue of the fresh-water fishes of Africa in the British Museum (Natural History). Volume **I-IV**. Printed by order of the Trustees, London. 373 + 529 + 526 + 377 p.

3. Courtenay W.R., Jr. & Robins C.R., 1973, Exotic aquatic organisms in Florida with emphasis on fishes: a review and recommendations. Transactions from the American Fisheries Society, **102,** 1, 1-12.

4. Daget J., Gosse J.P., Teugels G.G. & Thys van den Audenaerde D.F.E., 1984, 1986, 1991, Check-list of the freshwater fishes of Africa (CLOFFA). Volume **I-IV**. ORSTOM, Paris & MRAC, Tervuren. 410 + 520 +273 +740 p.

5. Dawes J., 2002, The ornamental aquatic industry in the new millennium. OFI Journal, 39, 4-11.

6. De Vos L., 1995, A systematic revision of the African Schilbeidae (Teleostei, Siluriformes). Annales du Musée Royal de l'Afrique Centrale, Tervuren, Sciences Zoologiques, 271, 1-450.

7. Eknath A.E., Tayamen M.M., Palada-de Vera M.S., Danting J.C., Reyes R.A., Dionision E.E., Capili J.B., Bolivar H.L., Abella T.A., Circa A.V., Bentsen H.B., Gjerde B., Gjedrem T. & Pullin R.S.V., 1993, Genetic improvement of farmed tilapias: the growth performance of eight strains of *Oreochromis niloticus* tested in different farm environments. Aquaculture, 111, 171-188.

8. Eschmeyer W.N., 1998, Catalog of fishes. Volumes **1-3**. California Academy of Sciences, Special Publication 1, San Francisco. 2905 p.

9. Froese R., 2001, Ten years of FishBase. EC Fisheries Cooperation Bulletin, **14,** 1-4, 13.

10. Legendre M. & Lévêque C., 1999, L'aquaculture. pp. 425-438. *In:* C. Lévêque & D. Paugy (editors), Les poissons des eaux continentales africaines. Diversité, écologie, utilisation par l'homme. IRD Éditions, Paris. 521 p.

11. Lévêque C., Paugy D. & Teugels G.G. (editors), 1990, 1992, Faune des poissons d'eaux douces et saumâtres de l'Afrique de l'ouest, Tome 1 & 2. Éditions de l'ORSTOM, Collection Faune tropicale, 28, 902 p.

12. Nelson J.S., 1994, Fishes of the world, 3rd edition. John Wiley & Sons, New York. 600 p.

13. Pauly D., Christensen V., Dalsgaard J., Froese R. & Torres F. Jr., 1998, Fishing down marine food webs. Science, 279, 860-863.

14. Penman D.J. & McAndrew B.J., 2000, Genetics for the management and improvement of cultured tilapias. pp. 227-266. *In:* M.C.M. Beveridge & B.J. McAndrew (editors), Tilapias: biology and exploitation. Kluwer Academic Publishers, Fish and Fisheries Series 25, Dordrecht. 505 p.

15. Poll M., 1953, Exploration hydrobiologique du lac Tanganika (1946-1947). Poissons non Cichlidae. Résultats scientifiques de l'exploration hydrobiologique du lac Tanganika, **3,** 5A, 1-25; 1956, Exploration hydrobiologique du lac Tanganika (1946-1947). Poissons Cichlidae. Résultats scientifiques de l'exploration hydrobiologique du lac Tanganika, **3**, 5B, 1-619.

16. Risch L., 1985, Description of two new species in the genus *Chrysichthys* Bleeker 1858 (Pisces, Bagridae). Revue de Zoologie africaine 99, 185-193.

17. Risch L., 1987, Description of four new bagrid catfishes from Africa (Siluriformes: Bagridae) Cybium, **11**, 1, 21-38.

18. Snoeks J., 1994, The haplochromine fishes (Teleostei, Cichlidae) of Lake Kivu, East Africa: a taxonomic revision with notes on their ecology. Annales du Musée Royal de l'Afrique Centrale, Tervuren, Sciences Zoologiques, 270, 1-221.

19. Snoeks J., 2004, The cichlid diversity of Lake Malawi/Nyasa: identification, distribution and taxonomy. Cichlid Press, El Paso, USA. 360 p.

20. Tacon A.J., 2003, Aquaculture Production Trends Analysis. pp. 5-29. *In:* FAO, Review of the state of world aquaculture. FAO Fisheries Circular, 886(Rev.2). FAO, Rome. 95 p.

21. Teugels G.G., 1986, A systematic revision of the African species of the genus *Clarias* (Pisces; Clariidae). Annales du Musée Royal de l'Afrique Centrale, Tervuren, Sciences Zoologiques, 247, 1-199.

22. Teugels G.G., Denayer B. & Legendre M.A., 1990, A systematic revision of the African catfish genus *Heterobranchus* Geoffroy-Saint-Hilaire, 1809 (Pisces: Clariidae). Zoological Journal of the Linnean Society, **98**, 3, 237-257.

23. Teugels G.G., Stiassny M. & Hopkins C. (editors), in prep., Faune des poissons d'eaux douces et saumâtres de la province ichthyologique de la basse Guinée. IRD Éditions, MNHN, MRAC.

24. Thys van den Audenaerde D.F.E., 1964, Révision systématique des espèces congolaises du genre *Tilapia* (Pisces, Cichlidae). Annales du Musée Royal de l'Afrique Centrale, Tervuren, Série in-8°, Sciences zoologiques, 124, 1-155.

25. Thys van den Audenaerde D.F.E., 1966, Les *Tilapia* (Pisces, Cichlidae) du sud-Cameroun et du Gabon. Étude systématique. Annales du Musée Royal de l'Afrique Centrale, Tervuren, Série in-8°, Sciences zoologiques, 153, 1-98.

26. Vreven E.J., in press, Mastacembelidae (Teleostei; Synbranchiformes) subfamily division and African generic division: an evaluation. Journal of Natural History.

27. Wheeler Q.D., 2003, Taxonomic triage and the poverty of phylogeny. Philosophical Transactions of the Royal Society of London, Series B – Biological Sciences, 359, 571-583.

28. Witte F., Goldschmidt T., Goudswaard P.C., Ligtvoet W., van Oijen M.J.P. & Wanink J.H., 1992, Species extinction and concomitant ecological changes in Lake Victoria. Netherlands Journal of Zoology, **42**, 2-3, 214-232.

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