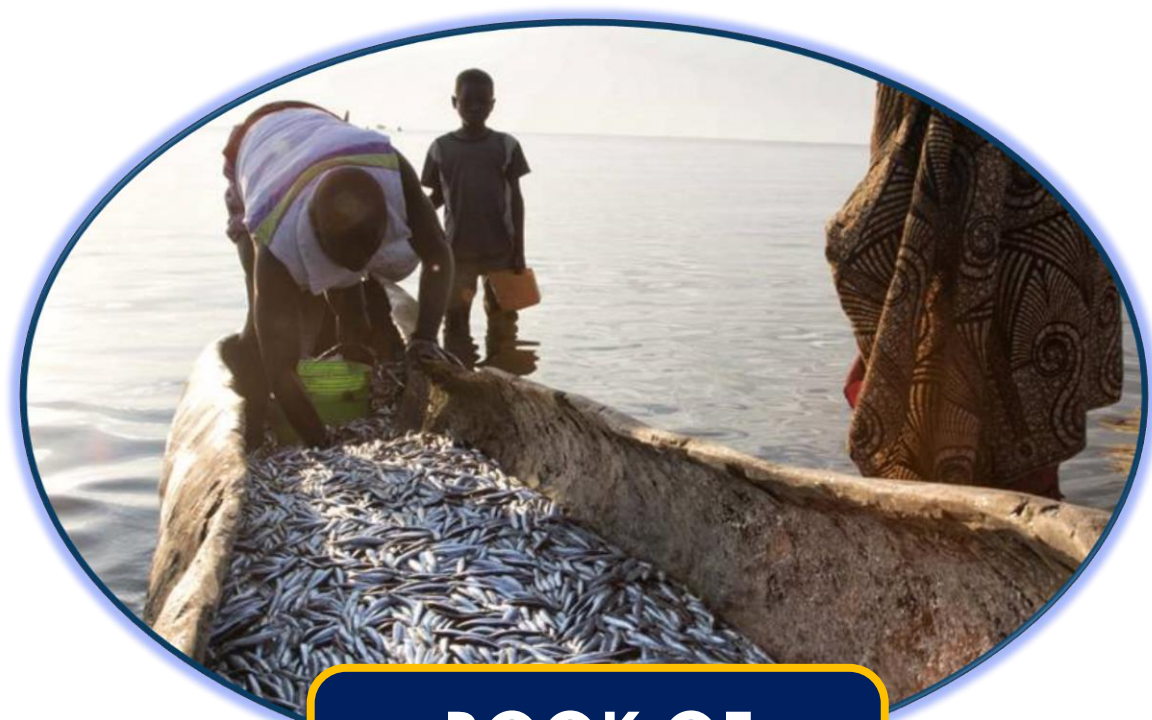


SIXTH INTERNATIONAL CONFERENCE OF THE PAN AFRICAN FISH AND FISHERIES ASSOCIATION (PAFFA6)



BOOK OF ABSTRACTS

Sun N Sand Holiday Resort in Mangochi, Malawi
24th to 28th September 2018.



About This Booklet

This publication includes abstracts for oral presentations and poster presentations at the Sixth International Conference of The Pan African Fish And Fisheries Association (PAFFA6) held at Sun 'n' Sand Holiday Resort in Mangochi, Malawi from 24-28 September, 2018.

Section One: Oral Presentations

Oral presentations are grouped by conference theme. Please refer to the Conference Programme for details about date, time slot and location for each thematic session.

Section Two: Poster Presentations

Poster presentations are grouped by conference theme. Please refer to the Conference Programme for details about date, time slot, and location for group poster sessions.

All presentations are subject to change after the printing of this publication.

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KEY NOTE PRESENTATIONS – PLENARY SESSIONS (NYANJA HALL)

Day 1, Monday, 24th September, 2018

Rapid Radiation of the Cichlids of Lake Malaŵi

Jay R. Stauffer, Jr. and Adrianus F. Konings

The cichlid fishes of Lake Malawi probably represent one of the best examples of rapid radiation of vertebrates. The species status and phylogenetic relationships of many of these fishes continue to remain unresolved. The taxonomic uncertainty of these fishes prompted authors studying these fishes to promote the use of a combination of morphological, genetic, and behavioral data (Stauffer et al. 1995; Stauffer and McKaye 2001) to diagnose the taxonomic status of these fishes. The importance of behavioral information has been undervalued in the assignment of autapomorphic and synapomorphic characters to the varying levels in the Linnean hierarchy of these fishes. Behavioral differences have suggested that various populations were, in fact, heterospecific. We identified different populations of sibling species by observed differences in color patterns, bower shape, or courtship behavior. Once these differences were observed, various authors were able to discover morphological and genetic differences to diagnose these species. Without the behavioral information, many of these species would have remained undiscovered. Secondly, differences in the shape of bowers and courtship dances not only identify different species, but also, provide important information needed to construct phylogenetic relationships. Finally, given the diversity of these Lake Malawi fishes, we conclude that detailed in situ and laboratory studies on the behavior of these organisms, are necessary to reveal the evolutionary processes and patterns of speciation among Lake Malawi haplochromine cichlids.

Day 2, Tuesday, 25th September, 2018

Understanding Adaptive Radiation and Explosive Diversification Through Cichlid Fish Genomics

Walter Salzburger

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Owing to their spectacular taxonomic, phenotypic, ecological and behavioral diversity and propensity for explosive speciation, the assemblages of cichlid fishes in the East African Great Lakes Victoria, Malawi and Tanganyika are prime role models in evolutionary biology. With the release of five reference cichlid genomes and many additional genomic resources as well as the establishment of functional genomic tools, the cichlid system has fully entered the genomic era. The in-depth genomic exploration of the East African cichlid fauna — in combination with the examination of their ecology, morphology and behavior and

information on the geological history of the Great Lakes — permits novel insights into the way how organisms diversify and how adaptive radiations progress.

Day 3, Wednesday, 26th September, 2018

The Evolution of Extreme Phenotypic Convergence across Fish Lineages in the Hyper-Diverse Lower Congo River -

M.L.J. Stiassny¹, R.J.C. Monsembula Iyaba², T. Liyandja^{1,2}, J. J. Mbimbi Mayi Munene², M. Yoko², E. Alter³.

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Recent estimates of species richness in the Congo basin vary but converge on a number close to 1270. However, that diversity is not evenly partitioned and the lower Congo River (LCR) is highlighted as a hotspot of species richness and endemism within the basin. In marked contrast to the river upstream of Pool Malebo, the LCR channel is entirely bedrock, and littoral habitats are mostly rocky and rock strewn. In situ measurements have recorded dramatic changes in channel topology and in addition to fluctuating bed bathymetry, regions of extreme depth have also been recorded. A combination of high annual discharge, steep elevational incline, and fluctuating channel width and depth result in high-energy flow regimes throughout the system. These hydrological features appear to play a key role in isolating fish populations by restricting both cross-channel and upstream-downstream movement, and likely present powerful drivers for micro-allopatric isolation often over remarkably small geographical scales. Among the many species endemic to the LCR are a group of distantly related fishes exhibiting a striking series of multi-trait morphological convergence (including microphthalmia or eye loss, depigmentation, laterosensory enhancement etc.). These "cryptophthalmic" forms have arisen independently in at least six phylogenetically disparate families (Cichlidae, Mastacembelidae, Mochokidae, Claroteidae, Clariidae, Mormyridae), likely in response to similar selective pressures within the extreme environments of the LCR. Here we present results of an ongoing investigation to characterize and quantify of this case of extreme eco-morphological convergence.

Day 4, Wednesday, 27th September, 2018

One Man's Meat Is another's Poison: Benefits, Impacts and Conflicts of Fisheries Based on Alien Species in South Africa

Olaf LF Weyl

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Southern Africa has a long history of introductions of aquatic plants, invertebrates and fish. Direct introductions, escapes from captivity, and unintentional spread have resulted in many introduced species becoming invasive. Impacts of invasions include the predation on and competition with native biota, habitat alterations, disease transfer and hybridization with

native species. While the control of nuisance species (e.g., water hyacinth *Eichhornia crassipes*) typically enjoys public and institutional support, attempts to control species that have negative environmental but positive economic impacts often results in conflicts between stakeholders e.g., conservation authorities, fisheries departments, anglers and/or aquaculture practitioners. In a region where inland fisheries and aquaculture are investment areas for addressing economic development, food security and poverty eradication, resolving such conflicts is crucial if invasions are to be managed effectively. Here I provide an overview of the current knowledge on invasion pathways, status and ecological impact of two southern African conflict species: rainbow trout *Onchorhynchus mykiss* and Nile tilapia *Oreochromis niloticus*. These are discussed in the context of social and economic benefits derived from these species, the strong opposition to management interventions intended to contain invasions, and the process that South Africa is engaged in to try to negotiate potential win-win solutions.

Consequences of Stocking Tilapia Species outside their Natural Ranges in Tanzania - Assessed by Genome Sequencing

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Global attention has focussed on the threat to long-term food security posed by the impacts of climate change and emerging diseases and pests on crops which often have limited genetic diversity. For this reason, major initiatives have been launched to preserve wild relatives and local domesticated strains of crops, including the creation of a multimillion dollar seed bank on the Arctic island of Svalbard. Similar issues are likely to threaten the tilapia aquaculture industry, now dominated by a few fast-growing strains of Nile Tilapia: for example the emergence of Tilapia Lake Virus (TiLV). East Africa, particularly Tanzania, is a global hotspot of the diversity of *Oreochromis* species, the most widely farmed tilapia. Most species can be hybridized, making wild genetic material potentially available for incorporation into farmed strains. However, recent studies have shown that hatchery-reared ‘farm’ strains have become established in almost all major catchments in Tanzania. This is partly through escape from fish farms, but more commonly by deliberate introductions in the belief that ‘restocking’ water bodies will add to their productivity (although there is no evidence for this in practice, as reductions in yield are most likely to be the result of the usual “growth overfishing”). These farm strains are generally not, as was believed, pure stocks of the fast-growing Nile Tilapia (*Oreochromis niloticus*), but also include red bellied tilapia (*Coptodon* spp.) and the small-maturing spotted tilapia (*Oreochromis leucostictus*), which often dominates in shallow eutrophic conditions. Here, we present the results of genome sequencing analysis which shows that the ‘farm’ *Oreochromis* species will both hybridize with a range of native species, sometimes resulting in genetic swamping and replacement of the natives. We also show that in open hatchery systems fed by natural streams, farm strains also incorporate genes from natives. This in-farm hybridization and the ‘contamination’ of farm strains with small-maturing species are likely to lead to the loss of traits desirable for aquaculture, such as fast growth and maturation at large sizes. At the same time, the stocking of farm strains in natural water bodies

threatens the existence of unique natural varieties that may contain precious genes that will be vital for the regional and global tilapia industry in the future. We also report on the development of methods (SNP chips) which have the potential to allow hatchery strains to be quickly and cheaply screened for genetic integrity.

Day 5, Friday, 24th September, 2018

African Fish Diversity in Fisheries and Conservation: A Happy Marriage or Conflicting Extremes?

Jos Snoeks

Fresh and brackish water fishes constitute about half of the fish diversity, distributed over only a small fraction of the planet's surface. The diversity of Africa's continental fishes is very rich (>3500) and highly endemic, with many hundreds of species still to be described. FishBase-for-Africa is the largest initiative to make published information publicly available to all scientists and interested stakeholders. Another important exercise is the more than a decade-long effort to assess the IUCN red list status of African fresh and brackish water fishes, and their threats. Currently more than a quarter of those fishes for which enough data are available, are considered to be threatened. In various African water bodies overfishing occurs, threatening, together with other anthropogenic pressures, not only the survival of this unique natural treasure but also the livelihoods of a large share of people that is dependent upon fishes as the main source of animal proteins. While fish diversity and people's livelihoods may be affected by the same threats, suggested remedies and management measures not necessarily serve both. Published fisheries statistics by country are not very informative as examples will show. In addition, they do not take into account most of the artisanal fisheries. Because of their important role in local economies of poor and middle-income households, fish have been described as a bank in the river (and lake). Yet, detailed catch statistics are lacking and, if existing, are only seldomly reported and analysed in international peer-reviewed publications, and even then they often lack sufficient taxonomic detail to allow a crucial insight into what is happening. Documented concepts from marine fisheries such as 'the tragedy of the commons', 'shifting baselines' and 'fishing down the food web' also apply to African continental waters and some cases will be discussed.

ORAL PRESENTATIONS

Theme 1: Fish Systematics Biodiversity Research and Data Management

Citizen Science Monitoring and Museums: Bridging Science-Policy Gaps in Fish Biodiversity

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Museum curators are increasingly using citizen science in order to improve the quality of information on biodiversity and as a tool to engage citizens in museums. At the Ichthyology Section of National Museums of Kenya, existing since 1997, participatory methods involving water resource users has provided mutually beneficial data and information sharing. Interactions with water users associations and beach management units to monitor changes in fish biodiversity, water levels and quality, new specimen acquisitions, sharing information on fish introductions and invasive species, and local extinctions. For tilapia species, this information is especially important due to expansion of aquaculture, which culminated in the mid 2000s, and saw the introductions of Nile Tilapia (*Oreochromis niloticus*) and hybrids with Sabaki Tilapia (*O. spilurus*) introduced in ponds in almost every hydrological system of Kenya. A citizen science platform TilapiaMap has upgraded ongoing efforts, allowing information input by citizens to enable monitoring of fish introductions from aquaculture ponds in the victim of rivers and lakes. This platform provides policy relevant information to enable local community associations, county fisheries officers and the Ministry of Fisheries of Kenya, monitor fish biodiversity changes and based on effects of aquaculture. TilapiaMap will also provide fishermen a platform to see how information they provide is useful for scientific work and to inform policy, thus bridging the science-policy gap.

Mouth Polymorphism in the *Labeobarbus* (Cypriniformes: Cyprinidae) of the Inkisi River Basin (Lower Congo, DRC, Africa): New Insights from an Integrative Approach.

Emmanuel J.W.M.N. Vreven^{1,2}, Tobias Musschoot¹, Eva Decru^{1,2}, Soleil Wamuini Lunkayilakio³, Kevin Obiero⁴, Alexander Cerwenka⁵ and Ulrich K. Schliewen⁵

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Labeobarbus are large (up to ± 1 m), hexaploid cyprinids. The genus is known from Africa, the Arabian Peninsula and the Tigris-Euphrates region and with a total of ± 127 valid African species is one of the most speciose genera of African freshwater fishes. Recently, the genus *Varicorhinus* was formally synonymised with *Labeobarbus*. As a result, the latter genus now retains enormous inter- and apparently intra-specific mouth phenotype variation and polymorphism. A morphological case study including 25 meristics and 31 measurements of 37 *Labeobarbus* specimens from the Inkisi basin, a right bank affluent and the largest of the Lower Congo affluents, is presented. The basin houses a group of highly similar specimens, with high

numbers of lateral line scales and a flexible last unbranched dorsal fin ray, but composed of (i) specimens with *Labeobarbus*-like (L: rubberlip), i.e. with well-developed fleshy lips and a mental lobe; (ii) specimens with a *Varicorhinus*-like (V: chiselmouth), i.e. with a horny cutting edge on the lower jaw; and (iii) specimens with intermediate-mouth phenotypes (I). Rubberlip (L) and chiselmouth (V) specimens differ significantly from each other in some meristics and morphometrics and all three phenotypes form a strongly supported monophylum based on mitochondrial (COI) and nuclear (AFLP) DNA phylogenetic inferences. Tree-based analyses designed to differentiate between polymorphism, incipient speciation, and hybridisation scenarios, in combination with multivariate PCA of AFLP multilocus genotypes, revealed substantial, non-random genomic variation, which strongly covaried with the three major mouth-phenotype groups. Analyses favour a scenario of secondary hybridisation between primarily distinct parental lineages. Consequently, the two distinct mouth phenotypes (L & V) are taxonomically identified as species taxa and the various morphological intermediates (I) are characterised as hybrid phenotypes. This study suggests that a new interpretation of the alpha-level taxonomy of the hexaploid Torini is necessary which is highlighted and discussed for its African representatives.

***Labeobarbus caudovittatus* (Boulenger, 1902) (Cypriniformes: Cyprinidae) from the Congo basin: A Re-Evaluation of Its Putative Intraspecific Variation**

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Labeobarbus caudovittatus has originally been described from the Ubangi River, a right bank affluent of the Middle Congo near Mobayi-Mbongo, formerly Banzyville. The species is considered to have a wide distribution throughout the Congo basin, covering the lower, middle and upper Congo. Five junior synonyms are currently known. *Labeobarbus pojeri* (Poll, 1944), a former junior synonym, has been revalidated by Kullander & Roberts (2012). Variation in mouth phenotypes is a well-known phenomenon in *Labeobarbus*. Such a variety in mouth phenotypes has also been observed among the examined *L. caudovittatus* specimens, i.e.: (i) specimens with a large mental lobe (L: *Labeobarbus*-mouth phenotype); (ii) specimens with a horny cutting edge on the lower jaw (V: *Varicorhinus*-mouth phenotype); and (iii) specimens with intermediate mouth-phenotype specimens (I). All these observations have incited a revision of this species. Sixteen counts, 31 measurements and 12 qualitative observations were taken on 128 specimens previously identified as *L. caudovittatus*, including the type specimens of the five junior synonyms: *L. stappersii* (Boulenger, 1917) (V); *L. euchilus* (Boulenger, 1919) (I); *L. miochilus* (Boulenger, 1919) (I); *L. lestradei* (David, 1936) (I); and *L. chilotes sakaniae* (Poll, 1938) (I). The two syntypes of *L. pojeri* (I) have also been studied to evaluate its separate specific status. This study revealed that: (i) although *L. stappersii* (Boulenger, 1917) is a valid species it requires a replacement name as the name is preoccupied by *L. stappersii* (Boulenger, 1915); (ii) *L. euchilus* needs to be revalidated with *L. chilotes sakaniae*, *L. miochilus* and *L. pojeri* as its junior synonyms; (iii) some specimens previously identified as *L. caudovittatus*, represent a new species for science that is characterized by the presence of a well-developed mental lobe and is endemic to the Ituri and Lowa Basins; and (iv) a redescription of *L. caudovittatus* is needed.

DNA Barcoding Using Topotype Specimens Sheds Light on the Diversity of Galaxiid Fishes (*Galaxiidae*, *Galaxias*) in Africa

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The Galaxiidae is comprised of generally small osmeriform fishes confined to cool temperate regions in the southern hemisphere. Africa is currently represented by a single galaxiid species, the Cape Galaxias *Galaxias zebratus*, which is considered to have a wide distribution range across multiple isolated river systems in the Cape Fold Ecoregion (CFE) at the southern tip of the continent. Recent studies have revealed that the current taxonomy severely underestimates the diversity of galaxiid fishes in Africa. We extensively collected DNA tissue samples and voucher specimens of *G. zebratus* across the species' entire distribution range in the CFE, including topotypes of three synonyms of this species, *G. capensis*, *G. dubius* and *G. punctifer*. We assessed the degree of genetic divergence among populations of *G. zebratus* based on the mitochondrial DNA cytochrome c oxidase subunit I (COI) gene and employed molecular species delimitation approaches to test the existence of cryptic and putative candidate species. The molecular species delimitation analyses suggest that the nominal taxon *G. zebratus* comprises a complex of at least 12 highly supported and geographically

structured candidate species. Support was found to elevate *G. dubius*, *G. capensis* and *G. punctifer* to species status. Morphological examinations are underway to determine the taxonomic integrity of the other candidate species identified within the *G. zebratus* complex. Our results indicate that the south-western CFE represents a previously neglected centre of endemism for stream fishes in the broader CFE.

The Fishes of the Lefini River Basin (Congo Basin: Republic of Congo): What after the Construction of the Imboulou Hydroelectric Dam?

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The Lefini River basin drains both the Lefini Faunal Reserve and the Lesio-Louna Gorilla Natural Reserve. It belongs to both, the Oubangui and Sangha freshwater ecoregions (sensu Thieme et al., 2005), which given the low level of threats were identified as a relatively intact and a relatively stable ecoregion respectively. However, in 2009, the Imboulou hydroelectric dam, constructed on the Léfini about 15km upstream of its confluence with the main Congo River, became operational. Fortunately, a fish diversity and an ecological study on the basin were performed before (2005-2008). Recently (2014-2017), a comparative study has been conducted in order to assess the impacts of the dam. The present fish overview results from the latter study. For that, a total of 125 stations mainly situated within the two reserves were sampled. A variety of collecting methods was used to sample as much of the available habitat diversity as possible. In addition, 12 stations, spread over a stretch of ± 103 km along the main river, were also sampled in a standardized way for an ecological study, using monofilament gill nets. A total of 140 species belonging to 77 genera and 27 families are reported. The three most speciose families are the Mormyridae, Alestidae and Distichodontidae with respectively 23, 20 and 18 species. Three endemic species were found: *Aphyosemion lefiniense*, *Congolapia louna*, and *Steatocranus* sp. “lefiniensis”. One introduced species, *Heterotis niloticus*, is reported. As a result of the dam construction, the water level of the Léfini raised over a distance up to ± 60 km upstream of the artificial lake, inducing changes in its fish communities. In addition, the Massala-ma-soso rapids, situated about 3km downstream of the dam and the only locality in the basin where *Parananochromis* sp. “lefini” and *Steatocranus* sp. “lefiniensis” were found, have been flooded. Therefore, both species have not been resampled since.

Using Baited Remote Underwater Videos (Bruvs) to Assess Diversity and Abundance of Fishes In The Lake Niassa Reserve, Lake Niassa, Mozambique

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Lake Niassa (Malawi) contains the greatest ichthyofauna diversity on the planet (>1000 species) and as such, the conservation and sustainable use of fishes becomes imperative. Lake Niassa Reserve (LNR), located on the eastern shores of Lake Malawi (Niassa) was declared a national reserve in 2011 by the Mozambican government and subsequently provides an exciting opportunity to evaluate the benefits and limitations of a freshwater protected area. In collaboration with the WWF and Instituto Nacional de Investigação Pesqueira (IIP), members of SAIAB assisted in the deployment of baited remote underwater video (BRUVs) at 400 sites in 2016 and 556 in 2017 to provide baseline information on the abundance of commercially important fish species and the biodiversity status within LNR.. These sites ranged from 0 to 70m in depth and with varying levels of fishing intensity and substrates. Consequently, the results presented are discussed with specific reference to: 1) year on year comparisons, 2) diversity and relative abundance of fishes in shallow (<20m) habitats within and outside of protected areas; 3) diversity and relative abundance of fishes in relation to fishing intensity, depth (up to 80m) and habitat complexity, and 4) the continued utility of BRUVs as monitoring tools in one of the most ichthyologically diverse ecosystems on the planet.

Assessing the Fish Biodiversity of Gabon's Komo River

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In 2017, our international team extensively surveyed the fish biodiversity of Gabon's Komo River and adjacent Mbei River above and below the site of a proposed hydroelectric dam at Ngoulmendjim. We sampled main channel and small tributary habitats with gillnets, seines,

castnets and a backpack electroshocker, amassing a collection of 3500 samples comprising about 90 nominal species. These include several regional endemics and potential new species, particularly within Cyprinodontiformes and among the diminutive characiform, cypriniform and siluriform species inhabiting the smallest tributaries. The IUCN lists four species present in the region as vulnerable or endangered. Several species previously known only from drainages further north or south also appear to occur in the Komo and Mbei, and numerous potadromous species achieve high biomass in the region, with large bodied cypriniforms in *Labeobarbus* and *Labeo* particularly numerous. We noted substantial marine influence in the ichthyofauna of the Komo River below the site of the proposed dam, including juveniles of commercially important species like the Giant African Threadfin (*Polydactylus quadrifilis*). Overall, these collections and their associated metadata will be critically important in informing plans for the development of this region, which must balance biodiversity conservation with the need to provide reliable electricity to the 700,000 people living in Gabon's capital of Libreville, which lies at the Komo's estuary.

Phylogenomics of Lake Malawi Cichlid Fish Relationships: The Evolution of Markers from Mitochondrial Genes to Targeted Enrichment to Whole Genomes.

C. Darrin Hulsey and Axel Meyer

The cichlids of Lake Malawi likely began diversifying as recently as 2 million years ago and currently could comprise up to 1000 species. Because of this rapid rate of speciation, reconstructing their evolutionary relationships continues to be a significant challenge. I will discuss the evolution of inferences based on single mitochondrial markers, targeted enrichment of hundreds of genes, and finally what we are learning from complete genome sequences. I will discuss several hypotheses that we have tested with the new phylogenies. Finally, the assumption of bifurcating tree-like relationships will be used to highlight problems with all of these data types when inferring the evolutionary history of an adaptive radiation like the Lake Malawi cichlid flock.

In Need of Correct Identifications for Species of Economic Importance: The Case of the Senegalese Tonguesole in the Eastern Central Atlantic

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Taxonomically, the Senegalese tonguesole, *Cynoglossus senegalensis*, contains three junior synonyms: *C. gorensis*, *C. guineensis* and *C. simulator*. Instead, *C. browni*, highly similar and originally described as a subspecies of *C. senegalensis*, is considered a valid species and distinguished from the latter by the lack of a lateral line on the blind side. Nevertheless, recent sightings of specimens of *C. senegalensis* from the coast of the DR Congo have revealed specimens with two different mouth morphologies: (i) a mouth angle not exceeding the level of the posterior border of the lower eye; and (ii) a mouth angle exceeding that level. Morphologically, 3 counts, the position of the mouth codified as a qualitative character, and 8 measurements were taken on a total of 110 examined specimens. In addition, a genetic analysis (mtDNA, COI) on some recently collected specimens is in progress. Multivariate analyses on the morphological data have confirmed the presence of two groups of specimens within *C. senegalensis*. The specimens with a mouth not exceeding the level of the posterior border of the lower eye also have a small interorbital distance compared to those with a mouth exceeding that level and a large interorbital distance. In terms of identification, the first group represents *C. senegalensis* whereas the second group, although containing the holotype of *C. browni*, is to be named *C. gorensis* following the priority of the last name. Indeed, the reported absence of a lateral line on the blind side in *C. browni* is erroneous. As such, it is clear that current fishery statistics are based on doubtful identifications, which most likely have also skewed their IUCN category assessment. The present case study thus highlights the crucial importance of correct identifications for fisheries and conservation assessments on which sustainable management plans for marine fish species of economic importance also rely.

Fish Base for Africa at the Royal Museum for Central Africa.

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Since its conception in 1987 by Rainer Froese and Daniel Pauly, FishBase has become the largest online encyclopedia on fishes in the world, currently with information on more than 33.900 species. After an initial period of financing by mainly the European Union, a FishBase Consortium was founded in 2000 to consolidate the further development of FishBase. Within this consortium, the Royal Museum for Central Africa (RMCA) in Tervuren, Belgium, is

responsible for the data on African fresh and brackish water fishes. This includes checking and updating the relevant information in FishBase based on historic and newly published literature. Since 2005, the RMCA organizes an annual training session for five African scientists, which includes theoretical and practical aspects of fish taxonomy and an in-depth introduction to FishBase and its scientific tools. A case study is carried out in order to practice the acquired knowledge. A follow-up program of one month offers the opportunity to complete the work started during the training or to refine the expertise gained. Under guidance of the RMCA team, three former FishBase trainees have also organized a training session in Africa. Species distribution forms an important part in FishBase, resulting in country lists, ecosystem lists and various types of distribution maps, including AquaMaps. In order to improve these efforts, the African continent and Madagascar were divided into some 240 different

ecosystems mainly based on rivers and lakes. Species are assigned to these ecosystems, what will eventually result in a better analysis of distribution patterns of fish in Africa. Some plans for the future include a local FishBase training session, development of an ecosystem model and fisheries management plan, and the publication of field guides.

Fish Diversity and Distribution in the Congo River Basin.

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The Congo River basin, with a surface area of about 3.4 million km², is the second largest river basin in the world, draining about 10% of the African continent. Its ichthyofauna is, however, still not well known, lacking even an updated checklist of the fishes reported from the basin. The last full list was published by Boulenger in 1901 and contained 319 species. For the purpose of this study, a list of the fishes of the Congo basin (excluding the Lake Tanganyika drainage with lakes Kivu and Tanganyika and associated rivers) was compiled and updated in FishBase. The distribution status (endemic, native, introduced, questionable, misidentification) of all freshwater species, excluding marine species and estuarine species of marine origin, was recorded. Initial compilation of the checklist started in the framework of the IUCN Pan African assessment and was continued based on distribution data and occurrence records from museum fish collections and a review of old and recent literature. In total, almost 950 described species are present, about 2/3 of which are endemic. Thirty-three families are represented, but more than half of the species belong to only four families (Cyprinidae, Cichlidae, Mormyridae and Alestidae, in decreasing order of importance). The distribution of the Congo basin fishes is studied by their presence in 29 newly defined subbasins, largely corresponding to the main rivers and lakes. Initial results of an analysis of species distribution throughout this immense basin are presented.

Genetic Characterization of Subclass Clarias (Clarias) Species of Burkina Faso Using Microsatellite Markers

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The subgenus *Clarias* (*Clarias*) Scopoli, 1777 (Clariidae) contains only two species, *Clarias gariepinus* (Burchell, 1822) and *C. anguillaris* (Linnaeus, 1758). These two species have a very strong resemblance to such an extent that the number of gill rakers on the first branchial arch in relation to standard length is the best criterion to discriminate them. However, an overlap was observed. Individuals identified as *C. anguillaris* have a smaller number of gill rakers, ranging from 13 to 39 for individuals whose standard length varies from 98 up to 610 mm. This number in *C. gariepinus* individuals is higher and varying between 28 and 120 with standard length from 109 up to 583 mm. The objective of the present study is to investigate for genetic criteria discriminating the two species using microsatellite markers on genomic DNA. Thus, 330 samples were collected from 11 sites across the country of which 275 identified as *C. anguillaris* and 55 as *C. gariepinus* during a previous morphological identification study (Compaoré *et al.*, 2015). On each sample, a piece of the caudal fin was removed and the total DNA extracted with the Promega® Kit. After the development tests, 7 of the 10 markers developed by Galbusera *et al.*, (1996) were selected (Cga01, Cga03, Cga05 Cga06, Cg07, Cga09, Cga10). Genotyping was performed on a Li-Cor 4300 sequencer. The analysis revealed the existence of a significant number of null alleles on all markers, but not a linkage imbalance in either species. The genetic differentiation calculated using Wright F-stats, particularly the Fst between population pairs shows a weak differentiation between the two species, which does not allow to discriminate them sufficiently. This result is confirmed by the genetic distances obtained by the rope distance method of Cavalli-Sforza and Edwards. Other studies using phylogeny tools are underway to discriminate them.

Fish Species Diversity in Floodplain Rivers of the Lower Reaches of the Blue Nile and Tekeze-Atbara Basins Along the Alitash National Park (ALNP), Northwestern Ethiopia

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Ethiopia is considered as the “water tower” of East Africa where major parts of the subcontinent

are arid. The inland water bodies of the country are estimated to encompass about 13,637 km² of lakes and 8,065km of rivers. These freshwater bodies harbour a large numbers of fish species,

but except for most lakes and some larger rivers, there is a lack of robust and trustworthy information concerning fish diversity. The present study was carried out to assess the ichthyofaunal diversity of the tributaries of the Blue Nile and Tekeze-Atbara basins in the ALNP to set appropriate management options. We used different fishing methods and identified 43 freshwater fish species allocated to 6 orders, 15 families and 26 genera from the Ayima, Gelegu

and Shinfa rivers that drain along the ALNP to Sudan. Some new species records for the basins were identified, mostly Mormyridae. The Cyprinidae are represented by the largest species number (10), followed by Mormyridae (6) and Alestidae (5). The Gelegu and Ayima Rivers in the Blue Nile system were found to be the richest in species (N= 38 and 35, respectively). Higher

numbers of specimens were also counted for the Gelegu River. The Shinfa River in the TekezeAtbara system has a relatively small number of species (N= 25), but, the different local and global measurements of diversity indicated a high species diversity for this temporary river. Based on the index of beta diversity, there is species turnover in the rivers. The ichthyofaunal diversity of these floodplain rivers is addressed, an annotated checklist for native species of the basins is presented, and voucher specimens are available in the Natural History Museum of Addis Ababa University equipped with relevant tags

Chiloglanis Sp. 'Upemba' A New Species of African Suckermouth Catfish (Siluriformes: Mochokidae) From the Upper Lualaba and Lukuga Basins

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With 61 valid species, the genus *Chiloglanis* is the second largest genus of African suckermouth catfishes, adapted to rapids and turbulent flows. Its greatest species diversity occurs in the

Congo basin sensu lato, harbouring 19 valid species, nine of which are endemic to the basin. Several *Chiloglanis* specimens were captured in the recent expeditions in Mwanza and Fungwe

rivers, both located in the Buffer Zone of the Upemba National Park (UNP) in the Upper Lualaba.

Some of these specimens could not be attributed to any of the currently known species in the Congo basin. In addition, studies of some unidentified *Chiloglanis* housed in the RMCA, originating from

the Lukuga basin, Lake Tanganyika's outflowing river, were found to be conspecific with those recently collected in the Upper Lualaba. However, these specimens were most similar to *C. swierstrai* from South Africa. Nine counts and 45 measurements were taken on 30 specimens from Mwanza and Fungwe rivers, 4 from the Lukuga river basin, and 20 specimens of *C. swierstrai*, following Skelton & White (1990). In addition, a genetic (mtDNA, COI) study is on its way. *Chiloglanis* sp. “upemba” could be separated from its Congo basin congeners by a long, single, row of widely spaced mandibular teeth, and could easily be distinguished from *C. swierstrai* by a low total number of vertebrae (34-36 vs. 37-40), a deep caudal peduncle (10.2–12.9 vs. 8.3–10.0 % SL) and a long postcleithral process (8.8–14.4 vs. 5.9–9.0 % SL). Currently, *Chiloglanis* sp. “upemba” is only known from the Mwanza and Fungwe rivers and the Lukuga River basin. It becomes the fifth valid *Chiloglanis* species to be formally identified from the UNP. To protect the new species, and other species in the UNP, the use of destructive fishing practices such as ichthyotoxin need to be controlled

A Systematic Study of the Pelagic *Haplochromis* Species from the Lake Edward-George System

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The present study intended to review the systematic status of the pelagic *Haplochromis* species

from the Lake Edward-George system. Detailed morphometric analyses were performed on 99 specimens identified as *Haplochromis pappenheimi* in the collections of the RMCA and the RBINS from the pelagic zone of Lake Edward. These specimens were collected recently, and in the 1950's. For each specimen, 21 point-to-point measurements and 11 meristics were taken, which were analyzed using principal component analysis (PCA). Our results indicated that the collections contained three distinct species that could be separated

based on morphological features. The first group (n=47) was composed of specimens with

relatively small eyes ($ED\%HL = 30.9 \pm 1.2$; range = 28.4 - 33.0), slender bodies ($BD\%SL = 25.8 \pm 1.1$; range = 23.4 - 27.6) and with longitudinal dark-grey bands on the upper and lower lateral lines. The second group ($n=22$) contained specimens with large eyes ($ED\%HL = 35.6 \pm 0.8$; range = 34.1-37.1), slender bodies ($BD\%SL = 26.4 \pm 1.0$; range = 24.1-28.1) and no bands. The third group ($n=30$) contained specimens with large eyes ($ED\%HL = 34.45 \pm 1.2$; range = 32.4 - 36.4), deep bodies ($BD\%SL = 30.8 \pm 1.1$, range = 28.9-32.9) and no bands. The first group was identified as *H. pappenheimi*, based on a comparison with the relevant literature. Groups two and three probably represent new species.

The Status of Wetlands of Ethiopia: Challenges and Prospects

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It has become increasingly evident that several wetlands in Ethiopia are facing imminent threats of degradation and total disappearance. The goal of this presentation is, therefore, to discuss the status of wetlands in Ethiopia, assess the challenges faced and suggest restoration options for degraded wetlands using practical approaches and recommendations. The study was based on self conducted works, which the authors had earlier amassed during their numerous field studies in limnology and fisheries. The operational definition used for 'wetlands' is the one adopted by the Ramsar Convention (1971), and includes (in the Ethiopian context) water bodies such as lakes and rivers, and other wetlands. The presentation highlights the major wetlands from the 12 drainage basins of the country and provides the major ecosystem services of wetlands – provisioning, supporting, regulatory and cultural. The wetlands are described in terms of their location and biophysical characteristics. Major causes for the degradation of wetlands in Ethiopia include, among others, water abstraction, catchment degradation, mining, overgrazing, pollution, overexploitation and unregulated settlement. Exotic plants introduced in wetlands, such as water hyacinth, have caused ecological havoc in some lakes and rivers. Besides anthropogenic impacts, climate change and natural hazards such as tectonism (seismic instability) also cause wetland degradation. Accordingly, some wetlands were prioritized and they are ranked from high to low degradation, with priorities set accordingly for their restoration. Finally, it discusses the type of restoration approaches in which a pragmatic approach is used to practically deal with the restoration of these wetlands.

State of the Ichthyological Diversity of the Cavally River, Subject to Strong Pressure of Gold Panning (Western Ivory Coast)

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The Cavally is a cross-border river shared by three countries: Guinea, Ivory Coast and Liberia. Although the river is strongly disturbed by intense gold panning activities in the Ity area in Ivory Coast, it contains a rich ichthyological community including some endemic species which are important for conservation. A hydrobiological study has been conducted since September

2014 to assess and characterize the basin and its biodiversity. The three sampling areas defined are: upstream of the exploitation zone, direct impact zone and downstream of the exploitation zone. A total of 66 species belonging to 35 genera, 18 families and 9 orders were observed. For 11 of these species, special attention must be paid according to the IUCN (2016) conservation system. The largest number of species (47) was encountered upstream of and the lowest (15) in the direct impact zone. This area of low diversity is characterized by a strong anthropogenic pressure, including the presence of gold panning units installed directly in the river bed. In addition, it is planned to deviate the river course at several parts in the area. This action can involve the destabilization of the River banks, the destruction of the riparian forest, the disturbance of the river system functioning, the modification of the substrate, a high concentration of suspended matter, hydrocarbons and a strong noise nuisance. This habitat deeply disturbed by mining is a danger to the endemic species with distribution restricted present in the zone and which are of interest for the conservation.

Characterization of Habitats and Haplochromine Diversity in the Upper Victoria Nile to Guide Conservation Amidst Hydropower Dam Developments

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Dams are constructed for various economic uses but conservation of biodiversity and ecosystem services also have to be considered. A study was undertaken in October and November 2016 in the Upper Victoria Nile (UVN), a hotspot for dam operation and development in Uganda, to examine the relationship between habitat diversity and haplochromine species occurrence and to infer changes likely to occur after the construction of a new dam. Fish were sampled in different habitats including those with macrophytes, rocky or sandy bottom and in reservoirs (lake like conditions) created by existing dams. Sixty-two species, and some previously unknown haplochromine taxa seemingly endemic to the area, were encountered. Change in species composition was observed from the habitats near Lake Victoria, which mainly contained inshore Lake Victoria species, to the middle section of the UVN, dominated by species mostly adapted to rocky rapids including the endemic *Haplochromis (Neochromis) simotes*, a species of conservation importance. The latter habitats, which are less disrupted, harbored the highest number of haplochromine species with no known counterparts in either Lake Victoria (upstream) or Lake Kyoga (downstream). The populations upstream from the dam construction site could be affected through loss of habitat when a standing water like environment is created, and increased predation by Nile perch (*Lates niloticus*) whose population is expected to increase under the new conditions. Because some species are of conservation importance while others are still undescribed and could disappear unnoticed, there is need for conservation of the habitats, especially those downstream the dam and those upstream, that will not be transformed into lake like conditions. These results justify the expansion of an existing conservation area designated for offsetting impacts of dams on biodiversity.

Fish Breeding and Nursery Areas on Lake Victoria: Mapping for Protection

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The expanse of Lake Victoria's shallow inshore (< 5 m deep) areas is characterized by a high concentration of fishing activities that threaten fish survival and disrupt vital feeding and breeding functions for many fish species. Between 2012 and 2016, a study was conducted to identify, characterize and map these areas on the lake so as to guide gazettement and subsequent protection of the critical habitats. Experimental gillnetting to determine fish species composition, distribution, relative abundance, and breeding state was conducted at selected sites in nearshore areas of bays and gulfs. Altogether, 22 fish taxa representing 11 families were collected from the catch with haplochromines and Nile perch dominating in terms of numbers (55.3%) and weight (37.3%) respectively. Out of the 89 sites that were experimentally fished lake-wide, 46 sites had a breeding score above average (11 points) and could be considered for protection as breeding and nursery grounds. Major river mouths obtained the highest breeding score (> 24) and species richness (> 10 species) and are highly recommended for gazettement and protection of breeding fish that migrate up rivers to spawn. Twenty five nearshore sites (mean gonad state ≥ 5) were identified as suitable for tilapia breeding, while ten sites ($\geq 70\%$ contribution of Nile perch < 15 cm TL) were recognized as possible nursery areas for Nile perch. The protection of fish breeding and nursery areas would also facilitate the recruitment, recovery and sustainability of commercially important stocks. A clear demarcation of the size and location of these habitats needs to be done to provide for appropriate management interventions.

Ichthyofauna and Ecological Stress in Lake Nokoue and Porto-Novo lagoon (Benin, West Africa)

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The study of fish species and their ecological stress in Lake Nokoue and Porto-Novo lagoon was carried out from July 2015 to June 2016. A total of 62 species from freshwater, marine and estuarine waters were inventoried throughout the two lagoons. The Porto-Novo lagoon contains 54 species belonging to 49 genera and 35 families and Lake Nokoué 44 species divided into 33 genera and 23 families. Cichlidae (6 species), Carangidae (5 species), Eleotridae (4 species) and Gobiidae (4 species) are the most diverse families. Waters of Lake Nokoue are characterized by higher values of Biological Oxygen Demand during five days (BOD-5 average 55 ± 47.7 mg/L) and Chemical Oxygen demand (COD, average 407 ± 182.6 mg/L) compared to those in the Porto-Novo lagoon (BOD-5: 22.7 ± 11.6 mg/L; COD: 95.5 ± 64.9 mg/L). In the Porto-Novo lagoon, the mercury level (1.7 ± 1 g/L) is beyond the norm accepted by the World Health Organization (0,5ug/L). Lead values are also abnormally high in both water bodies. The invasion of the two lagoons by the water hyacinth (*Pistia stratiotes*) during the flood and the widespread water pollution consequent increasing salinity in the decline are

important factors of stress for the resources of the two lagoons. The effects of the excessive multiplication of fish-parks (acadja), a traditional method of intensive fishing, on the ecology of the lagoon are also discussed.

A Conceptual Framework for the Integrated Management of Fish and Fisheries in Lake Tana, Ethiopia: DPSIR as a Tool to Support Decision and Policy Makers

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Lake Tana has a remarkable and conservation-worthy assemblage of fish species, which are of great value to the local fisheries. However, due to anthropogenic impacts, the fish species and attributes of the lake fisheries are threatened. Hence, management of these resources is important. A better understanding of the cause-effect relationships between human activities and environmental components is vital for optimum management of the resources. The Drivers-Pressure-State-Impact-Responses (DPSIR) framework is a useful tool to describe these links in a meaningful way to managers and policy makers. Despite its potential, application of DPSIR is virtually lacking in developing countries like Ethiopia. This paper assesses the potential of the DPSIR framework and uses it to comprehensively describe the available knowledge in the lake catchment. Rapid population growth and the economic transformation are the main driving forces of various pressures. Due to these pressures, degradation of the fish population, water quality, wetlands and forestland is intensifying, which is detrimental to the socio-economic state and health of the local inhabitants. Optimal multi-level responses (including family planning, policy revision and proper implementation, construction of wastewater treatment plants, restoration and subsidizing) are developed as feedback to the driving forces, pressures, state changes and impacts. This study aims at providing policy makers a better understanding of the lake catchment in order to bridge the gap between science and decision-making.

The Nature of Eco-Morphological Divergence in the Adaptive Radiation of Cichlid Fishes in Lake Tanganyika, East Africa

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The assemblage of cichlid fishes from East African Lake Tanganyika consists of about 200 described and approximately 50 un-described species and shows an extraordinary degree of morphological and ecological diversity. The endemic cichlid fauna of Lake Tanganyika thus provides a prime model system to study adaptive radiation in general and in a comparative context in particular as it harbors both extremely species-rich as well as species-poor lineages that have evolved alongside each other within the same lake. We undertake an integrative

study of the Lake Tanganyika cichlid assemblage, combining whole genome sequencing with 3D geometric morphometric of the lower pharyngeal jaw bone and stable isotope measurements (as a proxy for ecology) of all ~250 Tanganyika cichlids, making it the most comprehensive examination of a cichlid radiation so far. First results show how the different cichlid species densely filled up an incredibly diverse (trophic) “morpho-space”, whereas the extent of overlap and scattering seems to vary among phylogenetic lineages. As trophic morphology strongly correlates with the ecology of the species, a similar pattern can be observed in niche use. This extensive dataset offers the opportunity to investigate how morphological and ecological differentiation progressed during Lake Tanganyika's cichlid adaptive radiation and will ultimately allow us to disentangle the factors responsible for rapid organismal diversification.

Morphometric Characters and Meristic Counts of *Pateobatis Jenkinsii* (Annandale, 1909) and *Himantura Uarnak* (Gmelin, 1789) (Dasyatidae) from Mafia Island, Tanzania

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There is a controversy on the morphometric characters and meristic counts of *Pateobatis jenkinsii* (Annandale, 1909) and *Himantura uarnak* (Gmelin, 1789) in the marine coastal waters of Tanzania. The goal of this study is to provide taxonomic information which will help to solve the identification problems of these two most commonly caught rays in gill nets in Mafia Island, located in the southern circuit of Tanzania. The samples for the study were purchased from a small fleet at some identified landing sites based on seasons (northeast and southeast monsoons). Fifteen morphometric characters and meristic counts for *P. jenkinsii* are presented and compared to *H. uarnak*, and are analysed using principal component and discriminant analyses. The analysis of the external characters of *P. jenkinsii* shows the presence of a row of spear-shaped thorns from behind the head to the tail, a uniformly brownish colouration dorsally but whitish ventrally, a relatively broad mouth, and a triangular and relatively broad snout. In contrast *H. uarnak* has a diamond shaped disc with rounded outer corners and no thorns, a light brown disc with dark spots dorsally and a whitish disc ventrally, a tail with bands of black and white, and a relatively pointed snout tip. This study is expected to provide biodiversity information which will contribute to the management of rays in Mafia Island.

A systematic revision of the five-spotted *Hemichromis* complex (Perciformes: Cichlidae) from West Africa and Lower Guinea, with the description of a new species from Cameroon

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The group of large five-spotted *Hemichromis* species from the West Africa and Lower Guinea regions was revised using an integrative approach of morphometry (metrics, meristics and colour patterns) and genetics (822 base pairs of cytochrome b gene). Specimens, collected from 42 populations, were sorted into three main groups on the basis of morphological criteria. Based on the analysis of molecular sequences, all samples from West Africa clustered together, hence implying the synonymy of *H. frempongi* with *H. fasciatus*. The samples from Lower Guinea, including the type locality (Gabon) of *H. elongatus*, constituted a second cluster. Populations from the Atlantic coastal basins and the upper Chad basin in Cameroon formed a third clade, which corresponds to a new species, *Hemichromis* "camerounensis". The results obtained independently by both morphological and molecular analyses are congruent.

Do scales of the cichlid *Altolamprologus compressiceps* in Lake Tanganyika function as a morphological defence against scale-eating?

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Many species of cichlids in the shallow-shore areas of Lake Tanganyika suffer damage from attacks by the scale-eater *Perrissodus microlepis*. Many prey fish engage in warning behaviours in response to this predator. It has been hypothesised that, if prey fish have difficulty employing such behavioural tactics, morphological defences against scale-eating, such as hard scales, will evolve. The shrimp-eating cichlids, *Altolamprologus compressiceps* (Ac) and *Neolamprologus fasciatus* (Nf), exhibit hunting behaviours in which they remain motionless for up to 10 seconds while aiming at prey, during which time they are vulnerable to scale-eating predators; thus, these fish have likely evolved morphological defences against "scale-attacks". We tested this hypothesis in Ac and Nf, as well as three other predatory fish that are not motionless for such a long period of time. Under natural conditions, Ac and Nf were rarely attacked, while the other three species were attacked frequently. When freshly killed specimens of these five species (i.e. individuals that were unable to employ behavioural measures against scale-attacks) were displayed underwater in the presence of *P. microlepis*, Ac was rarely attacked, while Nf and the three other species were attacked frequently.

Among the five fish species, the force required to tear off scales was highest for Ac, and this force was negatively correlated with the frequency of attacks on the displayed fish. These results support the hypothesis that the hard scales of Ac function as an anti-scale-attack measure, although it remains unclear why free-swimming Nf were rarely attacked while aiming at prey, despite the fact that the force required to tear off its scales was not large.

Morphometric and meristic variations of four groups of Nile tilapia broodstocks

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The study evaluates phenotypic variations of Nile tilapia broodstock from Lake Victoria basin using morphometric and meristic characters. Fish samples were collected from Lake Victoria basin. The samples were frozen and then transported to the laboratory at Department of Animal, Aquaculture and Ranges Sciences, Sokoine University of Agriculture. Morphometric measurements were carried out using vernier calliper to the nearest millimetres. Morphometric analysis of the character measurements was carried out using Principal Component Analysis (PCA). Findings indicated that Nile tilapia from Lake Victoria, and those from fish farmers from Mwanza and Mindu dam in Morogoro appeared on both sides of PC1 and PC3, while tilapia believed to originate from Egypt appeared on both sides of PC1 only. However, there was no clear separation among the groups of Nile tilapia collected from Lake Victoria basin. The two groups Mindu and Egypt Nile tilapias were clearly separated indicating phenotypic differences. Factors that contributed to the separation of the two groups for PC1 were eye diameter, inter orbital width, head length and body depth. For PC3 the groups were separated by premaxillary pedicel length, head length, prepectoral distance and prepelvic distance. Egypt Nile tilapia had smaller eye diameter (26.05 ± 2.40), inter orbital width (36.88 ± 2.26), and body depth (36.24 ± 1.57) compared with Nile tilapia from Mindu dam. However, Egypt Nile tilapia had bigger head width (69.78 ± 3.14) compared to Nile tilapia from Mindu dam (61.73 ± 2.14 mm). Generally there was a slightly difference on meristic characters among the four groups. It is recommended that hatchery operators and fish farmers should be carefully on Nile tilapia broodstock collection and selection.

Phylogeography and Unrecognized Diversity of the *Enteromius Paludinosus* Species Complex Across Interior and Indian Ocean Drainages Of East Africa

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A study of phylogeography of populations of the straightfin barb, *Enteromius paludinosus* Peters, from interior and Indian Ocean drainage basins of Kenya and other parts of East Africa, has revealed an interesting pattern of genetic divergence, involving two cases in which populations on opposite eastern and western sides of southern Kenya and northern Tanzania form clades with low intra-clade divergences. The two clades themselves are highly divergent, suggesting long divergence times. One of these clades is sister to a large clade of closely-related populations from Kenya's major eastern rivers (Athi and northern Ewaso Nyiro) and a minor endorheic river in the Kenyan Rift Valley. Morphological differences between specimens from the divergent clades involved characters (a pigmented latera strips and basicaudal spot) that others have described as ecomorphic. We present molecular and morphological evidence that Kenyan and northern Tanzanian populations of *E. paludinosus* form at least four species, all of which are genetically distinct from populations of *E. paludinosus* from southern Africa. We based our taxonomic decision on morphological differences between Kenyan populations and syntypes of *E. paludinosus* Peters 1852 from Mozambique.

Fish Diversity, Assemblage along the Pendjari River and Impact of Human Activities

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The Pendjari River runs through 12 protected areas. But despite its strategic role in the conservation of fauna and flora, there is curiously almost no data on the fish fauna. Diversity, assemblage and exploitation of this fauna are studied. From February 2006 to June 2008, fish were caught monthly by artisanal fishing gears and small seine (0.5 cm mesh). Fish were identified and their assemblage was studied using a non-linear method (Self Organising Map). The indicator species were defined by IndVal method. **Disturbance** on fish communities was determined by ABC method.

A total of 131 species belonging to 56 genera and 27 families are collected and 29 species are reported for the first time in the Volta Basin. The maximum species richness predicted is 137 ± 2 . Thus, this sampling effort is evaluated to $97.4 \pm 1.8\%$. The Pendjari River constitutes a refuge of more than 7/9 endemic fish of the basin. Four relatively homogeneous fish communities with their indicator species were defined. The composition of fish fauna was progressive and related to continuous variations from upstream to downstream. The increase in species richness and diversity from upstream to downstream is regular but, at the downstream, the number is not sufficient due to the disturbance. Fish communities are less stressed in areas where fishing activities are seasonal and controlled. The stress level was high in areas where fishing activities are permanent and uncontrolled while it was relatively low in areas

contiguous to those areas where fishing activities are seasonal and controlled. All this testifies the positive effect of conservation and of human disturbance on fisheries resources of the Pendjari River.

Adoption of Novel Approaches to Preservation of Fish Genetic Resources in Africa: A case for Cryopreservation of Fish Sperm and Blastomeres

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Genetic degradation of cultured and wild stocks is a major challenge facing aquaculture and aquatic biodiversity conservation efforts worldwide. Addressing this challenge calls for innovative and practical solutions that will help ensure preservation of genetic resources for both their present and future conservation and utilization. In this regard, considerable advances have been made in the field of aquatic biotechnology. However, the adoption of such techniques in Africa, with a few notable exceptions, has been worryingly slow. There is, of course, no single reason for this but we reckon creating awareness as to what can be achieved with these techniques should help create interest and serve as a catalyst for their adoption. To this end, our presentation will demonstrate how two novel approaches to fish genetic resource preservation, cryopreservation of sperm and blastomeres, have been successfully utilized elsewhere in aquaculture production and conservation efforts. We hope this will make a case for, at the very least, their consideration in Africa.

Chromosome Composition of the African Weakly Electric Fish, *Gymnarchus Niloticus* Suggests the Presence Of Another Species in the Genus *Gymnarchus*.

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Metaphase Chromosomes of *Gymnarchus niloticus* collected from Oluwa River and from Lekki Lagoon in western Nigeria were studied with a view to understanding their chromosome composition. *G. niloticus* chromosomes were obtained *in vivo* from the cephalic kidney after injecting the fish intraperitoneally with 0.05% colchicine. Slide preparation followed the conventional Giemsa staining technique. The result revealed that the chromosome composition

of *Gymnarchus* species from the two locations were significantly different in terms of their numbers and characteristics. Specimens from Oluwa River had a chromosome number of $2n = 54$ characterized by both uni-armed and bi-armed chromosomes. Comparatively, *G. niloticus*, specimens from Lekki Lagoon had chromosome number of $2n = 34$ composed only of bi-armed

chromosomes suggesting that the species from the two sampled locations belong to different evolutionary lineages and are probably two separate morphospecies.

Dietary Comparison of Two Haplochromine Species Living Sympatrically in Both the Littoral and Pelagic Zones of Lake Kivu, Rwanda

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Populations of Haplochromine fish species have been declining over years yet these are among the endemic and most important fish species in Rwanda. A diet and niche partitioning among two sympatric species of Haplochromine fish species, *Haplochromis kamiranzovu* and *H. insidiae*, was conducted in Lake Kivu, to unveil their feeding co-existence and their habitat partitioning within populations of the same species. Adult specimens were collected in the littoral and pelagic zones during the dry seasons for free years. The diet was determined and five common dietary indices calculated including the dietary overlap. Tooth shape of the species was explored to help understanding their niche partitioning. Both species were found to feed mainly on Cyanophyceae in the littoral zone as an important prey. Diatoms were more prevalent in the diet in littoral than in pelagic zone as the secondary prey. Zooplankton was as secondary prey both littoral and pelagic zones. Diet overlapped significantly between the species. The overlap was greater at the habitat level. Tooth shape was found to be species-specific. Further research on the feeding ecology of both these Haplochromine species is needed to explain their coexistence, including vertical distribution, and the role of tooth shape in their niche partitioning.

A Comparison of Life History Traits of Mpsa (*Opsaridium Microlepis*) From Bua and Linthipe Rivers

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Management of *Opsaridium microlepis*, locally known as Mpsa during migration to breeding rivers takes a lot of approaches. Biological studies form important approaches to understanding the species for management. There has been data scarcity on the species' biology and its relationship to water quality in different breeding rivers of *O. microlepis*. This study is one attempt to sustain the fish during breeding through the study of species' life history traits. A comparison of life history aspects of mpasa between Bua and Linthipe Rivers was conducted from March, 2007 to February, 2008. A total of 301 male and female *O. microlepis* (82 from Bua and 219 from Linthipe) were sampled monthly using trawled gill nets. The fish ranged from 181-452 mm SL in Bua and 106-446 mm SL in Linthipe. Estimate of age was done using lapillus otoliths and validation of otolith annuli formation was done using the marginal zone analysis. The Principal Component Analysis (PCA) was used to compare the morphology

of 60 *O. microlepis* from two rivers. Stepwise multiple regression was used to predict the effect of water quality on biological parameters. To compare the biology of stocks from the two rivers, a two-way ANOVA was used by considering the effect of river site and month of sampling. The data collected in this study included: otolith dimensions, GSI, condition factor, egg diameter, relative fecundity, morphology, water temperature, dissolved oxygen, salinity, pH, conductivity, turbidity, alkalinity, total hardness, total suspended solids, total dissolved solids and chlorophyll *a*. Growth of fish from two rivers was described by simple linear regression model with the following parameters: *Fish total length (mm) = 197.41 + 27.22* Fish age; r²=67%, P = 0.000* for Bua and *Fish total length (mm) = 237.68 + 12.57* Fish age; r²=41%, P = 0.000* for Linthipe. The maximum age for *O. microlepis* was 10years and 12years for Bua and Linthipe stocks, respectively. Marginal zone analysis indicated that otolith annuli (opaque zones) was visible in the cross-sectioned otoliths were formed yearly in March and September for Bua and Linthipe, respectively. Growth was significantly different between two rivers. Egg diameter and condition factor were significantly ($P<0.05$) different between two sites due to differences in food availability, water levels and some water quality parameters. GSI and egg diameter were also significantly different among months. *O. microlepis*' breeding period extended from May to December implying plural stocks adapting to different optimum temperature for reproduction. There were some morphological differences between the stocks especially in structures related to swimming. Total suspended solids (TSS), total dissolved solids (TDS), Chlorophyll *a* (Chl *a*), turbidity and alkalinity influenced biological parameters. TSS was significantly higher (6.78 ± 0.14) in Linthipe than in Bua (4.64 ± 0.21), where most of its catchment is in the Game Reserve and large vegetation cover along the River reduces the amount of TSS during rainy season. Water quality affected some biological traits; as a result attention should be paid to factors of water quality so that catchment mismanagement should not lead to collapse of the stocks in any of the river system.

Diversity, Abundance and Distribution of Snails in Lake Malombe Kingsley Kamtambe

The diversity, abundance and distribution of snail populations in Lake Malombe was assessed. Using an Ekman grab sampler and a 25hp boat, 35 stations were sampled, each grab was replicated three times. Samples were immediately sieved using a standard 500 μ m, separating sand particles, debris and macro-invertebrates. The Macro-invertebrates were fixed in 10% formalin, preserved in 70% ethyl alcohol and transferred to a laboratory for taxonomic identification and quantification. GSP coordinates, temperature, water depth and anthropogenic activities of the surrounding areas were recorded. Results showed that Lake Malombe the Lake is dominated by *Melanoides spp* and *Bellamyia capillata*, 177m² and 35m², respectively. *Bulinus spp* and *Lanistes spp* were only found rarely in shallow near shore water. The lake's bethos is not highly diverse having a Shannon index of 0.64. Snail distribution was affected by water temperature and substrate type and water depth. *Bellamyia capillata* was common in sandy sediments in waters of less than 2.3m deep and abundant in waters above 24°C. The proportion of live versus dead snails increase water depth whereby and increase in depth resulted in less life snails. Benthic substrate varied with the socioeconomic activities of the surrounding area especially farming and fishing. The results show that snail population in

Lake Malombe is high although the diversity of the snails is low. Farming practices of riparian communities, fishing and the absence of snail eating fish species is positively influencing the snail population

Exploring the *Kneria Steindachner, 1866* (Gonorhynchiformes: Kneriidae) « Miringiri» Diversity of the Luanza and the Luongo Rivers (Bangweulu-Mweru Basin; DR Congo & Zambia)

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Kneria is an ostariophysan fish genus in which only males have an opercular organ. Thirteen valid species are currently known including five reported, of which two originally described, from the Bangweulu-Mweru ecoregion. Only *K. wittei*, described from the Lukuga River, and whose distribution extends up to the Bangweulu-Mweru ecoregion is reported from the Luanza River. *Kneria paucisquamata* was described from the Luongo. Its distribution covers the eastern side of the Bangweulu-Mweru ecoregion and encompasses the southern Lake Tanganyika tributaries. Recent collections in the Luanza and Luongo rivers revealed populations with colour patterns, body and mouth shape differing between up- and downstream populations of the Sanshifolo Falls for the Luanza and of the Mumbuluma Falls for the Luongo. A total of ten counts and 34 measurements were taken on 75 specimens from the Luanza, 27 from the Lukuga basin, including the *K. wittei* holotype, and 14 from the Luongo, including eight *K. paucisquamata* paratypes. In addition, a full mitogenome study was performed.

Results support previous inferences about morphological sexual dimorphism of the opercular organ in *Kneria*, but also of other morphological characters. In the Luanza, the up- vs downstream population differ respectively from *K. wittei* by its narrow mouth and its wide body. The first two differ from each other by colour pattern and some body shape measurements. In the Luongo, both the up- and downstream populations differ from *K. paucisquamata* by a higher number of lateral line scale and more slender bodies. The first two are separable based on anal fin rays counts and some body shape measurements

Mitogenome haplotype differentiation supports the species status of each of the two populations of the Luanza compared to *K. wittei* and those of Luongo, but specimens from the exact type locality of *K. paucisquamata* need further study.

A Revision of the Lake Tanganyika Cichlid *Tropheus* Complex from Lake Tanganyika: Current Species in Ancient (Paleo) Lakes.

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The endemic Lake Tanganyika cichlid genus *Tropheus* consists of highly stenotypic rock dwellers, whose limited capacity for dispersal gave rise to over a hundred, mostly allopatric, colour varieties. This made *Tropheus* an important model for evolutionary research. Yet, the genus' taxonomy is confusing and most species are ill-defined. Therefore, a revision was carried out. Groups were made based on clusters obtained from genome-wide AFLP scans from over 200 specimens. These were compared to morphological data taken from 1186 specimens from 155 locations, consisting of 23 measurements and 16 meristics. This data was analysed by means of principal component analysis (PCA). When analysing the morphological data of the radiation on a lake-wide scale, a large degree of overlap was seen between different groups as defined by the AFLP analysis. This suggested that morphological data was of little value to delineate species in *Tropheus*. However, when the bathymetry of the Lake was taken into account, this pattern changed. As Lake Tanganyika was, at some times, divided in at least three different paleolakes, they contain lineages of *Tropheus* that, for a long period of time, evolved in separation. Hence, these paleolakes can still be seen as the baseline to explain the complex distributions of colour varieties of *Tropheus* today. Analysis of measurements and meristics from specimens from the northern two thirds of the lake retrieved groupings that largely agreed with those obtained from AFLP scans. Yet, for groups from the southern third of the lake, this was far less the case. Here, a large amount of morphological overlap was seen between probable species, mostly following clinal patterns. As the southernmost part of the lake consists of a large and shallow area this was interpreted as being caused by multiple occasions of admixture between neighbouring lineages caused by fluctuations in water level.

The ichthyological diversity of the Ruzizi National Park (Burundi): a first synthesis

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Reestablished as a park in 1990, the Ruzizi National Park (RNP) edges the northern shore of Lake Tanganyika. It covers part of the lower Ruzizi basin and its delta on the Burundi-DR Congo border and is divided into a Palmeraie sector (± 8749 ha) in the north, a Delta sector (± 1363 ha) in the south, and a Corridor sector (± 443 ha) connecting both. Although located in an area of high anthropogenic pressure, to date, the RNP fauna has received only relatively limited attention from scientists and conservationists. The current species list is based on a literature compilation, the study of the historical collections present in different museums and the study of recently made new collections (2014-2017) for a total of 60 sampling stations covering the different types of aquatic habitats available in the park. Thirty two native species (62% of the 52 species actually present in the Ruzizi basin), have been identified: 19 for the Palmeraie sector; 25 for the Delta sector; and 13 for the Corridor sector. The Cyprinidae family with 12 species (38%) is the most diversified, followed by the family of the Cichlidae (5 species; 16%), Clariidae (4; 13%) and Alestidae (2; 6%). Unfortunately, both *Amphilius ruziziensis* Thompson & Page, 2015 (Amphiliidae) and *Chiloglanis ruziziensis* De Vos, 1993 (Mochokidae), respectively largely endemic and endemic to the Ruzizi, have not been found in the park. Instead, one native species, *Enteromius innocens* (Pfeffer, 1896) (Cyprinidae), and one introduced, *Poecilia reticulata* Peters, 1859 (Poeciliidae), are here reported for the first time for the park. In addition, unfortunately, the occurrence of two introduced cichlids, *Oreochromis leucostictus* (Trewavas, 1933) and *O. macrochir* (Boulenger, 1912) was also confirmed. Unregulated sand mining in the Corridor and harmful fishing practices in the Delta and Corridor sectors have been identified as the most pressing anthropogenic threats to its fish fauna.

Fish Diversity of The Lulua River (Kasaï Ecoregion)

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In order to provide an ichthyofaunal inventory the Lulua River, a tributary of Kasaï River in DR Congo, and in preparation for a checklist of the fishes of this river, sampling was carried out along the main channel and in many tributaries (from Luebo to Sandoa) between 2007 and

2014. An analysis of all collected data allows for the characterization, for the first time, of the river's ichthyofaunal diversity and the distribution of that diversity within the basin, as well as the anthropic activities likely negatively impacting the basin and its fauna. Our results reveal that the Lulua catchment harbors a high number of fish species in

comparison to some other Congo River tributaries (Wamuini et al. 2010; Mbimbi and Stiassny 2011; Raoul J C Monsembula Iyaba and Stiassny 2013; R.J.C. Monsembula Iyaba, Liyandja, and Stiassny 2013). A total of 222 species distributed in 80 genera, 26 families, and 11 orders is reported from the Lulua. Only the Itimbiri and Aruwimi Rivers, in the Kisangani region, have been reported to harbor a higher species number than the one reported in the present study (Decru et al. 2017). The species richness reported in this study represent a substantial improvement of the documentation of the Lulua ichthyofauna historically estimated at 59 species. Thus, 163 species are recorded for the first time in this basin. Among these species, two: *Epiplatys attractus* Van Der Zee, Mbimbi & Sonnenberg 2013, and *Hypsochanx stiassnyae* Van Der Zee, Sonnenberg & Mbimbi Mbimbi 2015 have been described as new to science. Furthermore, five other undescribed species have been identified,

including *Synodontis* sp., *Tetracamphilus* sp. "Lulua", *Epiplatys* sp. "pale" Van Der Zee, Mbimbi & Sonnenberg (in prep), *Lacustriola* sp., and *Micropanchax* sp. Their descriptions are currently underway. In addition to those undescribed species, some taxa such as *Chelaethiops luluae*, *Haplochromis luluae*, *Labeo* cf. *lukulae* "Lulua", *Labeo* cf. *parvus* "sandoa", and *Thoracochromis stigmatogenys* require further taxonomic attention. The highly diversified ichthyofauna of Lulua is mainly threatened by exploitation of forest products for building materials, deforestation for shifting agriculture, charcoal exploitation, inappropriate fishing techniques, and diamond mining that keep increasing in the watershed. Therefore, the present results represent a baseline documentation that can be used in conservation and future developmental projects in the Kasai ecoregion in general and Lulua River in particular.

On the discovery of a new *Synodontis* species (Siluriformes: Mochokidae) for the Middle Lufira (Congo basin: DRC) and its relevance for local subsistence fisheries

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The genus *Synodontis*, commonly called squeakers, is the most diverse genus of Mochokidae with 131 valid species. Specimens of *Synodontis* have recently been collected in the Middle Lufira, a right-bank tributary of the Upper Lualaba, and its associated lakes. These specimens show a close morphological resemblance to *S. greshoffi*, which in the Upper Lualaba is only known from the Kamalondo Depression, and to *S. unicolor*, a species endemic to Luapula-Moero. Ten counts and 30 measurements were taken on 139 specimens including the holotype of *S. greshoffi*, the lectotype of *S. unicolor* and 33 specimens of the Middle Lufira. In addition, a genetic analysis of the mitochondrial gene COI has been executed. The morphological and meristic results demonstrated that *Synodontis* sp. "lufira" belongs to a new

species. It differs from *S. greshoffi* and *S. unicolor* by: a non-villous skin (vs. villous skin), short maxillary and mandibular barbels (vs long), numerous and strong serrations on the posterior side of dorsal fin (vs few and weak), and its low maximum size (89.1 mm SL vs 185.0 and 190.7 mm SL). In addition, this species differs from *S. greshoffi* by its weak serrations on the anterior edge of the pectoral spine (vs strong) and from *S. unicolor* by its brown mottled and marbled livery on a yellowish-gray background (vs. uniform dark brown livery). The results of the genetic analysis confirm that *Synodontis* sp. "lufira" is a distinct species which is most closely related to *S. unicolor*. *Synodontis* sp. "lufira" seems to be endemic to the Middle Lufira and its associated lakes. The species is caught regularly and abundantly as bycatch; this through gillnet fisheries in lakes and with ichthyotoxic plants in the rivers. Due to its small size, the species has no commercial importance but forms an important food supply for the fishermen's families.

Genetic Diversity and Fisheries-Induced Evolution in the Lake Malawi Cichlid Adaptive Radiation

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The hundreds of cichlid fish species in Lake Malawi constitute the most extensive recent vertebrate adaptive radiation. We have characterized its genomic diversity by sequencing 134 individuals covering 73 species across all major lineages. Surprisingly, both genetic diversity within species and genetic divergence are low (0.08-0.25%). Phylogenetic analyses suggest that diversification initially proceeded by serial branching from a generalist *Astatotilapia*-like ancestor. However, no single species tree adequately represents all species relationships, with evidence for substantial gene flow at multiple times. Common signatures of selection on visual and oxygen transport genes shared by distantly related deep-water species point to both adaptive introgression and independent selection. These findings enhance our understanding of genomic processes underlying rapid species diversification, and provide a platform for future genetic analysis of the Malawi radiation. Besides their role as a model system for biological diversity and speciation, cichlids of the Lake Malawi radiation are the most important source of animal protein for millions of people and subject to intensive fisheries. This is particularly true for the utaka (mainly genus *Copadichromis*), a group of open water species that dominate the catch of small scale fisheries. Theory predicts that heavy fishing pressure induces selection for faster life histories and early maturation. To test this hypothesis, we are currently analysing whole genome and RNA sequencing data of two *Copadichromis* species from Lake Malawi and the heavily fished lake Malombe. I will discuss first results and future directions of this project.

Exploring the Unexpected Diversity of Haplochromines in the Lake Edward System

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Haplochromine cichlids are well known for their extraordinary diversity and their ability to form adaptive radiations. They radiated in many of the East African Great lakes, giving rise to the Lake Malawi species flock and the Lake Victoria superflock, which includes the haplochromines from lakes Albert, Edward, George, Kivu, and Victoria. Their rapid evolution, numerous ecological adaptations, and distinct colour patterns have intrigued aquarists and biologists alike. The HIPE-project investigates the human impacts on ecosystem health and resources of Lake Edward. Within the framework of this project, we perform a systematic revision of the largely-unexplored *Haplochromis* species assemblage of lakes Edward and George. Hitherto, only 30 of the estimated 100 species that inhabit these lakes have been formally described. As a first step in this revision, specimens are grouped based on morphological characteristics that suggest a similar ecology. For each group, a morphometric study is carried out by taking measurements and counts, which are analysed separately by principal component analyses. Additionally, qualitative characteristics are observed, species are delineated, and stomach content observations are performed to verify their ecology. Newly discovered species are formally described, while valid species are redescribed. Hitherto, 14 undescribed species were discovered and are being described. These include three species of oral snail shellers, which differ in tooth morphology and lower jaw shape; three species of paedophages, which differ in tooth number, lower jaw morphology, and caudal peduncle depth; and one insectivore with a very slender snout and lobate lips. In addition, we also discovered seven undescribed species of piscivores, which differ mainly from each other by their head and oral tooth morphologies, and their colour patterns. All species strongly resemble morphologically species from lakes Kivu and Victoria that have a similar ecology.

Hidden Diversity in the Small African Barbs

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Small African barbs are taxonomically very challenging. This is especially the case for the members of the genus *Enteromius*. This genus comprises currently 211 valid species, making it the world's second largest fish genus. Many species of *Enteromius* are morphologically very similar, and identification keys are lacking. No large-scale taxonomic revisions have been executed on *Enteromius* species in the last decades. Recently, a combination of DNA

barcoding and morphometrical analyses on some species of the Congo basin revealed an unexpected high number of possible cryptic species within the genus. Initially, the examined specimens were identified as 4 tentative species based on literature. The DNA barcodes however revealed the presence of 23 mitochondrial lineages, which, after intensive morphometric examination, also appeared to be morphologically different from each other. The majority of these lineages seemed to be endemic to particular rivers or river stretches. During an ongoing study on the ichthyofauna of the Lake Edward basin, five species have been delineated morphologically, though nomenclatorial uncertainties still exist. Within three of these, two lineages (COI) have been found. These examples illustrate that a revision of *Enteromius* is certainly needed. One particularly mesmerizing African barb is the Congo blind cave fish, *Caecobarbus geertsii*. It was the first African cave fish to be formally described, and is the only African freshwater species on the CITES list. It occurs in cave formations of the Lower Congo basin, where it was only known from several caves of the north-eastern zone, Mbanza-Ngungu. Recently, however, specimens have been discovered in two caves of the south-eastern zone, about 50km to the south. With a genetic distance of 1.4-2.1% (COI, mtDNA) with the populations of the north-eastern zone, and some clear morphological differences, these recently discovered populations may well constitute a distinct species.

Function and Evolution of Electric Communication Signals in Mormyrids

Carl D. Hopkins

Electric organ discharges (EODs) serve multiple functions in the behavior of electric fish from Africa. In communication, they signal the identity of the signaler: its species, sex, and in some cases individual identity. Signals also convey the signaler's willingness to attack or to flee, to court and to mate, to approach or withdraw. EODs are also used for electrolocation of objects, and for object discrimination: composition, texture, distance, and size. How do these competing demands on signal function influence signal form? In this lecture I discuss the structure of signals in relation to function including the following: what makes an EOD signal sexy or scary, easy or hard to locate, short range or long range? What makes it contrast with the noisy environment, or interference from nearby fish? How much does it cost to signal, and what are the advantages of an enlarged active space? These and other questions help us to understand the function and evolution of EODs, and their possible importance to systematics.

A “veritable Gordian Knot”: The Systematics of the Mormyriinae

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With 228 species placed in 21 genera, Mormyridae is currently the second most speciose family of freshwater fishes endemic to the continent of Africa (after Nothobranchiidae and just ahead of Mochokidae) and have long been of special interest due to their highly evolved active electrosensory system. The subfamily Mormyriinae contains the bulk of this family's morphological and species diversity (182 species in 20 genera). In this talk we review the state of our knowledge of mormyrid systematics and

phylogeny. While new mormyrid species continue to be discovered and published (17 so far in this decade with many more in the pipeline), the "veritable Gordian knot" of mormyrid generic names and concepts described by Myers in 1960 remains tightly tied to this day, a product in part of unresolved nomenclatural issues dating to the 19th Century and misinformed rulings of the ICZN. We review both published and unpublished nucleotide sequence datasets that collectively reveal two mormyrid superclades in particular need of taxonomic scrutiny: a group containing species described as *Marcusenius*, *Gnathonemus*, *Campylomormyrus*, *Cyphomyrus*, and *Hippopotamyrus* and a second informally called the "Lower Guinea clade" that includes a taxon described as *Marcusenius ntemensis* and genera *Paramormyrops*, *Ivindomyrus*, *Boulengeromyrus* and new genus *Cryptomyrus*. Progress in mormyrid systematics will spring from a new era of morphological study facilitated by CT scanning technology and next-gen phylogenomic methods. Species-level taxonomy will benefit from integrative approaches that include electric organ discharge data. A new website dedicated to mormyrid taxonomy is described.

Systematics And Biogeography of *Petrocephalus* (Mormyridae)

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Within the African weakly electric fish family Mormyridae, the genus *Petrocephalus* (subfamily Petrocephalinae) is the sister group of the rest of the genera (subfamily Mormyrinae). In terms of number of species, forms and functions, *Petrocephalus* are far less diversified than mormyrids. However, due to their phylogenetic position, their distinctive combination of ancestral and derived characters, their widespread distribution in Afrotropical freshwaters where they often, locally, represent the largest biomass of weakly electric fish, the study of *Petrocephalus* is central to understand the early evolution of African weakly electric fish. In this talk, we will first shortly review what it is known on the taxonomy and systematics of *Petrocephalus*. Then, we will present new results on the historical biogeography of *Petrocephalus* using a large multi-gene time-calibrated phylogenetic tree onto which the evolution of the ancestral geographical ranges is inferred.

The *Parakneria* Poll, 1965 (Gonorhynchiformes: Kneriidae) "Miringiri" in the Upper Lualaba and Luapula-Mweru basins (Upper Congo, DRC)

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The genus *Parakneria* currently contains 14 valid species, nine of which are known from the Congo Basin. Three of them, *P. damasi* Poll, 1965; *P. lufirae* Poll, 1965 and *P. thysi* Poll, 1965 are endemic to the Upper Lualaba drainage, while *P. malaissei* Poll, 1969 is endemic to the Luapula-Mweru. Recent collections in these basins revealed numerous identification problems, in particular for those originating from the Upper Lufira River, i.e. upstream of the confluence with the Panda River. Ten counts and 33 measurements were taken on 211 specimens including numerous types. A mitogenom analysis was undertaken as well. Important results are: (i) The specimens of the Upper Lufira, here identified as a not yet described species, *Parakneria* sp. 'kapolowe', differ from Congo Basin congeners by their more or less continuous lateral line and a low number of caudal bands. They further differ from those of the Upper Lualaba and Luapula-Mweru drainage by their narrower pectoral fins and short post-dorsal distance, respectively. (ii) The *P. damasi* holotype and its paratype are non-conspecific and also differ from newly collected topotypical specimens. (iii) *Parakneriathysi* shows significant colour pattern and body shape variation according to rivers. (iv) *Parakneria lufirae* has two distinct populations distinguished by head shape and fin length. (v) *Parakneria malaissei* also varies in colour pattern according to rivers. (vi) The mitogenomic study preliminarily supports at least three clades with *P. damasi*, *P. thysi* and *P. malaissei*. Known for climbing falls, upstream and downstream *Parakneria* populations appeared to be often genetically indistinct. This study confirms the validity of all known species from the Upper Lualaba and Luapula-Mweru basins and also identified a new one, apparently endemic to the heavily mined Panda drainage area. The latter discovery illustrates the need of improving aquatic conservation efforts in this area.

Amazon Fish database

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Tropical rivers concentrate the highest freshwater fish diversity on Earth. However, studies explaining the main processes that had generated the distribution patterns of fish are scarce and suffer from spatial scale constraints. Understanding such patterns and processes requires a database at the appropriate spatial scale, which is a challenge when involving some of the largest river basins of the planet. We have built a transnational collaborative project (www.amazon-fish.com – involving researchers from France, Belgium, Brazil, Colombia, Bolívia, Peru and USA) to generate the most comprehensive fish biodiversity database for the Amazon compiling information available in articles, books, grey literature,

online databases, foreign and national museums and universities and by checking for systematic reliability and consistency for each species recorded. The dataset contains at this time 2,258 described species (including 1248 endemics) representing 15% of all freshwater fishes described worldwide. We also detected some important sampling gaps, and field studies are currently being conducted to fill them. In Brazil, one major gap was detected in the Javari River Basin, an area inhabited by several indigenous populations (including some uncontacted ones) close to the border with Peru. Our expedition covered 94 sampling sites and resulted in ~430 species sampled, with 20 new records for Science. The AmazonFish database will be released for public use at the end of the project. Our main objective here is to present the AmazonFish project and stimulate our colleagues in organizing similar databases for the largest (and threatened) basins in Africa. The world's most biodiversity-rich river basins—Amazon, Congo and Mekong—are experiencing an unprecedented boom in dams construction, mining and infrastructure expansion. Organizing databases at the appropriate scale will allow to build scenarios considering those impacts and their possible interactions with future climate changes, which may improve our ability to propose and implement more effective strategies for biological conservation

‘Haplochromis’ Devosi, A New Species of the River Ruzizi Basin (Perciformes : Cichlidae)

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This study describes a new species of the *Haplochromis* genus (Cichlidae) from Kaganga river, a tributary of the East part of the Ruzizi basin in Burundi. The measurements and the counts were made at the Museum of Tervuren according to Snoeks (1994) on seven specimens of the new species morphologically compared with 18 specimens of ‘*Haplochromis*’ *paludinosus* from the Malagarasi basin and 14 specimens of *Haplochromis* *stappersii* of Ruzizi basin. In all, 17 morphométric characters and 16 meristics were respectively measured and counted for the holotype and six paratypes of the new species. Individuals are small-sized (maximal size 61,8mm in SL) with a moderately elongated body (height of the body varying between 32,9-35,6 % LS) and a straight snout profile slightly bigger than the diameter of the eye (33,1-35,4 vs 31,7-33,0 % of the length of the head). The head entering 2,8 times the length of the body (33,6-35,8 % LS) and reaching almost half of the length of the head (46,8-49,3 %). The height of the cheek is small, entering 4,5 times the length of the head (22,6-24,6 % HL). The caudal peduncle is longer than wide (16,1-18,0 vs 12,1-13,4 % LS) and its caudal fin is truncated or emarginated. The new species has no ctenoid scales on the chest but they are cycloid. Dorsal and anal fins do not exceed the origin of the caudal peduncle and ventral fins do not attain the first ray of the anal fin. The pharyngial bone is thin and all its teeth are bicuspid. Etymologically this species is dedicated to Dr Luc De Vos (died in 2003) who had collected with the third author the first specimens in 1994 in Burundi and who contributed to the knowledge of fishes of many rivers in the the African Great Lakes region. At present, ‘*Haplochromis*’ *devosi* is only known from Kaganga River in the Ruzizi basin at Cibitoke Rugombo in Burundi.

The Ichthyofauna of the Kundelungu National Park (KNP; DR Congo): A First Overview

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Established in the southern Congo basin since 1970, the Kundelungu National Park (KNP) covers a small part of the Upper Lualaba and the Bangweulu-Mweru ecoregions. It comprises: (1) a core zone ($\pm 2200\text{km}^2$) covering the southern part of the Kundelungu plateau (altitude 1300-1700m), with significant falls on its rivers; (2) an annex zone ($\pm 5300\text{km}^2$) situated at low altitude along the middle Lufira (ca. 800-1000m), and (3) a buffer zone (BZ) extending up to 50km around the two previous zones. Until now, its ichthyofauna has remained largely understudied. The first checklist of its ichthyofauna is presented based on a literature compilation and the study of historical and newly made collections (2012-2017). Hundred and four species, divided over 40 genera and 15 families, are known from the KNP. Of these, 76 species occur in the middle Lufira basin of the Upper Lualaba ecoregion, while 51 species occur in the left bank tributaries of the Luapula basin in the Bangweulu-Mweru ecoregion, and 31 species are shared between both basins. Cyprinidae (21 species, 20%) and Kneriidae (19, 18%) dominate its ichthyofauna, followed by Cichlidae (13, 13%) and Amphiliidae (10, 10%). The KNP and its BZ harbour 35 endemic species (34%), 10 of which are formally described and 25 new to science. This endemic fauna is composed of Kneriidae (16 species), Amphiliidae (6), Mochokidae (5), Nothobranchiidae (3), Cichlidae (3) and Mormyridae (2). These endemics are either restricted to the Kundelungu plateau, i.e., mostly upstream but sometimes also downstream of the falls, while others inhabit the swampy areas of the Lufira or Luapula basin. Unfortunately, this fish diversity experiences severe anthropogenic pressure due to overfishing as a result of using harmful techniques, pollution, and habitat degradation. Given the significant diversity and endemism levels, the protection of the ichthyofauna of the KNP should be given particular attention.

The Freshwater Fishes of Angola, a Biogeographical Assessment

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Current knowledge of Angolan freshwater fishes is briefly described according to the main drainage systems that include Cabinda, Lower Congo, Angolan coastal region including the Cuanza, the southern Congo tributaries, the Zambezi, Okavango, Cunene and Cuvelai drainages. The freshwater fishes of Cabinda and the Lower Congo are unknown from the Angolan territory but information is drawn from studies made in rivers originating beyond Angolan borders. The fishes of Angolan Atlantic coastal rivers are known primarily from the Cuanza river with a few small collections published on other rivers in the region. The Cuanza fauna is diverse and related to three sources, Lower Guinean, Congolese and Zambezian. A cluster of large *Labeobarbus* cyprinids is the most outstanding feature, especially from the Lucalla tributary. Fishes of the Cunene River in the south are known from studies in Namibia, and indicate a fauna that is Zambezian in character with certain species indicative of an early origin. Fishes of the Cassai and southern Congo rivers in Angola are described from the collections in the Dundo Museum as studied by Poll (1967), and reflect a mix of Congolese and Zambezian species. The Upper Zambezi fishes are poorly known from Angola but well studied from neighboring states. The

fauna is closely similar to the relatively well documented fauna of the Okavango basin. This fauna has evolved partly *in situ* with the geomorphological evolution of the Kalahari basin and has been supplemented by infusions of Congolian species. The small endorheic Cuvelai basin wedged between the Okavango and the Cunene in the south is poorly recorded from Angola but indications are a diminished pioneering fauna of Cunene and Cubango origins. A biogeographic model to explain the freshwater fish fauna of Angola is presented.

Taxonomic Revision Of The African *Nannocharax* Günther, 1867, With Recognition Of A New Species.

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Nannocharax are small sized distichodontid characiforms distributed in streams and rivers across sub-Saharan Africa and the Nile River basin. The genus is hypothesized to form a natural lineage within the family Distichodontidae based on the presence of a series of morphological synapomorphies involving multiple body systems. *Nannocharax* includes 41 valid species, nevertheless the diversity of these genera is certainly underestimated; hence our study aims to review the taxonomic status of the species of *Nannocharax*. Preliminary results show that within *Nannocharax* two large complexes of species centered around *N. fasciatus* and *N. taenia* require reassessment. *Nannocharax fasciatus* complex presents a hidden diversity and wide morphological variance along its distribution in the West Coast of Africa, from Guinea to Cameroon, including large drainages such as the Niger and Volta rivers, and the lake Chad basin. *Nannocharax taenia* presents hidden diversity especially noteworthy in members from headwaters of the main tributaries of the Congo River. A third species complex possessing vertically barred coloration was delimited from headwaters of the southern portions of the Congo River basin, Okavango and Zambezi River basins, and includes *H. machadoi*, *H. minutus*, *H. monardi*, *H. multifasciatus* and *H. wittei*. Within this group, a new species was identified from the Luapula river basin in Zambia. The new species is diagnosed from all congeners by the body coloration formed by a series of narrow vertical bars, usually one-scale wide, and a small caudal-peduncle spot surrounded by a light clear area at the base of the middle caudal-fin rays; by the number of circumpeduncular scales (12 vs. 14-16 in *N. multifasciatus* and *N. wittei*); and by the number of scales in the lateral line (33-35 vs. more than 36 in *N. machadoi*, *N. minutus*, *N. monardi*, *N. multifasciatus* and *N. wittei*).

Multigene Fossil Calibrated Analysis of the African Lampeyes (Cyprinodontoidei: Procatopodidae) Reveals A Late Eocene Origin and Neogene Diversification Driven By Palaeogeographic And Palaeoclimatic Events.

Pedro Bragança

The African continent undergone several palaeogeographic and palaeoclimate changes since the Paleogene, but the effects of Africa landscape evolution over its fish fauna remains largely unknown with few large continental-scale studies. Here we present the first molecular and fossil dated analysis of the widely distributed and little known African oviparous killifish

family, the Procatopodidae. The procatopodids occur in Africa main river drainages, inhabiting different environments such as black water streams, swampy areas, small ponds, lakes and even brackish water estuaries. Relationships between all Procatopodidae lineages, except the monotypic *Apticheilichtys*, are herein established through the analysis of one mitochondrial and five nuclear genes of 36 procatopodid and 24 outgroup species. The molecular dataset, 5691 bp, was analysed under maximum parsimony, maximum likelihood and bayesian approaches. Most Procatopodid genera were recovered as monophyletic, except *Micropanchax*, *Poropanchax*, *Lacustricola* and *Hypsopanchax*. Two cyprinodontiform fossil, *Prolebias stenoura* and *Aphanius chebianus* were used to calibrate the analysis. We estimated that the Procatopodidae split from its sister group, in the Eocene/Oligocene transition around 34 mya, probably as a consequence to the retreat of the Eocene trans-saharan sea. *Plataplochilus* was considered the most basal procatopodid genera originating in the early Oligocene (33mya) and *Aplocheilichthys spilauchen* the unique member of a lineage originated during the late Oligocene. *Procatopus*, *Hypsopanchax*, "*Hypsopanchax*" and *Hylopanchax* constituted a well supported clade originated during Africa moist-wet climate in the early/middle Miocene (22mya) as well as the clade comprising *Congopanchax*, *Lacustricola* and *Lamprichthys* (17mya). The diversification dates between the *Congopanchax-Lacustricola-Lamprichthys* clade agrees with the disruption between a drainage connection between the Congo and East Africa river drainages and with the estimated formation of the Tanganyika lake (9-12mya). The high diversification rate on the clade comprising the genera *Poropanchax*, "*Poropanchax*", *Micropanchax*, "*Micropanchax*", "*Lacustricola*" and *Rhexipanchax* is probably related to late Miocene aridification and subsequent climate instability.

Higher Genetic Diversity in Lake Kanyaboli than Lake Victoria *Clarias Liocephalus*: Evidence from Mitochondrial DNA Sequences.

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Poor survival of larval *Clarias gariepinus* constrains expansion of *Clarias* aquaculture in East Africa for food and incomes. Using a different Clariid species may help increase catfish seeds supply through higher survival of larvae. We used 389 bp DNA sequences of D-loop region of *Clarias liocephalus* collected from Lakes Victoria (LVC) and Kanyaboli (LKL), and University of Eldoret reservoir (UoE), Kenya, to infer genetic diversity and population structure. A total of 22 haplotypes was reported. LVC had 7 (31.8%) haplotypes, while LKL and UoE had 14 (63.6%) and 1 (4.6%) haplotypes respectively. Haplotype diversity was higher in LKL with 0.891 compared to LVC with 0.693 and UoE with 0.00. Similarly LKL had higher nucleotide diversity than LVC and UoE. A total of 15 haplotypes (68.2%) were singletons, with LVC having 3 (20%), while LKL had 12 (80%). The three populations formed three clades, while F_{ST} values were 0.822 between LVC and LKL, 0.825 between LVC and UoE, and 0.933 between LKL and UoE, with all comparisons significantly different ($p < 0.05$). Results suggest LVC population, which should be larger than LKL suffered a population bottleneck, possibly by predation by exotic Nile perch. Higher indices in LKL possibly mirror LVC population in pre-Nile perch era, and presence of dense papyrus of Yala swamp prevents entry of Nile perch into Lake Kanyaboli from Lake Victoria, conserving LKL population. The UoE population is severely bottlenecked, possibly due to very small size, and annual desiccation, with predation by birds increasing fish mortality. Use of species in artificial propagation may increase survival of larvae and conservation of haplotypes

A Comparison of the Weakly Electric Fishes of Africa and South America: Richness, Size, Distribution, and Extinction Risk

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This study aims to compare the richness, body size, area of distribution, and extinction risk of the weakly electric fishes of Africa and South America, the osteoglossiform superfamily Mormyroidea and the ostariophysan order Gymnotiformes, respectively. The list of species of the Mormyroidea was obtained from Bill Eschmeyer's Catalog of Fishes and that of the Gymnotiformes was compiled from Carl Ferraris' checklist and updated with the Catalog of Fishes. Species distributions were partially obtained from the International Union for Conservation of Nature (IUCN) red list database and used to calculate the Extension of Occurrence (EOOs) as a proxy for distribution areas in square kilometers. Distributions were also superimposed on the map of Aquatic Freshwater Ecoregions of the World to obtain a list of ecoregions for each species. Maximum body size was obtained from Fishbase or original descriptions. Extinction risk was obtained from IUCN red list database for Mormyroidea, the Brazilian Ministry of Environment red list of endangered species for Gymnotiformes, or assessed using IUCN criteria. Several comparisons are presented regarding the two groups of fishes, including richness and distribution area, body size of species and distribution area, body size and generic richness, body size and extinction risk, among others. Contrary to gymnotiforms, where larger genera include medium- or large-sized species, the richest mormyroid genus has mean small-sized species. A further comparison of the two larger river basins in each continent revealed a similar diversity. While the Amazon River basin, with 7.05×10^6 square kilometers harbors 61% of the 244 gymnotiform species, the Congo River basin, with 4.01×10^6 square kilometers, is home to 52% of the 221 mormyroid species. These two ancient and unrelated fish groups, further on having independently evolved remarkable key innovations like the electrolocation and electric communication and body shape parallelisms, possess many similarities in their richness, body sizes, distribution areas, and vulnerabilities.

Morphological and Genetic Variation of *Tilapia Guineensis* Populations from Nigerian Coastal Waters

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Morphometric and molecular techniques were used to characterize and investigate genetic diversity of *T. guineensis* populations from some Nigerian coastal waters for breeding and conservation purposes. Results of morphometric analysis showed that *T. guineensis* populations can be differentiated into only two distinct groups. The results implied low variability among the populations of *T. guineensis* from the coastal locations studied. This implied that *T. guineensis* populations from Nigerian coastal waters are morphologically different. Iwoama and Brass (Bayelsa state) populations were the most varied among all the studied populations. Furthermore, When compared to other locations, fish in Iwoama and Brass had the highest mean weight of 0.29 ± 0.006 kg and 0.27 ± 0.004 kg with mean total length of 0.24 ± 0.002 m and 0.23 ± 0.001 m. Molecular studies showed that Buguma in Rivers state, Badagry in Lagos state and Brass in Bayelsa state populations had the highest genetic diversity as was revealed by heterozygosity and

shannon indices. Clustering using SSR data gave four major clusters reflecting some level of genetic variability. Rivers, Lagos and Bayelsa states show greater genetic and morphological divergence and are therefore considered suitable areas for sourcing *T. guineensis* for fish improvement.

Sexual Dimorphism in South American and African Siluriformes (Ostariophysi): 120 Million of Years of Separation Produced Similar Traits Evolving Independently

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In Africa seven lineages of Siluriformes were recognized with three showing sexual dimorphism (SD). In SA the Siluriformes comprises 16 lineages with nine showing SD. Some works hypothesized a SA and AF relationship such as the Doradoidea (SA) as sister group of Mochokidae (AF); molecular analyses, however, had not recover any African-South American catfish clade. The SD was here grouped in 20 types (displays/expressions): 1- Elongate filament extending from the tip of the first of the dorsal and/or pectoral fin; 2- Opercular spine development; 3- Postcleithral process shape; 4- Odontodes development; 5- Opercular gland tissue; 6- Urogenital papilla modification; 7- Lip development; 8- Fleshy tentacles on snout; 9- Lower lip filaments; 10- Mandibullary teeth enlargement; 11- Modification of caudal fin; 12- Modification of anal fin; 13- Modification of pelvic fin; 14- Different color pattern; 15- Modification of dorsal fin; 16- Development of pectoral-fin spine; 17- Modification of maxilar barbel; 18- Modification of dorsal-fin spine; 19- Modification of anal fin for insemination; 20- Breeding tubercles on many areas of body. These types were present in 12 families (9 SA; 3 AF). The most generalized condition was the modification related to the urogenital papilla, observed in seven families (5 SA; 2 AF). The family with more SD characters was the SA Loricariidae with 10 types (4, 6-10, 12-14,16) followed by the AF Mochokidae (1-3, 6, 11, 20). Odontodes is a synapomorphy of Loricarioidea and the SD related to this structure was restricted to Scoloplacidae, Loricariidae and Callichthyidae. The family with the richest elaboration of SD is Loricariidae wich currently comprises around 980 species. Four families showed exclusive SD, Scoloplacidae (5), Auchenipteridae (17-19), Loricariidae (7-10, 14) and Mochokidae (2, 3, 11).

Biodiversity Threats among Finfish and Shellfish in Punnaikayal Estuary, Gulf of Mannar, Tuticorin Coast, India (08°38'16.28"N, 78°07'34.38"E)

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Aquatic biodiversity includes flora and fauna of freshwater, brackish water and marine environment. The human societies had long been depending upon aquatic biodiversity for food, medicine and other uses including commercial and industrial nature. The economic value of aquatic biodiversity is immeasurable and immense. In recent times, the factors like over-exploitation, pollution, habitat alteration and destruction etc., are overwhelmingly causing impacts and threats to aquatic biodiversity. The present study mainly focused on commercial important species of finfish and shellfish species in Gulf of Mannar, India. Study area mainly affected by a various threats like anthropogenic effects. This study further stressed that strict management measure need to be undertaken to conserve finfish and shellfish

from further exploitation and to restore the estuarine biodiversity of finfish and shellfish population of Gulf of Mannar in general and Tuticorin District coast in particular.

The Ichthyofauna of the Luki (Lower Congo Basin): Diversity and Distribution

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This study has two main objectives: to draw up an inventory of the ichthyofauna of the Luki River and to evaluate the influence of environmental factors on the distribution of these fishes. The inventory was made by compiling the literature, by studying collections of museums and of recent sampling campaigns, conducted between July 2014 and February 2018. From the main channel and its tributaries 36 species were collected, distributed in nine orders, 15 families and 25 genera. Only 14 of these 36 species are present in the Luki Biosphere Reserve that is situated within the Luki drainage system. Two zones can be considered, effectively separated by an old hydro-electric approximately 45 km from the source. Twenty six species were found downstream from the dam, 14 upstream and 11 are common for the two zones. Twenty three species were found in the main course, and also 23 in the affluents, while 17 are in common. To study the influence of environmental factors on the distribution of fish species, the communities were sampled in the dry season (from July to mid-October) in 2016 and 2017 using gill nets of different mesh-sizes (10, 12, 17, 20 and 22 mm knot to knot). Sampling was performed at 10 sampling sites on the main channel with eight located upstream and two downstream of the dam. Twenty three physico-chemical and environmental variables were taken at these sites. The ordination of the sampling sites in relation to their values for the abiotic variables and to their fish assemblages was studied using a linear method (canonical redundancy analysis). Two main groups of localities and their fishes were found in function of their physico-chemical and environmental variables. Distance to the source and altitude were the parameters that explained the distribution of the fish community best.

DNA Barcoding of Economically Important Fish Species of North – Central Nigeria and Applications

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Fishes are one of the main sources of animal protein for Nigerian populace. Recently, Nigerian inland water bodies have drawn considerable attention due to decline in the number of fish catch resulting from overexploitation and pollution. Insufficient information both on the taxonomy and diversity of Nigerian fishes, particularly from north – central (NC) region, have limited efforts in conservation and management. Herein, we analyzed the mitochondrial cytochrome C oxidase subunit I (COI) of 46 Nigerian freshwater fishes belonging to 21 species from six freshwater bodies in north – central (NC) Nigeria and verified the taxonomic reliability of DNA barcoding against the traditional method (morphological characters). Identification using COI Neighbourjoining tree analyses was successful (94.40%) for most fish samples. Comparison of DNA barcode and traditional approach reveals that DNA barcode is effective in the identification of morphologically similar species. Further, using DNA barcode reference data, unknown fish samples collected from fishermen were accurately identified and cryptic lineage diversity within *Schilbe intermedius* were uncovered. Finally, our study demonstrates the efficacy of DNA barcoding in species identification, conservation and management planning of the freshwater fishes in Nigerian inland water bodies

Morphological Characterization of *Oreochromis* Hybrids

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Morphometry is a field concerned with studying variation and change in form. The study was carried out to morphologically characterized hybrid strains from pure parental strains by determining morphological variation using traditional, geometric morphometric and meristic characters. Twenty specimens on each strain (4) were collected. Results on Traditional morphometric showed a significant difference between hybrid strains and pure parental strains. Influential variables include total length, head depth and length of anterior dorsal fin to posterior of pelvic fin. From the influential variables it imply that the hybrids compared to same cohort are to outperform the pure lines such that hybrid strain from pure *O.karongae* female crossed with pure *O.shiranus* male are the largest, have a deep head and a deeper body whereas hybrid strain from *O.shiranus* female crossed with *O.karongae* male are larger in size, have a deeper head and a deep body. PCA on meristic counts did not clearly separate the strains. Geometric morphometric using Neighbor joining tree plot with their corresponding spline deformation grids showed that both hybrid strains have large mouths compared to pure *O.karongae* shown by reduced distance between tip of maxilla and posterior extremity of the gape, and pure *O.shiranus* is differentiated from the hybrids by having a thin anal-pelvic region shown by contracted anal-pelvic fin region. Both traditional and geometric morphometric were able to characterize the hybrid strains in the genus *Oreochromis*.

***Leucosia Rhomboidalis* (De Hann, 1841), A New Record of Leucosiid Crab (Crustacea: Decapoda: Leucosiidae) Off Thoothukudi Coast, India (08° 31.912'n 78° 25.327'e) (318 M)**

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A new record of leucosiid crab off Thoothukudi coast of Gulf of Mannar, Southeast coast of India and reported. *Leucosia rhomboidalis* (De Hann, 1841) was newly recorded from Thoothukudi coast. One specimen was caught at a depth of 318 m as an incidental by-catch in the fisheries. It was found in tropical waters from about 08° 31.912'N 78° 25.327'E/22.3 miles off Thoothukudi fishing harbor, southeast coast of India.

Lac Bleu on the Léfini Basin and Its Fish Fauna (Congo Basin; Republic of the Congo)

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The Lefini River basin includes, in addition to its rivers, some lakes, of which the largest is Lac Bleu, also called Lac Ndza-Mvula, located in the Lesio-Louna Gorilla Natural Reserve. The lake connects with the rest of the hydrographic network by the Liya River, a sub-tributary of the Louna River. Unlike the numerous oxbow lakes, Lac Bleu occupies a basin resulting from rain and fluvial erosion and is surrounded by a forest dominated by *Symphonia globulifera*, beyond which lays the savannah. The aquatic vegetation comprises mainly *Nymphaea* sp., *Chara* sp. and *Lasimorpha senegalensis* towards its banks. While the lake has as a maximum depth of ±11m its waters remain transparent up to ±7m depth only. Surveys of water physicochemical parameters revealed an oligotrophic polymictic lake as illustrated by its limpid waters and the lack of remarkable aquatic vegetation. Two ichthyological surveys, using monofilament gillnets, were undertaken during the dry and rainy season. Sampling was intended to obtain a first overview of the lake's ichthyofauna. Twenty-four fish species were collected, belonging to 23 genera and 12 families. Mormyridae dominate the fauna with 7 species (30%), followed by Cichlidae with 4 species (17%); the remaining 10 families being represented by two or only one species. Analysis of the stomach contents revealed that the food web of the lake comprises plankton at the base, with diatoms and Chlorophyceae of the genus *Scenedesmus* being the most abundant and some macrophytes including Characeae. The primary consumers are *Distichodus noboli*. Three carnivores are at the top of the aquatic food chain: *Hepsetus microlepis*, *Chrysichtys thonneri* and *Parachanna insignis*. The lake's complicated access is an asset for the conservation of its aquatic biodiversity. such as that of the ichthyofauna whose lake is surely a refuge for some ecophases, at one time or another of the year.

An Integrative Approach to the Possible Occurrence of Hybridization in the *Labeobarbus* Species (Cypriniformes: Cyprinidae) Of the Luhoho Headwaters (Lowa Basin, Upper Congo, DR Congo)

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The Congo basin harbours 34 valid *Labeobarbus* species, 28 of which are considered to be endemic. Recent explorations in the Luhoho headwaters revealed the presence of six species, four of which were originally described from the basin: *L. longifilis* (median fleshy lobe); *L. paucisquamatus* (minute median fleshy lobe); *L. brauni* and *L. longidorsalis* (both with a cornified cutting edge on the lower lip), the newly reported *L. caudovittatus* (median lobe developed) and *L. cf. progenys* (prognathous mouth). Furthermore, numerous specimens with intermediate-mouth phenotypes (without lobe) were also identified. Morphological and mitochondrial DNA data were used to address the alpha-taxonomic issues uncovered in the *Labeobarbus* of the basin. Except for their mouth phenotype differences, *L. longifilis* and *L. paucisquamatus*, as well as part of the intermediate-mouth phenotype specimens are indistinguishable by meristics and measurements. In contrast, *L. brauni* and *L. longidorsalis* are well differentiated from each other based on the number of barbels (two pairs vs one), and the distance between their dorsal and pelvic fins. Maximum Likelihood phylogenetic analysis based on two loci (Cytb/COI), recovered five distinct lineages with three of them supporting the species status of *L. longidorsalis*, *L. caudovittatus* and *L. cf. progenys*. In contrast, specimens of the three nominal species, *L. longifilis*, *L. brauni* and *L. paucisquamatus*, fall into only two lineages, the *L. longifilis* and *L. brauni* lineages, with *L. paucisquamatus* and the intermediate-mouth phenotype specimen being dispersed over both lineages. This pattern suggests a hybridisation event, involving *L. longifilis* and *L. brauni*, at the origin of *L. paucisquamatus* identified specimens including the intermediate-mouth phenotype specimens. Such a scenario would be consistent with the morphological observations revealing that *L. paucisquamatus* and the intermediate-mouth phenotype specimens share traits of both species. Therefore, the taxonomic status of *L. paucisquamatus* is pending as it might be an interspecific hybrid.

Unknown Conservation Status of Five Threatened Lamiaceae of Tanzania and Kenya by Using Bioinformatics

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The IUCN conservation status was assessed for each of 42 target taxa (species, subspecies, and varieties) of the plant family Lamiaceae occurring in the Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya. Mapping the plants' geographic distributions using Geographical Information System Technology and application of IUCN quantitative criteria and expert knowledge of habitats and site protection status produced an assessment of the Red List status of each targeted taxon. Among the 42 targeted taxa, assessments were as follows: Critically Endangered (CR) (4 taxa; 10%), Endangered (EN) (10 taxa; 24%), Vulnerable (VU) (8 taxa; 19%), Data Deficient (DD) (1 taxa; 2%), Near Threatened (NT) (3 taxa, 7%), and Least Concern (LC) (16 taxa; 38%). Thus 22 taxa (52%) fall into the globally threatened categories of VU, EN and CR. While all 22 taxa evaluated in the globally threatened categories have major populations of about 69% growing in unprotected areas, in which five globally

threatened and endemic taxa were found to grow only on public lands with no legal protection: *Karomia gigas* (in Kilifi at North of Mwarakaya, in 1977 & 1980); *Clerodendrum robustum* var. *mafiense* (in Mafia Island, in 1933); *C. lutambense* (in Lake Lutamba, in 1934 and 1943); *Rotheca myricoides* subsp. *mafiensis* (Mafia Island, Kilindoni, Collected in 1937) and *Premna discolor* var. *discolor* (in Cha Simba, in 1989). Three of them have each been found only in one locality: *Clerodendrum lutambense*, *Clerodendrum robustum* var. *mafiense* and *Karomia gigas*. The survival of these five critically endangered, unprotected taxa depend entirely upon the surrounding communities. Thus biodiversity inventory and ecological studies in the areas inhabited by these taxa are of paramount importance both for effective *in situ* conservation measures and the determination of whether *ex situ* conservation measures are also needed.

River near the Mioki Rapids, Ogooué Basin (Gabon, Central Africa)

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With more than 407 species of freshwater and brackish fish in 74 families and 181 genera, Gabon is a country whose aquatic environments have not yet revealed all their ichthyological biodiversity. We a new species of *Enteromius* to the 13 species of *Enteromius* currently recorded in this region. This new species is characterized by spots on the dorsal fin, the presence of 3 or 4 round spots on the flanks, and dark dorsal coloration. In Gabon, it is distinguished from the most similar species (*Enteromiuistri spilomimus*) by the presence of spots on the dorsal fin, two pairs of moderately developed barbels and its limited distribution at the edge of the Mioki rapids. Among all the species currently recorded in Africa, the new species is very similar to *Enteromius walkeri* from Ghana, but the two species can be separated by color pattern, many morphometrics, and a much larger maximum body size in *E. walkeri*. Despite extensive recent collections in the Louetsi drainage, the new species is known from only one locality, highlighting the importance of conservation around its known habitat.

A Revision of the Cichlid genus *Mylochromis* (Teleostei: Cichlidae) from Lake Malaŵi

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Lake Malaŵi has the most speciose ichthyofauna compared to any freshwater lake in the world. Most species belong to the single family Cichlidae. New genera and species continue to be described from this family. Some genera don't have adequate descriptions to diagnose them. One such genus is *Mylochromis*, which is an unsatisfactory grouping because it has no

synapomorphies to diagnose it from other genera with similar diagonal stripe pattern. We propose that the genus *Mylochromis* should be restricted to species with a solid and continuous diagonal pattern. We are elevating *Maravichromis*, which was a junior synonym of *Mylochromis*, to full genus to contain species with a blotched diagonal stripe. We compared the *Mylochromis* species with spotted stripe to members of the genus *Sciaenochromis*. The results showed that members with spotted stripes do not belong the genus *Sciaenochromis*. We have tentatively left the species with spotted stripes in the genus *Mylochromis*, making the genus polyphyletic. We propose that a new genus should be erected to contain *Mylochromis* species with a spotted stripe.

The Cuckoo Catfish of Lake Tanganyika and Their Cichlid Hosts: An Experimental Approach to Brood Parasitism

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African lakes harbour large diversity of fish trophic and reproductive strategies. Mouthbrooding cichlid fishes in Lake Tanganyika are exploited by the only confirmed obligate fish brood parasite, the cuckoo catfish *Synodontis multipunctatus*. Brood parasites manipulate other species into raising their offspring. Using natural and experimental infections, we show that coevolutionary history and individual learning of host females interact in their impact on the success and costs of cuckoo catfish parasitism between coevolved (sympatric, from Lake Tanganyika) and evolutionarily naïve (allopatric, from other African lakes) cichlid species. Evolutionarily naïve cichlids were parasitized at rates 3-11 times higher than coevolved hosts. Sympatric hosts frequently rejected parasite egg, but at a cost of common own eggs rejection. This cost was largely mitigated in sympatric females by previous experience of catfish parasitism, demonstrating that both learning and individual experience contributed to successful host defense.

Diversity of the Freshwater Fishes of Equatorial Guinea: The Search for *Enteromius Potamogalis*

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Rivers and streams in the mainland portion of Equatorial Guinea (Rio Muni) have not been extensively sampled since the 1960's. New collections from this region are essential as it is the type locality for several fishes of taxonomic and nomenclatural importance. Most notable of these is *Enteromius potamogalis*; described from the area and only known from the type material. Genetic material from this species is necessary to resolve taxonomic uncertainty in the

African barbs. A three week expedition to the area in 2017 aimed to rapidly survey the freshwater fishes throughout the country, collect *E. potamogalis* from the type locality, and identify areas where further collections are needed. Specimens and tissue samples were

collected at 42 localities across the county. The collections focused on the Rio Muni and Rio Mbini drainages, but most of the drainages and smaller coastal rivers were also sampled. We successfully collected populations of *Enteromius potamogalis* within the Rio Muni drainage (type locality) and other coastal rivers. Numerous undescribed species of barbids, mochokids, and characids were collected throughout the region. The expedition also collected several populations of wide-ranging species (e.g. *Enteromius camptacanthus*) which will contribute to phylogenetic studies of these various species complexes. Here we present the results from expedition, highlight the diversity within some of the groups, and identify areas that need further study.

Origin and Dispersion of the Airbreathing Catfishes *Clarias* (Clariidae) In the Inland Waters of Afro-Arabia

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Clariidae (airbreathing catfishes) are emblematic of Asian and African freshwaters and over the half of the 116 species extant belong to genus *Clarias*. *Clarias* dispersals were first discussed by Menon (1951) but his study was rejected because based on the age of fossils without any phylogenetical consideration. Based on molecular data, extant African *Clarias* are known to originate in Asia and to have dispersed into Africa supposedly about 15 Ma (Agnèse & Teugels 2001) which would correspond to a known dispersal event related to the collision between Afro-Arabia and Eurasia. Today, a rich fossil record documents the presence of the genus in Afro-Arabia during the last 32 Ma (Otero & Gayet 2001) while the oldest African fossil known when Menon wrote his paper was dated around 4.5 Ma. Based on the study of cranial characters in 40 extant species and in the Afro-Arabian fossils we are able to identify the fossil members of the African clade. This allows to trace its dispersal in Afro-Arabia and in the African basins: the oldest fossil that certainly belong to the clade has 18 Ma, the oldest occurrence in Africa has 15 Ma and the minimum age of the presence of the extant clade in the various basins it occupies today are given.

The Ichthyological Diversity of the Mangroves Marine Park (Democratic Republic of the Congo): An Annotated Checklist

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The Mangroves Marine Park (PMM) is situated along the Atlantic coast of the DR Congo and the right bank of the mouth of the Congo River. It was created in 1992 to protect mangroves, manatees, sea turtles and migratory birds and also as a tourist attraction pole. The PMM covers ±768km² and comprises three major zones: A, the mangrove zone (integrally protected); B1, the coastline and coastal rivers zone (partially protected); and B2, the Congo River and its affluent rivers of the savannah zone (also partially protected). Unfortunately, despite its rich fish fauna, there is still no updated and published list of the fish species of this Ramsar site. Therefore, a checklist of the fish species of the park is being compiled based on a study of the literature, of historical collections from various museums and of recently new made ones as well (2014-2018). A total of 337 species belonging to 248 genera and 118 families have been recorded for the park. Of these species, 78 are known from the mangrove zone, 268 from the coastal zone, and 79 from the savannah zone. Further, 13 species occur throughout the entire park, while 214 species are found only along the coastal zone, 41 only in the savannah zone and one, *Periophthalmus barbarus* - the Atlantic mudskipper - is the only species restricted to the mangrove zone. Four species are endemic to the PMM and its surroundings: *Oreochromis lepidurus* and *Tylochromis praecox* (Cichlidae); *Micralestes holargyreus* (Alestidae); and *Marcusenius* sp. 'pmm' (Mormyridae), a recently discovered new species of elephant fish. Although important, e.g. as nursery habitats, in terms of fish diversity the mangrove zone is the poorest of the three. As such, the present insights might hopefully be an incentive to increased protection attention to the savannah and the coastal zones as well.

Gillnet selectivity and its' effects on population structure of two key species in Lake Victoria (Kenya)

Nicholas Gichuru Gichuru

The fisheries potential of dams within Uasin Gishu County needed to be known ahead of the government's initiative of introducing fish/fisheries in the area. The dams were constructed in 1950's and stocked with tilapia for recreational purposes and control of macrophytes. *O. niloticus* was selected for this study due to its popularity in the Kenyan market. Water samples were collected for phytoplankton analysis. The results were compared with phytoplanktons in the stomach of *O. niloticus* to reveal the fish's food preference in a natural environment. Fish samples were collected using a fleet of gillnets ranging from 1" to 4" stretched mesh size. A beach seine net of mesh size 1" was used to collect additional samples to supplement those caught by gillnets. The study revealed that the most important food items consumed by the fish were chlorophyceae (green algae), mainly *Botryococcus*, bacillariophyceae (diatoms), mainly *Navicula* and *Diatoma*, and cyanophyceae (blue-green algae) mainly *Phormidium*. The flagellate; *Gonatozygon* and the desmid; *Phacus* were important food items when available. Relative condition factor of around 1.00 showed that the dams are ideal for tilapia fisheries development. An effective management strategy is to legalize use of fishing gears that allows fish of 18-20cm to escape. This was found to be the most crucial breeding biomass needing some kind of protection. The use of 2" stretched mesh size gillnet is appropriate for sustainable exploitation.

A Revision of *Enteromius Apleurogramma* (Boulenger, 1911): A Widespread Minnow from Central and Eastern Africa (Cypriniformes: Cyprinidae)

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With more than 200 valid species *Enteromius* is by far the largest cyprinid genus. To date, *Enteromius apleurogramma*, has a vast distribution covering part of the Congo, East Coast and Nilo-Sudan ichthyofaunal provinces. In addition, the species contains eight junior synonyms. However, recent collecting confirmed some important meristic differences between populations; this especially in the total number of lateral line scales and of perforated lateral line scales, putting into question their conspecificity. Therefore, 9 counts and 19 measurements were taken 163 specimens, including type specimens of the different junior synonyms. In addition, colour pattern, and shape and distribution of breeding tubercles in

males were also documented. Finally, a mtDNA (COI) study is on its way. A detail study of the counts seems to point to the existence of two major groups. While the first group contains the holotype of *E. apleurogramma* and six of its present junior synonyms, the latter contains only the types of *E. lapsus*, a replacement name for *Barbus babaulti* Pellegrin, 1935. The first group has usually, less lateral line scales [20-23 (median 24) vs 22-27 (24)], less perforated scales (0-4 vs 2-10), and less predorsal scales [9-12 (median 9) vs 9-14 (10)]. Further, both groups seem to differ in shape and distribution of their tubercles also, with conical tubercles on snout and orbital margin only vs spherical ones on snout, cheeks, orbital margin and dorsum of head. In addition, the live colour of breeding males of *E. apleurogramma* is characterised by mainly golden-yellowish median flanks presenting up to three series of distinctly black crescent-like spots vs always with black crescent-like spots distributed all over the median and dorsal flanks. However, no morphometric differences were found between both groups. Nevertheless, other morphological differences seem to point to possible additional unrecognised species diversity. The question is under study.

Living Underground: Fishes of the Hyporheic Zone in the Amazon and Congo Basins

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Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil The Amazon and Congo basins concentrate a large portion of world's freshwater fish diversity, with thousands of species of many different phylogenetic groups showing a wide variety of body sizes, life strategies, behavioral characteristics and feeding specializations. The evolution and maintenance of such astounding fish diversity is closely linked to the occupation of a wide variety of habitats, including lakes, streams, large rivers (marginal areas, floodplains and the deep portion of the main channel) and temporary water bodies. One of the least studied fish habitats is the hyporheic zone, possibly because of its non-obvious conditions to support fish life. The upper portion of the hyporheic is commonly used as a temporary habitat by initial life stages of several groups of rheophilous fishes. However, some fishes spend their whole lives in the hyporheic. Here I report information about the diversity of fishes that inhabit the hyporheic zone of Amazonian streams and rivers, focusing especially on the deep and dense leaf litter banks. I also present details of the life history and behavior of the recently described *Tarumania walkerae* (Characiformes: Tarumaniidae), a remarkable inhabitant of the forest underground waters. These information were gathered along the last 20 years of field samplings throughout Brazilian Amazon and on observations of captive fishes maintained in aquaria for several years. Morphological characteristics (e.g. anguilliform body), as well as convergent physiological and behavioral traits present in several fish lineages allow the permanent occupancy of the hyporheic, despite the environmental challenges presented (e.g. lack of open water spaces, hypoxic conditions, and seasonal droughts). A preliminary comparison of the hyporheic fishes of the Amazon and Congo basins points out to the occurrence of similar traits related to the life underground, a kind of convergence already observed for other functional groups of fishes in African and South American waters.

Fish diversity of the Yangambi Biosphere Reserve (YBR): (DR Congo): An update

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The YBR has been created in 1939 and covers an area of ±220000ha. It is located about ±100km downstream from Kisangani on the right bank of the Congo River. The expeditions undertaken by Gosse (1963) inventoried a total of 205 fish species for the reserve; these distributed over 77 genera and 24 families. More than fifty years later, this study aims to update this list. For this, a survey of the literature, existing collections and recently made new ones (2013-2017) has been undertaken. In addition, anthropogenic threats currently affecting this fauna have been documented. A total of 268 species, distributed over 94 genera and 29 families are reported. The synonymy of some species previous listed by Gosse (1963) reduces the number reported by himself to 201 valid species. For example, *Hydrocynus vittiger* has since been identified a junior synonym of *H. goliath*. Sixty-seven species (33.5%) have been added to the list of Gosse (1963) among which: 29 new ones described after his publication; 38 species reported for the first time from the YBR this based on newly made collections, these including five new species for science. This is the case, for instance, for *Marcusenius* sp. "lilanda", first discovered in the YBR. Two introduced species are also reported: *Heterotis niloticus* and *Oreochromis niloticus*. In addition, the ichthyofauna of the YBR is submitted to multiple other anthropogenic impacts, such as: (i) the destruction of riparian vegetation for easy fishing; (ii) the cutting of *Raphia* which is used as roof construction material; (iii) fishing with mosquito nets; and (iv) pollution of the rivers with mercury, used in the gold extraction process. Therefore, although the YBR harbours an ichthyofauna that is even richer than previously known, it is threatened even within its borders, underlining the importance to further envision ways for its effective protection.

Stock Assessment and Estimation of Optimum Yield for Tilapia Stock (*Oreochromis niloticus*) in Lake Hawassa, Ethiopia

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The study was conducted on Lake Hawassa, one of the series Ethiopian rift valleys lakes. Data were collected from the area where fish are landed at one major landing site called fish market informally known as Amora Gedel, for one year (365 days) on a daily basis. The length

composition of tilapia caught by the fishery, total tilapia yield, fishing effort expanded as well as the price of tilapia and the cost of fishing operation were the basic information collected from the site. The aim of the analysis was to assess sustainability of fish stock, fishing level and to predict optimum yield and the bio-economic features of Lake Hawassa fisheries. Jones length based cohort analysis Model and length-based Thompson and Bell yield Prediction Model have been employed to estimate the maximum sustainable yield and maximum economic yield with their corresponding effort level. The estimated current annual yield was 182.94 tons of tilapia with the annual sale value of 4,158,760 ETB and 3,199,210 ETB of net profit for the fishermen cooperative. The predicted value of MSY was 186.72 tons/yr and this is obtained at fishing mortality factor of 1.6. And also MEY was 178.20 tons/yr and this is obtained at fishing mortality factor of 0.8. The fishery sector was found inefficient; the production was below its maximum sustainable yield level. Therefore harvest level should increase to its maximum sustainable yield level this might be possible by reducing the operating cost in order to increase both the level of yield as well as the net profit gained by the fishery sector.

Taxonomy and Systematics of the Haplochromine cichlidae, *Pseudocrenilabrus multicolor* in Kenya river system

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Abstract

The genus *Pseudocrenilabrus* is widely distributed in Africa, ranging in the north from Egypt to Sudan, across eastern Africa and part of eastern Congo basin, down to South Eastern Africa and Namibia in the west. The Genus currently constitutes 3 valid species; *P. philander* in south Africa; *P. multicolor* in the Nile River system and *P. nicholsi* in congo river basin. *P. multicolor* constitutes two subspecies, one colonizing the area downstream lake albert in the Nile river system (*P. multicolor multicolor*) -the Egyptian Mouthbrooder and the second (*P. multicolor victoriae*)- dwarf Victoria mouthbrooder known to occur in Lake Victoria basin. Considering this distribution patterns, only one sub-species is known to occur in Kenya (*P. multicolor victoriae*), in the Lake Victoria basin. More recently however, collections of this genus have been made in eastwards flowing rivers of Kenya, where they had not been documented before, namely; Tana, Athi and Ewaso Ng'iro systems. These collections have so far been classified as *Pseudocrenilabrus multicolor* with no specification of subspecies, it is suspected therefore to belong to a different sub-species than the Lake Victoria fish and a taxonomic study is currently underway to ascertain this. This current study proposes undertaking a rigorous systematic assessment to compare these new collections to other sub-species of *Pseudocrenilabrus* in order to find out if it constitutes a new sub-species and describe variability. Preliminary results from this assessment shows great difference in the morphology of these group of species in Kenya, in comparison with the dwarf Victoria mouth brooder. A total of 364 specimens from National Museums of Kenya, Ichthyology Section have been used in this study; from Lake Victoria system (194 specimens), Athi system (79), River Tana system (45) and Ewaso Ng'iro system (46). A total of 19 and 16 morphological measurements and meristic counts, respectively, have been carried out and will be analyzed using Multivariate statistical methods involving principal components.

On Some Chubbyhead Minnows Of The Upper Lualaba (Upper Congo Basin: DR Congo): The Case Of *Enteromius motebensis* (Cypriniformes: Cyprinidae) And The Populations Of The Kundelungu Highland Plateau

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Chubbyhead minnows are small, cold water, endemic cyprinids occurring mostly in South Africa but also in rivers of some highland plateaus of the Southern Congo basin. New specimens were collected during recent field expeditions (2012-2017) in the Kundelungu National Park (KNP) (Upper-Katanga, DR Congo). Preliminary identification showed these to be similar to *Enteromius motebensis* (Steindachner, 1885), originally described from the Limpopo basin in Southern Africa. For the Upper Lualaba, *E. motebensis kamaiae* (David & Poll, 1937) is the only subspecies described. However, its taxonomic status has changed over time from sub-species, as described, to full species and junior synonym of *E. motebensis*. These changes happened unfortunately several times and without arguments as to the suggested change in status. Moreover, clarification of the status of *E. m. kamaiae* is critical to enable proper identification of the specimens of the Kundelungu plateau (KP). Seven counts and 27 measurements were taken on a total of 127 specimens from the Upper Lualaba (*Enteromius* cf. *motebensis*) (107) and South Africa (*E. motebensis*) (20). A genetic study (mtDNA: COI) is ongoing. The morphologic results obtained allowed the identification of three distinct species: *E. motebensis*, *E. kamaiae*, as a valid species, and a new species for science. *Enteromius* sp. 'kundelungu' can be distinguished from these two other species by: its low number of scales on the lateral line and between the lateral line and the origin of the dorsal fin; its long barbels; and in males only, the disposition of the tubercles on its head. Several anthropogenic impacts, such as illegal mining and the use of rivers as troughs for cows are impacting on at least some of the rivers of the KP. As such, this study illustrates that, although depauperate, the fish fauna of the KP seems largely endemic and thus in need of better protection.

Characterization Of Fishing Gears And Practices In Lake Kivu, DR Congo

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The study dealt with the characterization of fishing gears and practices in Lake Kivu. Data were collected from March 2012 to February 2014 in Bukavu, Goma, and Kibuye fishing stations. The study findings indicate that gill nets, beach seine, lift net, trammel net (mosquito net attached to lift net parts), mosquito net, long line, single line, pots and cast net were identified as mains fishing gears used on Lake Kivu. Longline was more selective (2 species) in terms of species selection. The lift net presented the best catch (19.4 ± 11 kg), while the trammel net showed the highest Capture per Unit of Effort (7.9 ± 6.1 kg/h). The large dimensions of gears and the long fishing duration characterized gillnets (1023.2 ± 620.1 m²) and longline (10.3 ± 4.6 hours) respectively. Cast-nets (20 mm) showed the largest mesh size, while mosquito nets (1 ± 0.3 mm) were the smallest. Hence, there is a need to regulate fishing practices in Lake Kivu. Thus, local awareness campaigns are organized to this end towards local authorities and fishermen associations.

Keywords: Fishing, Awareness, Lake Kivu

Species Diversity In The Genus *Labeobarbus* (Cypriniformes: Cyprinidae): The Case Of The Kalumengongo And Kalule Nord Rivers In The Upemba National Park (Upper Lualaba, DR Congo, Africa)

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Eight valid *Labeobarbus* species are known from the Upemba National Park (UNP), but recent sampling in the Kalumengongo and Kalule Nord rivers revealed numerous specimens that could not be readily identified. A total of 57 and 152 specimens of these two rivers,

respectively, were studied morphologically, with 16 meristic and 29 measurements taken on each specimen. The typical mouth phenotype diversity was documented according to the following groups: Labeobarbus-mouth phenotype (L) specimens, with a well-developed mental lobe; Varicorhinus-mouth phenotype (V) specimens, with a keratinized outer cutting edge on the lower jaw; and several intermediate-mouth phenotype (I) specimens. Finally, based on a subsample of these specimens phylogenetic relationships of mitochondrial haplotypes were inferred using COI and Cytb. For the Kalumengongo, morphological results enabled unambiguous identification of three species: *L. gestetneri* (I), *L. upembensis* (V) and *L. sp. 'kalumengongo'* (L). Moreover, two groups of intermediate-mouth phenotype specimens, one highly similar to *L. upembensis* the other to *L. sp. 'Kalumengongo'*, were identified. In contrast, the mitochondrial data recovered only *L. gestetneri* constituting a separate lineage. For the Kalule Nord six species were identified morphologically, all of which are new to science, but only three mitochondrial lineages could be identified: (i) *L. sp. 'kapepe'* (V), (ii) *L. sp. 'kalule'* (L) and (iii) one containing the four remaining species, i.e. two with a L-, one with a V- and one with I-mouth phenotype. Furthermore, within the last lineage, two groups of intermediate-mouth phenotype specimens, one similar to the *Varicorhinus*-, the other to one of both *Labeobarbus*-mouth phenotype species, were also identified. Based on presented results, both rivers harbour a largely endemic *Labeobarbus* fauna. Both border the UNP and are thus prone to anthropogenic impacts such as selective subsistence overfishing. Hence the need to envision ways for conservation and sustainable management of this unique fish fauna.

Theme 2: Aquatic Resources Conservation And Management

Fish Populations Study in Littoral Biotopes in the Northern End of Lake Tanganyika (Burundian Side).

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It is documented that the highest fish diversity in Lake Tanganyika is found in the littoral zone. In Burundi where land use is under a high competition, conservation of the lake natural shoreline is a major issue. It is therefore needed to identify and indicate to managers the most relevant places to promote their conservation. Our hypothesis is that rocky and inundated macrophytes shallow habitats are the best places for reproduction and growth for number of species. Fish have been sampled in 8 stations along the lake shoreline, using 2 series of multi-mesh gillnets set in the lake for a period of 6 hours. Fish larva were collected with a mosquito net set on a conic structure of 50 cm of diameter and one meter deep. The sampling was conducted in September - October 2016 and in December 2016. The inventory has given a total of 58 fish species with 18 to 21 species on each station. The fish populations could be set into 3 groups. 1) Small species which reproduce et grow locally; these are mostly Cichlids species. 2) Medium to larger size species, which also reproduce locally, but whose adults can migrate in other places in the lake; these species are heavily exploited by fishermen; it is the case for *Boulengerochromis*, *Oreochromis*, *Raiamas* and *Bathybates* species. 3) A pelagic species, *Limnothrissa miodon*, whose mating populations migrate in shallower bays. Data analysis established the fish diversity and the juveniles/adult proportions in fish populations. This allowed to indicate which sites are the best for fish reproduction and growth, and to propose a ranking for habitats conservation.

Many Fish in Small Waters: Speciation in Cameroonian Crater Lakes

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For decades the cichlid radiations of the East African Great Lakes have famously proven to be prime model systems to study the processes of speciation and ecological adaptation. Even though first attempts in this direction are under way, these systems, due to their sheer size are notoriously difficult to assess in their entirety. A series of volcanic crater lakes in Western Cameroon have evolved independent cichlid radiations with estimated ages of several thousand up to one million years and around ten endemic cichlid species each. These systems provide the rare possibility to examine entire species flocks, which have repeatedly evolved in distantly related lineages in the light of very similar ecological backgrounds. Here we present first results from a multidisciplinary approach assessing the cichlid radiations of the crater lakes Barombi Mbo and Bermin in Western Cameroon. We are using RAD sequencing data for

phylogenetic reconstruction and genomic outlier analysis as well as geometric morphometric analysis of body- and LPJ shape and a number of different ecological indicators such as intestine length and stable isotope data to disentangle the speciation processes in the system. Overall we can show high levels of adaptive ecological and morphological specializations, which seem to seem to have evolved convergently between the different systems. The adaptation of the vision system of deep-water adapted species, occurring in both of the systems, provides a particularly striking example in this context.

Trade-offs between fisheries Conservation and Management in Fisheries Co-management Arrangements

Andrea Mjuma Gondwe

LUANAR

Fisheries Co-management approach is key conservation and management strategy in fish dependent communities in Malawi. However, results on effectiveness of fisheries co-management are mixed and often undesirable. Fisheries co-management implied transfer of state control for conservation objective to community level control for self-regulation. To provide an optimal trade-off through co-management arrangements, fishing communities incur transactions costs up to where the extra additional transactions costs of self-regulation are equal to the extra additional utility of risk of fishery collapse. This paper reviews existing literature to ascertain the efficiency of fisheries co-management arrangements in Malawi by investigating the extent to which these arrangements are transactions cost-reducing. Co-management can reduce transactions costs as shared authority and responsibility likely increases legitimacy and rule compliance. Co-management arrangements generate transactions costs because of the collective bargaining and action. Transaction costs also arise from the various actions taken by resource users to reduce the risk of failure of collective action. According to community development theory, resource user participation is fundamental both in ethical and practical grounds. In terms of ethics, fishing community members have a right to say in decisions which affect their net social benefits and well-being. In practice, active participation in decision making buys in the support and approval of participants who are the community members. Results show that fisheries co-management arrangements are downloading huge transactions costs of fish resource management onto the fish dependent communities instead of being transactions costs-reducing. Thus the fishing dependent communities are not the main cause of fish resource over-exploitation.

Assessment of Deep Pools in Likangala and Domasi Rivers of Lake Chilwa Basin Catchment

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The deep pools in Likangala and Domasi Rivers have a strong influence on aquatic diversity and the fisheries of the Lake Chirwa Basin. This study assessed functionality of the deep pools in the two rivers from a hydrological perspective. Specifically, the study mapped locations and characterised deep pools in Likangala and Domasi Rivers; assessed the climatic and hydrological regime of the area and recommended environmental flows for the two rivers. Primary data analysed included the location and characteristics of the deep pools, and local ecological knowledge of the communities living adjacent to the rivers. Historical rainfall data (1958-2012) and river flow data for the two rivers (1959-2002 for Likangala and 1957-2010 for Domasi Rivers) were analysed for temporal trends using standard methods and compared with the people's perceptions on the hydro-climatic regime. A desktop-based ecological reserve model was developed and used to estimate ecological flow for the two rivers. The study mapped a total of 22 deep pools along Likangala River and 16 deep pools along Domasi River. The results show that there is a gradual reduction in the depths of the deep pools in comparison to results from a previous study. The results from rainfall analysis suggest a decreasing trend that is not statistically significant at $\alpha=0.05$ level. River flows also have declining trends that are however significant in both rivers, suggesting the role of other forcing factors like land use degradation apart from changing and varying climate. Water quality analysis showed that the water for both rivers can be considered fresh, although some parameters registered stressful levels for survival of fisheries resources. Despite contribution of geological material deposit to ground water quality in the rivers, anthropogenic effect through agriculture and waste featured high. Based on present water commitments of each river, the desktop reserve model results show that Likangala River is more degraded compared to Domasi River, and can only be managed under ecological classes from BC to D, while Domasi River can be managed under ecological classes from B to D. The study recommends a well-structured local management regime to inculcate a sense of ownership of the riverine resources and the deep pools in the people living with the resources.

Control of Invasive Fishes in Priority Fish Conservation Areas in South Africa's Cape Fold Ecoregion: Partner Agencies Collaborate To Ensure Successful Use of the Piscicide Rotenone

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Predatory invasive fishes (e.g. smallmouth bass *Micropterus dolomieu*) are the prime threat to the highly threatened freshwater fish fauna of the Cape Fold Ecoregion of South Africa. Invasive fishes such as carp *Cyprinus carpio* pose a major threat to water quality in dams, and can make water unfit for human use. These impacts can be mediated by removing invasive fishes from priority reaches of rivers and dams using piscicides, of which

rotenone is most commonly used. Rotenone is used globally for this purpose, especially in the USA, and the American Fish Society has developed a manual for the use of rotenone to ensure best practice. Since 2006, CapeNature, the conservation authority of the Western Cape Province of South Africa, has taken the national lead in undertaken river rehabilitation projects that involve rotenone use. These projects were initially controversial, especially amongst some angling groups that targeted invasive species. However, successful execution of the Rondegat River project, with comprehensive pre- and post-treatment monitoring, and scientific publication of results has removed much of the criticism. The current focus of the programme is on the Krom River, with projects on two other rivers in the pipeline over the next three years. All rivers mentioned are in the Olifants-Doring River System of South Africa and have been mapped as Freshwater Ecosystem Priority Areas for fish.

Anthropogenic Impacts on Water Quality and Macro invertebrates Distribution of Toho Lake, South-West Benin

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Toho Lake is a water body in Benin strongly submitted to anthropogenic activities. An appreciation of the impact of these anthropogenic activities on the water quality and the distribution of the macrobenthic organisms of Toho Lake was conducted. Nine physico-chemical parameters were measured and benthic organisms were collected from May to August at 8 stations with an Eckman grab. The auto-organizing map (SOM) of Kohonen was used to determine the similarity between stations on the basis of the environmental variables collected. Benthic structure were performed using four indices of biodiversity (species richness, relative abundance, Shannon-Weiner and Pielou' equitability indices). Abundance-biomass Comparison (ABC) indices, Difference in Area by Percent" (DAP) and Shannon-Wiener Equitability Proportion (SEP) were used to reveal ecological stress in the lake. In total, 23 species of macroinvertebrates gathering into 18226 individuals and divided into 4 classes (Insects, Gastropoda, Achaeta and Arachnids) were inventoried. The insects (with 20 species representing 91% of the specific richness and 99. 01% of the total individuals) have largely dominated the group of this fauna with one species, *Enithares* sp. (Notonectidae family). Only one species of Mollusk Gastropoda, Thiaridae *Melanoïdes* sp. has been collected. Water transparency (40-90 cm), water temperature (26.50 - 30.3 °C), conductivity (213-350 mS/cm) and dissolved oxygen (1.75-6.06 mg/L) varied significantly in time whereas depth (0.60 - 1.68 m) showed spatial variation. Three clusters were discriminated by SOM analysis and have revealed stresses on the organisms. The feeble values of Shannon and equitability indexes

obtained have confirmed the scarcity of the water body in benthic organisms. The ABC, DAP and SEP indices have largely supported the impacts of anthropogenic activities on the distribution of macroinvertebrate species dominated by few taxa that showed to be indicators of the ecological status of the ecosystem observed.

Diversity and Ecology of the Ichthyofauna of the Mono Basin (Benin and Togo): a First Overview

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The Mono is a transboundary coastal basin for which its ichthyofauna remained quite poorly documented. However, a first hydroelectric dam was constructed and commissioned on its lower course at Nangbéto in 1987. A second dam is planned at the Adjarala Rapids, approximately 100 km downstream of Nangbéto. As such, the ichthyofauna of the basin was studied in order to compile a first checklist of its fauna and an ecologic study has been undertaken as well. The species inventory is based on a compilation of the literature, study of existing museum and other collections and newly made ones during several recent sampling campaigns (2011-2014). This resulted in an inventory of 91 fish species belonging to 67 genera, 42 families and 14 orders. The most species-rich families are the Cichlidae (9 species; 9.9%), Cyprinidae (9; 9.9%), Mormyridae (7; 7.7%), Clariidae (7; 7.7%) and Alestidae (6; 6.6%). A total of 29 species, seven of freshwater and 22 of marine or estuarine origin, are reported for the first time for the basin. For the ecological study, two seasonal sampling campaigns were performed in 2012 and 2013, these using five gill nets of different mesh-size (10, 12, 17, 20 and 22 mm knot to knot). Sampling was performed at 10 sampling sites located respectively up- and downstream of the Adjarala and the Nangbéto dam. Seventeen physico-chemical and environmental variables were taken at each site. The ordination of the sampling sites in relation to their values for the physico-chemical and environmental variables, and to their fish assemblages was studied using a non-linear method: the self organising map. The samples were arranged in four groups in function of their physico-chemical and environmental variables and three groups according to their ichthyofauna. A significant correlation was found between the distribution of the species and the physico-chemical and environmental parameters.

The Fate and Effects of Oxytetracycline in Fish Ponds: A Case Study from Ghana

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Freshwater tilapia farming has developed rapidly over the past ten years in Ghana. This has led to use of modern technologies including application of antibiotics and vaccines in some aquaculture farms in Ghana. Although the antibiotics help the farmers in reducing mortalities and skin infections, overuse may pose a risk to neighbouring aquatic ecosystems and human health via fish consumption. Consequently, this experiment was conducted to determine the relationship between the application dosages and maximum residue concentrations in tilapia tissues and in the aquatic environment in Ghana. Seven groups of male tilapia fishes (4 per group), weight between 150 and 170g, were fed (3% body weight/day) with diet containing OTC (30, 40, 60, 80, 100, 130 and 160mg/kg) for 14 consecutive days in artificial earthen ponds. The OTC-medicated feed was administered three times daily (8:30am, 12:00 and 4:30) without any additional feed. A standard HPLC method was used to detect the peak concentrations in the gill, muscle and the head with brain. The gills had the highest OTC residue level compared to other organs (numbers needed). Therefore, the study recommends that the gills should not be consumed unless an appropriate withdrawal period is applied, despite the gills "sweetness" as people stated during the field interviews in Ghana. The MRC found in the water samples (0.0032 µg/l) were below the maximum acceptable level of 0.4 µg/l. We recommend periodic water and sediment testing to minimise risks to aquatic ecosystems and human health. We conclude that OTC at the concentrations used in the study (30 -160 mg/kg) can be applied in Ghana if the recommended withdrawal period is applied as proposed by Choo (1995). However, preventative strategies such as vaccination and husbandry measures should be implemented to reduce or eliminate antibiotic use in line with global "One Health" policy.

Fish Invasions: Insights from The South Africa's First National Report on the Status of Biological Invasions and Their Management

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The South African National Biodiversity Institute (SANBI) is mandated through national legislation to monitor and report regularly (triennial) on the status of all listed invasive species in the South Africa. This presentation provides insights of fish invasions in South Africa that were obtained from the country first National Status Report on Biological Invasions. It also highlights the development of a set of indicators that were used to assess the main aspects of invasions, as well the effectiveness of control measures, and of the regulations at a national level.

Approaching Africa's Future Fresh Water Challenges through Capacity Building and Collaboration

Ted Lawrence and Jess Ives

The African Great Lakes support millions of people with protein, clean water, and transportation, but also face notable challenges, including climate change, agricultural runoff, deforestation, and overharvest of fish. Attempts to address the challenges facing freshwater resources often fall short due, in part, to the underinvestment in universities and research institutions and a lack of harmonization in research approaches. Environmental problems are often addressed by international agencies targeting short-term objectives, resulting in piecemeal or incomparable results, and driving research that may not be as important to the region. Strengthening research capacity and harmonizing research priorities on individual lakes can bolster long-term, strategic commitments, stable funding, and address ecosystem approaches to resource development and management. This talk focuses on a call from the international community to create centers of excellence to address African freshwater issues, and specifically, to enhance the capacity of riparian nations to conduct ecosystem research and monitoring to support sustainable basin development around the African Great Lakes. This talk discusses the institutional arrangements, objectives, essential features, and scope of an African initiative that can help build and sustain a system of world class research on the African Great Lakes.

Heavy Metal Concentration of Tropical Periwinkle (*Tympanotonus fuscatus*) from Benin and Ethiopie rivers in Delta State, Nigeria

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This study examined the heavy metal concentrations (Cu, As, Zn, Pb, Cr, V, Ni, Cd, Fe and Mn) in *Tympanotonus fuscatus* obtained from Ethiopie River and Benin River in Nigeria. Samples were obtained once monthly for a period of six months; April 2016 - June 2016 (rainy season) and November 2016 – January 2017 (dry season). The exoskeleton was separated from the edible portion and dried to constant weight at a temperature of 105°C. After which, samples were milled separately and stored in air tight plastic vials prior to digestion and analysis. Mean concentrations of metals in shell of *T. Fuscatus* from Benin and Ethiopie River respectively were: Fe (98.62 and 82.36mg/g); Zn (10.47 and 8.51mg/g);Cr (15.50 and13.30mg/g);Mn (9.91 and 8.44mg/g);Cu (20.93 and 13.16mg/g);Ni (34.98 and 25.18mg/g);Cd (3.00 and 2.78mg/g); Pb(9.19 and6.17mg/g); As (0.19 and 0.57mg/g) and V (16.16 and10.10mg/g) while mean concentrations of metals in the flesh of *T. fuscatus* from Benin and Ethiopie Rivers respectively were: Fe (51.52 and 44.01mg/g); Zn (5.13 and 3.20mg/g); Cr (5.34 and 4.85mg/g); Mn (4.24 and 3.42mg/g); Cu (12.86 and 6.08mg/g); Ni (13.43 and 6.25mg/g); Cd (0.66 and 0.67mg/g); Pb (2.01 and 1.09mg/g); As (0.02 and 0.20mg/g) and V (9.04 and 5.29mg/g).There was a significant difference ($P<0.05$) in the mean concentrations of Cu, Ni, As, Pb and V, while no significant difference ($P>0.05$) was observed in the concentration of Fe, Zn, Cr and Mn in the

shell of *T.fuscatus* between both locations. However Cr, Mn, Cu, Ni, Cd, Pb and V had higher concentrations than the recommended limits set by FAO and WHO thus indicating that the species is not safe for human consumption, especially over time. It is recommended that discharges from industries and refineries in the vicinity should be treated before eventual discharge into the environment.

Degradation of Malawi's Rivers Illustrated by Changes in Fish Biodiversity

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Concern over the health of Malawi's rivers was expressed as early as the 1950s. River degradation was implicated in the collapse of Ntchila (*Labeomesops*) in the 1960s. This species is now recognised to be Critically Endangered on the Red Data List. Deforestation has continued at an ever-increasing rate. Extensive *ad hoc* fish biodiversity surveys were conducted in Malawi's rivers in the 1970s. Since then many rivers have been re-sampled between 1995 and 2015. These surveys reveal major changes in fish species composition and abundance, directly attributable to the loss of riparian vegetation along the rivers, deforestation, and consequent siltation and decline in habitat availability. Formerly abundant species such as *Enteromius kerstenii* and *E. Choloensis* are now severely depleted or absent, while species that are tolerant of degraded environments such as *Enteromius paludinosus*, *E. trimaculatus* and *Astatotilapia calliptera* continue to survive and in some cases thrive. *Opsaridium tweddleorum* has been extirpated from its type locality, the Maperera stream, a tributary of the Lower Shire. Examples of river degradation are highlighted for the North Rukuru River, Nswadzi River and Mzimba River, but the situation is critical for the majority of rivers in Malawi, threatening the survival of many river-dependent species.

Fish-Environment Interrelationships and Its Management Implications for the Rusizi National Park

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Using a set of environmental parameters, we attempted to assess the fish-environment interrelationships in the Rusizi National Park (RNP) on two sections i.e. the swampy area (=lagoon) regularly connected to Lake Tanganyika water during the flooding season and the Rusizi River main course. A total of 23 native fish taxa were captured during dry and wet seasons sampling expeditions in 2016 and 2017 at seven sites within the RNP: 5 along the Rusizi

River and 2 in the lagoon. Gill nets of various mesh sizes were used for daylight (7.30–14.30 h) standardized sampling two times per year. The importance of the lagoon was demonstrated where Cichlids species i.e. *Astatoreochromis straeleni*, *Haplochromis* and *Oreochromis* species significantly prefer the lagoon. The main course of the Rusizi River harboured non cichlid and some rare fish species, such as *Bagrus docmac* and Cyprinids such as *Labeo*, *Labeobarbus* and *Raiamas* species. Multivariate and redundancy analysis of presence/absence and relative abundance data revealed three assemblages of sites, characterized by a different fish community structure in: (i) the lagoon, (ii) the Rusizi River section near the Lake Tanganyika and (iii) and the section of the Rusizi river near to its split into the large and the small Rusizi. The distribution of fish species mainly responded to a gradient of water quality parameters, conductivity very high in the lagoon, turbidity very high in the main course, and a habitat parameter, i.e. the river's width. Our results clearly showed that water conductivity in the lagoon increases in dry season due to the high loss of water through evaporation. The assemblages of sites and the corresponding fish community structure highlighted the close link between Lake Tanganyika, the Rusizi and the lagoon water and their respective fish populations. Therefore, extending the protected area of the RNP to include the northern part of the Lake Tanganyika is critical for fish conservation.

The Effect of El-Niño on Reservoir fish production in Ethiopia. A Review paper

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Drought is defined as the protracted absence, deficient or poor distribution of precipitation and it is a natural phenomenon that occurs for prolonged period of abnormally low precipitation. The underlying causes of most droughts can be related to changing weather patterns manifested through the excessive build-up of heat on the earth's surface, meteorological changes which result in a reduction of rainfall, and reduced cloud cover, all of which results in greater evaporation rates. Nowadays drought is the main problem in the world and also recently in Ethiopia. Ethiopia has experienced droughts for hundreds of years, with major events (i.e., ones involving famine or documented suffering) including 1888-92, 1899-1900, 1920-22, 1933-34, 1973-74, 1983-84, 1987-88, 1990-91, and 1993-94. Currently, Ethiopia has faced the ugliest drought in 2015/2016 which affects the environment and humans. Mostly the occurrence of drought in Ethiopia is related to El Niño Southern Oscillation (ENSO) events. Reservoirs are essential components of most irrigation systems worldwide and, together with those built for flood control and power generation, retain large volumes of water. In addition to their roles in power generation and provision of water for agriculture, industry and homes, most of these reservoirs also play an important role in fish production and contribute significantly to the livelihoods of the communities along their shores. It is known that Ethiopia has huge reservoir fish production potential which is not revealed and unexploited. One of these reservoirs, Tendaho Reservoir, is found in Afar region located between Dubti and Mile. This large reservoir has faced a great problem being highly vulnerable for drought in which it has dried, at least, once in the last two years. Recently, in February 2016, it has totally dried due to El Niño and all living organisms in the reservoir were damaged. It has distracted

community structure, habitat loss, decline and huge fish population has died out. In this area, there is a knowledge gap on cause and effect of El Niño in reservoir ecology; therefore it needs depth research which could be conducted on drought impact in reservoir in order to develop prevention techniques during drought season. Therefore, the purpose of this review paper was to identify effects of El Niño on reservoir fish production by synthesizing current knowledge on effects of drought on reservoirs that would ultimately be used to recommend and identify research direction.

The Usefulness of Single-Species Biomass Models in Providing Management Advice for the Lake Victoria Fisheries

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Nile perch (*Lates niloticus*), tilapia (*Oreochromis* spp), dagaa (*Rastrineobola argentea*), and haplochromines (Tribe Haplochromini) form the backbone of the commercial fishery on Lake Victoria, accounting for over 90% of the total catch in the three riparian states Uganda, Kenya, and Tanzania. The lake fisheries have been poorly managed, in part due to inadequate scientific analysis and management advice, resulting into drastic stock declines for the major commercial species. This paper evaluates the usefulness of single-species biomass models in providing management advice for the lake fisheries. Stocks of the four commercial fish species of Lake Victoria were modeled to determine reference points and current stock status. The Schaefer biomass model was fitted to available data for each stock (starting in the 1960s or later) in the form of landings, catch per unit effort, acoustic survey indices, and trawl survey indices. In most cases, the Schaefer model did not fit all data components very well, but attempts were made to find the best model for each stock. Results of the model fitted to the Nile perch data starting from 1996 estimated current biomass at 654 kt (95% CI 466–763); below the optimum (692 kt) and harvest rate at 40% (33–73%), above the optimum (35%); and that of Nile tilapia at 102 kt, below the optimal of 226 kt. At best, these can be used as tentative guidelines for managing the fish stocks. The model did not fit well to the data for the Dagaa and Haplochromine stocks. The results also indicate that there have been strong multispecies interactions in the lake ecosystem. These findings can be used as a baseline reference for future studies using more complex models, which could take these multispecies interactions into account.

Bio-Economic Analysis of Usipa (*Engraulicypris sardella*) in South East Arm of Lake Malawi

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A study to estimate the maximum economic yield and maximum sustainable yield was carried out for Usipa fishery in south east arm of lake Malawi. We used a structured quantitative questionnaire to collect the price of landings and cost of fishing effort. Catch and effort data for Usipa in the south east arm were used to estimate key parameters (r , q and k) of the Gordon Schaefer catch equilibrium model derived from the logistic population growth model and simple economic assumptions (using ASPIC software version 7 by Prager). The Gordon Schaefer model estimated the fishery to have yield at MSY and MEY of 9228.8 m.t. and 8227.1 m.t. respectively. The corresponding fishing effort was estimated to be 40,000 hauls and 30,000 hauls at MSY and MEY respectively. The Revenues and effort at MSY was estimated at MWK42.280 billion with 41,000 hauls while at MEY the revenue and effort were MWK39.309 billion with an effort of 30,000 hauls. The analysis shows that the current effort of 65,232 hauls has a yield of 6000 m.t., indicating that the Usipa fishery is currently being fully exploited below the bionomic or open access yield. Reducing the fishing effort by over 50% should protect the fishery from potentially imminent collapse.

Assessment of Brewery Effluent Quality Discharged into Treatment Ponds, Uyo, Akwa Ibom State, Nigeria

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The brewery effluent discharged with the sole aim of undergoing natural treatment was assessed seasonally for its quality using APHA standard method for examination of water and wastewater. The results obtained were compared with the Federal Ministry of Environment (FMENV) limits. pH in POND-1 ranged from 7.61 – 8.45 with the mean of 8.31 ± 0.59 ; and in POND-2 ranging from 6.23 – 6.46 with the average of 6.33 ± 0.12 during wet season, while in dry season, pH in POND-1 ranged from 5.07 – 5.37 with the mean of 5.19 ± 0.16 ; and in POND-2 ranging 5.77 – 6.01 with the mean of 5.866 ± 0.13 . Electrical Conductivity (EC) in POND-1 ranged from 1800.4 – 2100.2 $\mu\text{S}/\text{cm}$ with the mean of $1972.7 \pm 154.9 \mu\text{S}/\text{cm}$; and in POND-2 ranging from 1345.6 – 1620.5 $\mu\text{S}/\text{cm}$ with the average of $1469.266 \pm 139.5 \mu\text{S}/\text{cm}$ during wet season, while in dry season, EC in POND-1 ranged from 2722.1 – 3010.3 $\mu\text{S}/\text{cm}$ with the mean of $2872.166 \pm 144.5 \mu\text{S}/\text{cm}$; and in POND-2 ranging 2000.4 – 2161.6 $\mu\text{S}/\text{cm}$ with the mean of $2056.8 \pm 90.8 \mu\text{S}/\text{cm}$. Biological oxygen demand (BOD) in POND-1 ranged from 33.8 – 45.2 mg/l with the mean of $40.2 \pm 5.83 \text{mg}/\text{l}$; and in POND-2 ranging from 21.1 – 27.1 mg/l with the average of $23.566 \pm 3.14 \text{mg}/\text{l}$ during wet season, while in dry season, BOD in POND-1 ranged from 49.7 – 50.8 mg/l with the mean of $50.333 \pm 0.57 \text{mg}/\text{l}$; and in POND-2 ranging 35.3 mg/l – 38.8 mg/l with the mean of $37.5 \pm 1.92 \text{mg}/\text{l}$. Chemical oxygen demand (COD) in POND-1 ranged from 51.6 – 55.3 mg/l with the mean of $53.4 \pm 1.85 \text{mg}/\text{l}$; and in POND-2 ranging from 31.8 – 32.6 mg/l with the average of $32.266 \pm 0.42 \text{mg}/\text{l}$ during wet season, while in dry season, COD in POND-1 ranged from 78.6 – 85.3 mg/l with the mean of $82.1 \pm 3.36 \text{mg}/\text{l}$; and in POND-2 ranging 44.7 – 48.3 with the mean of $46.533 \pm 1.80 \text{mg}/\text{l}$. The results of other parameters are as shown in tables 1 and 2 below. The measured values of all parameters were higher than the FMENV limits. This is due to higher organic matter in the ponds. There is a great significant variation in the

physicochemical characteristics of the breweries wastewater effluent between the wet and dry season. It was also observed that the treatment ponds are polluted regardless of season and this could be hazardous to human health as vegetable farmers use it to water their vegetable gardens. Additionally, when this water is eventually released into the public drain, they tend to contaminate ground water resources and even open waters such as rivers and streams. These aquatic resources are sources of water for fish aquaculture and capture fisheries for food fish. Invariably, these contaminants pose a threat to human health when fishes captured from such facilities are eaten by man, through bio-accumulation and bio-magnification processes. For effective treatment of this brewery's effluent, it is recommended that standard waste treatment plants must be set up in the industrial estates, and sufficient regulations leading to strict penalties to prevent pollution of the environment must be enacted.

Out of Sight, Out of Mind, Out of Care: On Protected Areas, Fish Diversity and its Conservation in the Congo Basin

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With almost 1300 valid species, the Congo Basin harbours one of the most diverse ichthyofaunas in the world. However, even in protected areas (PAs), this fauna has largely remained undocumented and is often still not included in conservation strategies. The MbiSa Congo project aims to establish an inventory of the fish diversity, distribution, and anthropogenic impacts in ten PAs spread over the basin, i.e. one in the Republic of the Congo, two in Burundi and seven in the Democratic Republic of the Congo. These areas have mainly been established in order to protect large emblematic mammals and mesmerising landscapes leaving their ichthyofauna unaccounted for. Results indeed confirmed an often chronic lack of baseline fish diversity data for most of these PAs. In order to convey the message of conservation and a highly overlooked but diverse fauna, not only in species numbers but in lifestyle as well, three fish species have been designated flagship species for each these PAs. To appeal to a wide-ranging audience – from local fishermen to scientists over hobbyists and laypersons – these species have been selected based on three major attributes: (i) importance for local economy and subsistence; (ii) endemism; and (iii) a peculiar mode of life. In addition, practical recommendations for the conservation of the ichthyofauna in these areas are being formulated. These recommendations are based on the results obtained and field observations made during the project, and include i.a.: (i) regulating fishing gear; locations and seasons; (ii) reviewing park delineations as to include hydrographic units; and (iii) adding some endemic fish species to the threatened species list of each country. It is hoped that (i) by providing these baseline data, (ii) identifying flagship species, and (iii) proposing conservation guidelines the urgent need for and ways to protect this fascinating underwater world can be further emphasised.

Use of Benthic Macroinvertebrate Indices as Bioindicators of Ecosystem Health for the Detection of Degraded Landscapes in Malawi

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A study was conducted in Lilongwe West Rural Development Project (RDP) in central Malawi to investigate the potential use of benthic macroinvertebrates as affordable and cost-effective bioindicators of landscape degradation in Malawi. Benthic macroinvertebrates were studied in two reservoirs, Bunda and Kamuzu Dam I. A total of 778 individuals belonging to ten (10) taxonomic groups were encountered in the two reservoirs: oligochaete worms (30.70%),

bivalves (15.04%), leeches (12.08%), crustaceans (11.18%), chironomids (8.99%), gastropods (8.22%), stonefly nymphs (4.24%), mayfly nymphs (3.60%), caddisfly larvae (2.70) and dragonfly nymph (2.70%). Application of t-tests on community assemblage metrics, pollution tolerance index (PTI), biodiversity and physico-chemical indices showed the two reservoirs differed significantly ($p < 0.05$) in 69 per cent of biological indices and 11 per cent of physico-chemical indices, with Bunda reservoir having less EPT (mayflies, stoneflies, caddisflies), more oligochaete worms, more chironomid larvae, higher Simpson's index (D), lower Simpson's diversity index (1-D), Shannon's index (H), Margalef's (DMg) and Pielou's (J') indices, lower PTI, higher percentage chironomids and lower Secchi disk visibility than Kamuzu Dam I. Results show that Bunda reservoir is fairly polluted with organic matter washed into it from the surrounding farmed landscapes through soil erosion. Deforestation and unsustainable farming practices accounted for landscape degradation around the reservoirs, while Dzalanyama Forest Reserve protected much of the Lilongwe River on which Kamuzu Dam I is located. Landscapes in the catchment area of Bunda reservoir are considered degraded and recommended for restoration through establishment of vegetative land cover. Benthic macroinvertebrates have high potential for use as biological indicators of ecosystem health for the identification of deforested degraded landscapes in Malawi and other developing countries of the tropics.

Interrogating Community Perceptions: Perspectives and Prospects for Devolution of Fisheries Management on Lake Tanganyika

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In the last two decades, the government of the Republic of Zambia has advocated a "paradigm shift" in conservation and natural resource management, away from colonial adopted state over-centralization toward devolution in which local people play a much more active role. Government established formal policy and/or laws for decentralization of administrative functions and devolution of management responsibility and/or authority to local government and local level organizations. The enactment of decentralization policies to facilitate the participation of local communities in resource management was largely due to ineffective use and management of natural resources by the state as a result of lack of resources and capacity to enforce required controls. Fisheries experts have recognized continued resource management problems in the form of progressive decrease in fish catches, disappearance of valuable species, and existence of resource use conflicts. Where then have we gone wrong? This study systematically examined the knowledge base among local community dwellers of southern Lake Tanganyika in order to isolate influential variables. Twenty (20) fishing villages were sampled across all the four (4) strata of Lake Tanganyika from which sixty (60) focus group discussions of up to 12 purposively sampled, knowledgeable and enthusiastic individuals were conducted using a checklist to keep the discussions on track. Key informants were purposively sampled and interviewed, to verify and validate FGD data, as well as to understand different viewpoints, opinions, perceptions and concerns pertaining to collaborative management. Whilst variables discussed are no panacea for the problems, they

provide a basis on which more effective policies and institutions can evolve as well as conjectures for future investigations.

Identification and Mapping of Native Populations of Tilapias in Tanzania

Mariam Ahsadi, Nazael A. Madalla & George Turner

East Africa especially Tanzania has high diversity of native *Oreochromis* spp. These unique populations are well-suited for aquaculture because of their wide range of trophic and ecological adaptations, high disease resistance, high growth rate, high reproduction performance and tolerance to the harsh environments like extreme salinity, temperature and oxygen. Pure native tilapia is threatened by invasive exotic tilapia strains from different water bodies and escapees from fish farms. This poses a risk to stability of ecosystems which could result in extinction through long-term predation, competition and even outcompeting native strains or genetically removing them via hybridization. Recent surveys have indicated that exotics are now found in many water bodies in Tanzania. Assessing or eliminating the threat has been hampered by lack of species identification capacity and difficulty in archiving and accessing distribution data. Therefore this study aims to facilitate identification and mapping of distributions for remaining populations of native tilapias in Tanzania by using Tilapia Map, a smartphone application developed by software company Geosho for Bangor University and the Tanzania Fisheries Research Institute (TAFIRI). Findings from this study will inform practitioners and policy makers on zonation of strains used in aquaculture, importation and distribution of non-native species, ultimately helping to preserve the genetic diversity of Tanzania's native tilapia.

Extent of biological contamination and factors determining its distribution in the nearshore of Lake Malawi

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Communities residing along the shoreline of Lake Malawi depend heavily on nearshore water for washing dishes, clothes, cooking, bathing and drinking. Despite the importance of clean nearshore waters, there are no published studies of biological contaminants in Lake Malawi's shoreline waters. To address this gap, we explore seasonal and temporal trends of biological contamination using *Escherichia coli* (*E. coli*) as faecal indicator bacteria both in water and sand at selected beaches along the south-eastern and south-western arms of Lake Malawi. Results show that 91% of water samples exceeded the World Health Organization threshold for safe drinking water and 53% of all water samples exceeded the U.S. Environmental Protection

Agency standard for recreation. *E. coli* concentrations were highest at beaches of high use (e.g. fish landing sites) than low use beaches (e.g. hotel office). Distance from shore is the most predictive variable of *E. coli* in water. While shoreline water is frequently contaminated, *E. coli* concentrations declined with distance from shore. For example, at 15 m from the shore, *E. coli* concentrations dropped to between 0.3% and 17% of onshore values and this was consistent at both high and low use beaches. These results suggest that if communities rely on lake water for drinking and cooking water, collection at distances greater than 15 meters from the beach could substantially decrease exposure to faecal bacteria. While concentrations of *E. coli* in the onshore areas of Lake Malawi are high, more studies are required to identify the source of this faecal pollution since *E. coli* is ubiquitous to warm-blooded animals. In addition, we need to determine if there is any correlation between *E. coli* concentrations and the presence of waterborne diseases within the sampled areas.

Longitudinal Zonation of Fish Assemblages and Selected Benthic Invertebrates in a Tropical River: Awash River Basin, Central Ethiopia

Meulenbroek Paul, Englmaier Gernot, Graf Wolfram, Leitner Patrick, Tesfaye Genanaw, Aschalew Lakew, Yonas Terefe and Waidbacher Herwig

The present study aimed to clarify the fish and benthic invertebrates diversity of the upper and middle Awash river. Therefore, 650 rkm, from the headwaters in the Chilimo forest (2389 m a.s.l.) to the lowland reaches in the Afar region (570 m a.s.l.) were investigated. During November 2017 and January 2018 (dry season) we collected fish and benthic invertebrates three times at 12 sites along the longitudinal gradient. The sampling sites were selected based on habitat criteria, river morphology and anthropogenic impact. A combination of fishing gears was used (e.g. electrofishing, beach seine, gill nets) to sample a variety of mesohabitats for fish. MZB sampling was performed by benthic sampling (Multi-Habitat-Sampling approach) and using light traps with a focus on Trichoptera fauna. Physical and chemical water parameter were recorded at each site. Microhabitats and river morphological characteristics were quantitatively estimated along with human activities observed. Water temperature (°C) and conductivity ($\mu\text{S cm}^{-1}$) significantly increased from the source region to the lowland zone but showed unusual gradients possibly related to human impacts. The complex geomorphological setting and the river gradient (alternating steep and low gradients) determined the sediment composition. Fish diversity increased from the upstream (S1: 2 taxa) to the downstream sections (S12: 7 taxa), but was highest at site 8 (8 taxa). *Garra dembeensis* and *Garra aff. makiensis* were characteristic for the upper reaches, whereas *Garra sp.* and *Micropanchax cf. antinorii* were frequent taxa in downstream stretches. *Labeobarbus cf. intermedius* was most widespread in the Awash river. The impact of the Koka reservoir was detectable by a decline of water temperature (-2.7°C) and conductivity (-253 $\mu\text{S cm}^{-1}$) but had no observable effect on fish biocoenoses. The alternating steep and low gradient sections of the Awash river determined the succession of fish assemblages. Two clear transition zones (ecotones) were observed where fish communities clearly changed along environmental gradients. The faunal community of Trichoptera indicated three distinctive clusters describing the upper, middle and lower section of the river and additionally corresponded clearly to altitudinal gradients.

Assessment of Community-Driven Interventions as a Strategy for Fisheries Resources Conservation and Livelihood Improvement among Fisher Folk Communities in Lake Victoria, Kenya

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The aim of this study was to assess the effectiveness of implementation of LVEMP supported community-driven development (CDD) sub-projects for sustainability of the interventions. The survey was undertaken through a participatory approach (interviews and focused group discussions) covering 50 groups. Content analysis approach was used to analyze and interpret data collected. The results revealed that CDD approach contributed to not only achieving LVEMP project objectives but also played a key role in empowering vulnerable communities especially the rural poor. This approach should therefore be promoted, replicated upscale in the entire Lake Victoria basin.

Distribution and Abundance of African Lungfish *Protepterus Annectans* (Owen, 1839) In the Orashi and Sombreiro Rivers, Niger Delta, Nigeria

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The study on the distribution and abundance of the African lungfish *Protopterus annectans* in Orashi River and River Sombriero was carried out between October 2013 and September, 2014. Three hundred and forty-seven (347) specimens were sampled. The result showed that the fish was most abundant between April and July, which coincided with the rainy season, with values ranging between 10.95 and 11.24. The study also showed that the fish attained greater weight, same period. This signifies the period of flood and movement of debris and nutrients into the rivers, as food for the fish to support its growth, abundance and distribution.

Toxicity of Zinc Oxide Nano-Particles on Haematological Parameters and Growth Responses of *Heterobranchus Longifilis* Ameliorated with Ascorbic Acid

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The unregulated development, use and release of nanoparticles into the environment induce toxicity in the living organisms by interfering with normal cell processes. This study therefore investigated the toxicity effect of zinc oxide nano-particles on haematological parameters and growth responses of *Heterobranchus longifilis*, by exposing the juveniles to sub-lethal concentrations (0.00, 6.00, 8.00, 10.00 and 12.00 mg/l) of ZnO-NPs in static renewal bioassays for 60 days. The ZnO-NPs-exposed fish were subjected to depuration phase for 30 days, while graded levels (50, 250, 500, and 1000 mg/kg diet) of ascorbic acid (AA) were fed to *H. longifilis* for 30 days. After each experimental stage, fish were sacrificed and blood was collected for haematological assay. The results revealed a reduction ($P < 0.05$) in the values of erythrocytes with increase ($P < 0.05$) in the leucocytes levels compared to control. While a gradual increase and decrease in the values of erythrocytes and leucocytes occurred after the depuration period, however great improvement ($P < 0.05$) and reduction in the values of erythrocytes and leucocytes were recorded in the groups fed on 500 mg AA/kg diet respectively. The percentage weight gain and specific growth rate increased more in 500 mg/kg AA-treated fish than ZnO-NPs-exposed and depurated groups. This is an indication that ZnO-NPs induced physiological disorder in *H. longifilis* but 500 mg/kg AA is capable of ameliorating the toxic effects of ZnO-NPs on fish.

Multivariate Regression and Stochastic Modeling of *Labeo mesops* Catch Fluctuation in the Western Part of Lake Malawi

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Climate change and human population growth have globally emerged to be a serious threat to fisheries resources. In Malawi, the effects of climate change and human population growth have been evidenced by increasing harvesting pressure on the fisheries resource and serious depletion of high commercial value fish species from the major natural ecosystems of Malawi. *Labeo mesops* is one of the species seriously affected. The Western part of Lake Malawi used to have high biodiversity of *Labeo mesops* in the past. Recent statistics indicate otherwise. No scientific evidence has been provided to expound the reasons behind the negative catch fluctuations. To provide scientific bases for policy implementation and formulation, the present study applied multivariate regression models to analyse the factors influencing the *Labeo mesops* catch trend. The study further applied stochastic models to forecast future catch trend as opposed to fishing effort. The *Labeo mesops* catch and fishing effort data were obtained from Monkey Bay Fisheries Research Station of the Malawi Fisheries Department while temperature and rainfall data for Nkhotakota was obtained from Meteorological Department. Using regression models, the study revealed a strong negative correlation between annual *Labeo mesops* total landings and annual precipitation. Similar observation was noted in fishing effort. The t-value for annual rainfall ($t = 1.62$) and fishing effort ($t = -2.39$) were significant ($P < 0.05$) suggesting that annual rainfall and fishing effort significantly affected *Labeo mesops* population trend. The selected ARIMA (2,1,1) model showed that the annual catch trend for

Labeo mesops collapsed five years ago and there will be no catches in the upcoming years (*ceteris paribus*). On contrary, the fishing effort has been fluctuating positively and has been projected from 19.01million to 37.02 million by 2020. Therefore, the study suggests that *Labeo mesops* population requires critical attention otherwise the species will face complete extinction in Nkhotakota natural ecosystems.

Current Status of the Usipa (*Engraulicypris Sardella*) Stocks in the Southern Lake Malawi

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A stock assessment study on Usipa was carried out in five strata in the Southeast arm (SEA) and Southwest arms (SWA) of Lake Malawi. The landing sites were however, separated into SEA (2.1 and 2.3), Upper SEA (2.5 and 2.6) and SWA (3,1 Malembo and Msaka) for ease of data analysis. These were later combined and compared to find the best description of growth and mortality for Usipa. Length frequency data of Usipa specimens were collected monthly from May 2016 to May 2017. The fish specimens were sampled at the beach after landing, measuring the total length of the fish in mm. The length frequency analysis was performed using FISAT II package. Data from all sites were evaluated individually. Growth parameters for the SEA were $L_{\infty} = 141.75$ and $K = 0.54$, for the Upper SEA $L_{\infty} = 141.75$ and $K = 0.66$ whereas for the SWA $L_{\infty} = 141.75$ and $K = 0.94$. Recruitment pulses were generated. Natural mortality was calculated using Hoenig's relationship of $M = 2.98/T_{max}$. LCCA was used to estimate value of F and E . Relative Yield per Recruit was estimated. The following results were obtained: SEA, $F = 0.65$, $E_{calc} = 0.25$, $E_{max} = 0.339$ and therefore no overfishing. The Upper SEA had $F = 2.48$, $E_{calc} = 0.56$ and $E_{max} = 0.347$ hence overfishing occurring. The SWA had $F = 1.75$, $E_{calc} = 0.47$, $E_{max} = 0.364$ thus, overfishing was into play too. When all areas combined, $F = 1.95$, $E_{calc} = 0.50$ and $E_{max} = 0.342$ showing overfishing was happening in the entire Southern Lake Malawi and cause for urgent management decision to conserve the resource which is currently contributing to more than 70% of the total fish production. The study was fully funded by USAID through Fisheries Integration of Society and Habitat (FISH) project.

Prospects and Constraints in Culturing Mangrove Whelks (*Thais coronata* - Lamarck, 1816) in the Niger Delta, Nigeria.

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The mangrove whelk *Thais coronata* commonly known as rock snail is a mollusc species of the Niger Delta. The species occurs in the inter-tidal zone of the region where it is harvested. Its meat provides a source of cheap protein in the coastal towns and villages. Rock Snail is a good species for aquaculture, it grows up to 5cm in length and are dirty grey in colour. They are found in saline waters, like the other mangrove whelks such as *Thais callifera* (Lamarck, 1822) and *Thais forbesi* (Dunker, 1847). The settlement and distribution of *Thais coronata* is determined by the presence of suitable substrates. Knowledge of the breeding habits, larval development and behaviour of the whelks is important for culture purposes. The availability of *Thais coronata* seeds is seasonal. This could mean that the breeding cycle of this species is not all year round. There are no established culture methods for the cultivation of *T. coronata* in the Niger Delta. Culture technique for whelks in Asia and the Americas that can be adopted in the Niger Delta includes; artificial spawning in hatcheries, culture of the juveniles in earthen ponds and raising of the juveniles in designated sea bed, also known as sea ranching. Rock snail is a brackish water species found in prop roots of mangrove and other surfaces in the Niger Delta. The mangrove swamps is the region considered suitable for the culture of this species. The aquaculture of Rock snail is to meet the following objectives; to quickly produce large amounts of rock snail meat to bridge the gap in fish demand, produce gainful employment in rural area and exchange commodity to increase national wealth. The prospects for the culture of this species include; availability of the species, potential exchange commodity, environmental factors etc, while the constraints include; environmental degradation mainly oil pollution, poor infrastructure development of the Niger delta area, inaccessibility to loans and credit facilities etc. Innovative culture techniques practiced in other parts of the world could be adopted in the Niger Delta to culture these species.

Practical Approaches to Implementation of Fisheries Co-management: Experiences from Malawi

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Fisheries co-management has been introduced and implemented in many parts of the world. Different approaches have been used based on the co-management knowledge and experiences of those that have been in the forefront. This paper highlights four approaches that are derived from “Concept-based” and “Knowledge-based” approaches to co-management. The concept-based approach is where co-management implementers have a thorough understanding of the concepts of co-management. This requires having knowledge of what the core elements of co-management are and what processes are required in order to implement it. The knowledge-based approach is where the co-management implementers assess the co-managing partners to establish whether they have the knowledge of the concepts and implementation process of co-management and craft the implementation framework from there. The Malawi experience has shown that there has been a mix up of

approaches to co-management and this has led to different levels of success in its implementation. This paper concludes that core to the success of co-management implementation is the concept of communicative action, where the co-managing partners are able to communicate and constructively forge ahead to implement sustainable co-management arrangements.

Simulating Trade—Offs Between Alternative Fishery Policies and Goals in Lake Victoria (East Africa) Using a Multispecies, Ecosystem Model

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Lake Victoria, located in East Africa, is unrivalled world's number one freshwater fish production system, with fish landings of about one million tonnes per year. Fisheries regulatory frameworks on the lake often strive to strike a balance between profit (from fish sales), social welfare (largely fishing jobs), and ecosystem stability, but this seldom benefits from any scientific input (that would involve systematic analysis of trade—offs between these multiple objectives). In this study, we developed a historical ecosystem model, calibrated to run from 1960 to 2015, to predict biomass changes caused by pursuing each of the economic, social, and ecological goals, and a combination of these multiple goals. We used Ecopath with Ecosim (EwE) software because of the explicit policy exploration modules implemented within the modeling framework and modest data requirements. Our findings show that every management goal is associated with some benefits and losses. Outstandingly, however, fisheries make the greatest losses in profit and fishing jobs when the ultimate goal is to maximise ecosystem structure. The three goals can all benefit, although marginally for ecosystem structure, by optimising either for profit or fishing jobs. However, this cannot be achieved with all the gear types currently operating in the system, and fishing effort has to be significantly reduced for certain gear types, especially longlines. Crucially, this means before prioritization of any management goal, participation of all stakeholders should be ensured so that stakeholders decide for themselves which of the goals to optimize, based on what they would be prepared to sacrifice (which we term as trade—off in this paper). Our model is not a replacement to the existing single species models, which are used for short—term management actions, but is rather intended to complement single—species stock assessment and management by gaining more insight about long—term outcomes of management actions.

The Impact of Plastic Pollution on Aquatic Life and Mitigation Measures

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The low production cost, durability and versatility in the use of plastics has led to its tremendous multi-faceted use and availability in all kinds of environment. Available in diverse environments, these plastics, with relatively low density and improper disposal methods eventually underpin the Marine environment. With a capacity or very slow degradation into nano and microplastics over hundreds of Years and ability to sorp and desorp Persistent Organic Pollutants (POPs) from the environment. Plastic pollution of the Marine environment is a grave threat to marine life and disruption of interdependence in life which is essential for balanced and sustainable living on the earth. Existing frameworks and initiatives for mitigating physical, chemical and toxicological Impacts of plastic pollution on marine life can be expanded, acceded to by more nations, And implementation, especially in developing countries be seriously encouraged. Impacts from plastics such entanglement, ingestion, smothering, bioavailability habitat Destruction and toxicological impacts have been reported. There is much gap to fill by researchers in respect to adequate data that is necessary For Risk Assessment of Seafood safety; and certainty of plastic related chemicals Pathway of bioaccumulation in the aquatic organism through ingestion as opposed to other pathways.

Zambezi Fisheries in Crisis

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The fisheries of the Upper Zambezi and neighbouring river systems including the Kavango and Kwando experienced economic collapse over the past decade. This resulted from a rapid and uncontrolled increase in destructive fishing methods that communities appeared powerless to prevent. Improved access led to influx of migrant fishers, and availability of a lucrative market in the Democratic Republic of the Congo exacerbated the problem. Formerly valuable large cichlid species were severely depleted and replaced in catches by fisheries for small, low value species, notably *Tilapia sarrmanii* and *Brycinus lateralis*. The main fishing methods used are now small meshed (mostly 25-38 mm stretched mesh) monofilament netting, used for seining. In addition, long seine nets made of shade cloth and lined with mosquito netting, bedsheets and similar are widespread throughout the fisheries despite being illegal in all riparian countries. The ephemeral Lake Liambezi was an exception to the rule, with the development of a lucrative fishery for large cichlids after the lake filled in 2009. Although not without problems, this fishery, which peaked in 2012-13 with annual catches of 3,000 t, continued until the lake went into recession in 2016. Progress has been made in Namibia in improving management through the establishment of community-driven Fish Protection Areas and an annual closed season, together with a government ban on monofilament netting, but the situation remains critical.

Establishment and Operation Cage Fish Farming While Safeguarding Integrity of African Great Lakes

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Cage fish farming is increasing on the African Great Lakes (AGLs) and has potential to complement declining capture fisheries, but has proceeded without a clear policy and technical guidance. This can lead to conflicts with other water users, environmental degradation, and economic losses. To mitigate this, we use literature and experiences from different water bodies to propose generic best management practices (BMPs) for cage fish farming on the AGLs. The BMPs require adaptive research and management which involves: adherence to legal requirements and technical guidance involving: planning; site selection (suitability, capability, and mapping); application of appropriate culture practices (culturing native species, suitable stocking rates, maximizing feed efficiency, minimizing contamination, disease surveillance, maintaining production information and use of competent manpower); environmental monitoring; and farm decommissioning. These BMPs should be continuously adjusted and improved through onsite experiments if sustainable cage fish farming is to be achieved on the AGLs.

Predicting Fresh Water Fish Distribution in Gabon

Joe Cutler

Cameroon's volcanic crater lakes are a hotspot for endemic species yet most of the lakes have never been sampled by ichthyologists and few are protected. In 2015 I sampled throughout Cameroon's South West region to catalogue the fish biodiversity. I sampled a total of 9 volcanic crater lakes and 33 rivers, collected nearly 3,500 specimen representing ~80 fish species. Lakes Barombi Mbo, Barombi Kotto and Bermin were the most biodiverse lakes, holding 16, 14, and 11 fish species respectively. Lakes Debundsha, Nachtigal and Edib were fishless. Invasive Nile Tilapia (*Oreochromis niloticus*) were collected in both Lake Barombi Kotto and the Female Lake at Muanenguba. We will discuss these results and the conservation implications.

The Ogooue Megatransect

Joe Cutler

Gabon is developing hydroelectric infrastructure throughout the country and the impacts on freshwater fishes are poorly understood. Many of the proposed dam sites have never been sampled by scientists and we lack data on the diversity and distribution of Gabon's freshwater fishes. How can we inform project planners and conservationists given this lack of basic information? We developed a multiple-species Maxent model to characterize the distribution of the 54 most common freshwater fish species in Gabon and identify biodiversity hotspots. I will then discuss the potential of Gabon's hydroelectric development on freshwater fishes and how to apply this methodology elsewhere in Africa.

First Report Of Monogenean Flatworms From Lake Tana, Ethiopia: Gill Parasites Of The Commercially Important *Clarias Gariepinus* (Teleostei: Clariidae) And *Oreochromis Niloticus Tana* (Teleostei: Cichlidae)

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Lake Tana is the largest lake in Ethiopia and the source of the Blue Nile. The lake harbours unique endemic cyprinid fish species, as well as the commercially important endemic Nile tilapia subspecies *Oreochromis niloticus tana* and the North African catfish *Clarias gariepinus*. Its endemicity, especially within the *Labeobarbus* radiation, its conservation importance and its economic indispensability attract scientific interest to the lake's ichthyofauna. Fish parasites of Lake Tana, however, are hitherto poorly known, and no formal report exists on its monogenean flatworms. For sustainable aquaculture and fisheries development, it is essential to study monogenean fish parasites in these economically most important fish species. Moreover, it remains to be verified whether this unique ecosystem and its endemicity gave rise to a distinct parasite fauna as well. Nile tilapia and North African catfish hosts were collected from Lake Tana in 2013. Nine species of monogenean parasites of two orders, Gyrodactylidea Bychowsky, 1937 and Dactylogyridea Bychowsky, 1937, were recovered. *Gyrodactylus gelnari* Přikrylová, Blažek & Vanhove, 2012, *Macrogyrodactylus clarii* Gussev, 1961, *Quadriacanthus aegypticus* El-Naggar & Serag, 1986 and two undescribed *Quadriacanthus* species were recovered from *C. gariepinus*. *Oreochromis niloticus tana* hosted *Cichlidogyrus cirratus* Paperna, 1964, *C. halli* (Price & Kirk, 1967), *C. thurstonae* Ergens, 1981 and *Scutogyrus longicornis* (Paperna & Thurston, 1969). Conclusions: Except for *M. clarii*, all species represent new records for Ethiopia. This first study on the monogenean fauna of Lake Tana revealed that the lake's North African catfish, as well as its endemic Nile tilapia subspecies, harbour parasites that are known from these host species elsewhere in Africa.

Keywords: *Cichlidogyrus*, *Dactylogyridea*, *Gyrodactylidea*, *Gyrodactylus*, *Macrogyrodactylus*, *Monogenea*, *Perciformes*, *Scutogyrus*, *Siluriformes*, *Quadriacanthus*

Theme 3: Fish and Food Security in the 21st Century

Enhancing the Contribution of Fisheries to Food and Nutrition Security in Africa

Julia de Bruyn

Despite some progress in improving nutrition at a global level, sub-Saharan Africa remains the region with the highest levels of undernourishment. Around one in three children under five years of age (31%) suffers from chronic growth restriction or stunting, one in ten adults (11%) and one in twenty children under five (5%) are obese, and anaemia affects over a third of women of reproductive age (38%). Food systems across Africa must respond to these diverse nutritional challenges, alongside variable climatic conditions and finite natural resources. Fish provide a rich source of high quality protein, a range of micronutrients and fatty acids essential for cognitive development and function. In many resource-poor settings, they are the most accessible form of animal-source food and greatly enhance the nutritional adequacy of diets based largely on starchy staple crops. Beyond their own nutrient content, animal-source foods also increase the uptake of nutrients such as iron from plant-source foods. Output from capture fisheries has remained relatively stagnant in recent decades, while dramatic growth in aquaculture has been driven by population growth, rising incomes and urbanisation. Further research is needed to understand the impact of a transition from capture fisheries to aquaculture on food and nutrition security – both in terms of the nutrient profile of fish products and their accessibility to vulnerable populations. This presentation will discuss the most recent data on national fish production and consumption across the African continent. The multiple pathways linking fisheries with human nutrition will be discussed, along with opportunities for future research and interventions to sustainably enhance food and nutrition security in Africa. Effect of lipid levels on reproductive performance of *Oreochromis karongae* (Trewavas 1941)

Consumer Analysis of Fresh Caged Tilapia in Malawi, a Case of Lilongwe Urban: A Discrete Choice Experiment Approach

Francis Jiva

The study used both descriptive and inferential statistics and Choice Experiment (CE) to analyze caged Tilapia consumers in Lilongwe urban, Malawi. The CE included color, size, selling type, source of the fish and price as the attributes for the product. Using consumption frequencies, the results showed that the low density areas which are characterized by high income consumers were the target market for the caged tilapia. Results from a Multiple Linear Regression (MLR) showed that income and Location significantly affects consumption frequency of fresh Tilapia. Further, results from the CE using Mixed Logit model revealed that consumers were heterogeneous in their preference for these attributes. The Willingness to pay estimates indicated that the most important attributes were firstly fish coming from the Lake, well packaged, Silver color and Large (in that order). The study also interacted the fish attributes and the consumers' socio-economic factors to find their effect on preference.

Options For Out Scaling Solar Tent Fish Dryers for Fishing Communities in Mangochi and Salima Districts of Malawi

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In an effort to improve the supply of quality dried fish, a solar tent fish dryer for Lake Malawi fisheries has been designed. Several experiments and studies have shown that solar tent fish dryers are effective in reducing physical and quality post-harvest losses and improving the organoleptic qualities of dried fish. Sufficient demand for the technology has been established through willingness to pay studies. The remaining question as regards out scaling the technology is how best we can promote it. This study assessed options for out-scaling solar tent fish dryers for fishing communities in Mangochi and Salima districts of Malawi to inform the out scaling processes. Particularly, the study compared fish processors that used the technology in a group (comprising of 15 to 20 members) and those that used the technology as private individuals. There were four (4) groups and four (4) individuals that owned and utilized the technology. Study results had shown that most respondents (94.2%) indicated that the technology is good to be promoted and adopted by other fish processors country wide so as to reduce fish post-harvest losses and to maximize profits. However, respondents expressed concern that it is challenging to work in a group when utilizing the solar tent fish dryer because of lack of adequate space inside the structure to be used by all group members (20.5%); Laziness of other members (“social loafing – the case of the Free-Rider (20.7%); Conflicts and quarrels among group members (15.0%); Difficulties to manage and maintain the structure in a group (11.2%); Lack of trust of each other (5.6%); and benefits not shared equally (0.9%). Most respondents (84.3%) indicated that they preferred individual option than group option when it comes to ownership and utilization of the fish solar tent dryers because there are more benefits in an individual option as compared to the group option. The study concludes that most people prefer to own and use solar tent dryers as individuals but they cannot afford to construct and own the dryers privately. This provides lessons for scaling out strategies as it is always the case for capital intensive technologies such as solar tent fish dryers to be scaled out through formation of groups. In this case, individuals may need support that would improve their access to capital to enable them acquire the technologies.

Gender Division of Labour and Economic Returns to Labour: Analysis of Activities among Men and Women in Ilaje/Eseodo Coastal Area of Ondo State, Nigeria

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The fisheries and aquaculture sector is estimated to provide direct employment and revenue to 200 million people. The increasing demand on the sector is met by both large-scale, industrial production systems and small-scale/artisanal production systems. Fisheries enterprises extend from micro-livelihood enterprises to large multi-national corporations. Those who work in fisheries businesses, directly and indirectly, may be labourers through to top level executives and owners. World Bank 'Hidden Harvests' study, 2012 showed that nearly half of the workers in the fisheries sector are women, concentrated in but not limited to the processing sector and marketing jobs. Labour is a very vital factor in the efficiency and budget of the artisanal sector. While the Nigerian fish farming is a strongly male-dominated industry, fisheries activities in the coastal areas are actively carried out by both men and women. The gender division of labour in fishing communities is usually noticeable and hence calls for some economic consideration. Fishing is an economic activity that tends to be dominated by men, while women typically labour as processors, teachers, health carers, commerce, or other services. This paper examines the various fisheries activities among the men and women of Ondo state coastal areas and analyses the returns to labour based on the division of labour among them. Results showed that women play a critical role in every link of the value chain in the small-scale fisheries, although their best-known roles are in processing and marketing of fish and other fishery products. The paper further accentuates the fact that highly gender-segregated division of labour of men fishing/women processing is a major factor in the fishery. The paper suggests processes that can be introduced to improve women's participation and decision-making in the coastal small-scale fisheries outside the conventional approaches based on traditional or "typical" gender roles.

Socio –Economic Aspects of the Tana Delta Fisheries

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Kenya's Tana River Delta is a vast wetland complex, which is a home and source of livelihood to farmers, fishermen and a dry season grazing area for pastoralists from within and outside the Delta. The Delta is rich in flora and fauna and is designated as a wetland of international importance under the RAMSAR convention. The Tana Delta wetlands, which support numerous lives, are now becoming seasonal, while others have dried out completely. Data was collected through semi-structured interviews and focus group discussions in various landing beaches and fish markets in the Tana Delta. The most common species were identified to species level. Catch statistics data for the present and previous years was given by the Department of Fisheries. The most common fishing methods recorded include the use of gill nets of various mesh sizes, hooks and lines and the use of traditional traps called migono. The most common fishing vessel all over the delta was the use of dugout canoes that was operated by two to three fishermen. The most active fishing spots during the dry season were Lakes Moa, Chakako, Tamaso and fishing camps at Ozi, Kau and Mbililo. Many other lakes including Lakes Shakababo, Kongolola, Junji and Lango la simba were dry during the dry pre-flood season but an important fishing grounds during the during the flooding season. On

average, fishermen harvest approximately 2kgs/day during the dry pre-flood season and approximately 20kgs/day during flooding seasons. Fishing was mostly carried out by immigrant communities from the western region of Kenya, of Luo origin followed by Luhyas and the Manyala. Pokomo are the original fishermen in the delta and fish using mostly traditional fishing gear. Fish preservation was carried out using methods commonly applied by the immigrant communities for centuries in western Kenya - drying and smoking. Though fisheries have reduced in most flood plains, fishers continue to apply more effort in fisheries. They however have highly mixed livelihood strategies showing adaptation to more intensive farming and livestock production. Floods are also an important occurrence to fishermen since they come with increased catches and more income to the fishermen. Aquaculture has been recommended to supplement fish production and sustain fishermen livelihoods.

Fish Trade in Africa and its Implication to Aquatic Biosecurity in the Great Lakes Region

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Aquaculture is increasing as an alternative to reduce pressure on natural fish stocks in the Great Lakes Region. However, the risk of spreading Trans-Boundary Aquatic Animal Diseases (TAADs) through uncontrolled movement of live fish and lack of information on biosecurity measures in the EA region, threatens the development of aquaculture industry. A risk assessment resulting from fish trade and listing of important aquatic diseases that

impact on aquaculture development was conducted in the Eastern (Kenya, Rwanda and Uganda) and Southern (Mozambique, South Africa and Zambia) corridors of the SubSaharan Africa. The two corridors are challenged with regulating movement of live aquatic materials. Consequently, live materials continue to be shipped across borders without proper certification. Furthermore, regional expertise on fish health management is inadequate while the fisheries sector is growing. Coordination on aquatic disease management is minimal or non-existence among and within Member States. Therefore, member states will have to engage regional bodies like Lake Victoria Fisheries Organization (LVFO) and continental like AU-IBAR to establish mechanisms of controlling trans-boundary infectious fish diseases. This study identifies gaps in policies and management strategies, and recommendations to improve the aquatic biosecurity measures in the region. Therefore, Member states have the mandate to establish an effective regional biosecurity strategy that enhance fish trade but also protect the aquatic

biodiversity. Fish trade is increasing and dynamic, therefore, regional strategic health plans should be inclusive enough to ensure equity among main actors of the value chain. However, this can only be realized if the capacity of key stakeholders for example Custom Officers, Veterinary/Fisheries agents, scientists, traders, fish farmers and policy makers) is strengthened and functional. Consequently, healthy fish products will penetrate prime markets (regionally or internationally), and this will stimulate or improve fish production, nutrition and livelihoods.

Economic Assessment of Usipa (*Engraulicypris sardella*) Postharvest Losses in Manchochi District

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Fish and the fisheries sector are of great social and economic importance to Malawi. The sector plays a very significant role as a source of nutrition, income and employment. Fish provides over 60% of the dietary animal protein intake of Malawians and 40% of the total protein supply. In Malawi, the fisheries sector is divided into two: the aquaculture and capture fisheries (Banda *et al.*, 2005). Capture fisheries is projected to be the dominant supply of fish for many developing countries (World Bank, 2013). In Malawi, capture fisheries consist of 96% of the total fish caught dominated by Usipa (*Engraulicypris Sardella*) (GoM and EU, 2009). Food losses take place at production, postharvest and processing stages in the supply chain (Parfitti *et al.*, 2011, Abelti, 2016). Post-harvest food losses are measurable qualitative and quantitative food loss along the supply chain starting from harvest till consumption (De Lucia and Assennato, 1994, Hodges, Buzby and Bunnett, 2011). Fish is a very perishable commodity, hence susceptible to high post-harvest losses (FAO, 2011; Karungi, 2004). Locally processed fish fetch a low price resulting in low profit margins of fish processors and traders (Commonwealth & GIZ 2007, Kapute, 2008). Lack of information on profitability has also led to undervaluing of the fisheries sector, its efficiency and contribution to agriculture. (Tunde, *et al.*, 2015; Motaleb, *et al.*, 2013). Other studies have also pointed out that there are major gaps on the quantification of PHL in Sub-Saharan Africa. They emphasize that more quantitative evidence of the actual level and kind of PHL across different commodities including fish needs to be done (FAO-World Bank, 2010; Gustavsson *et al.*, 2011; Parfitt *et al.*, 2010; Prusky, 2011). Therefore, the study responds to policies that are in play in Malawi and will also provide information on loss levels along the post-harvest fish value chain in Mangochi district. The objectives of the study is therefore to measure post-harvest fish losses along the fish value chain, assess the profitability of fish actors along the fish value chain and to determine factors that influence post-harvest losses along the fish value chain. The study will use both purposive and simple random sampling to select the sample size of 368. Fishers, fish processors, fish traders and other fish stakeholders who have knowledge of post-harvest losses will be targeted for interviews

Advances in Capacity Building for Training and Research in Health of Aquatic Resources in East and South African Region: A Case of Sokoine University of Agriculture, in Morogoro, Tanzania

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In the developing world including countries in the Eastern and Southern Africa (ESA), there is a significant documented knowledge gap on health of aquatic resources and environmental stressors. This includes lack of understanding of aetiologies, diagnostics and management of diseases in aquatic animals and other resources through preventive and control measures. Lack of knowledge hampers the socio-economic development of aquaculture and fisheries industries in the region, precludes evidence-based policies and decision-making and also has societal implications. There is also a need to build competence for monitoring and protection of wild freshwater and marine resource populations which are essential for food and nutritional security, employment opportunities and income generation in the region. In cognisance of these challenges, in 2013, six Universities, including one in Norway and five in East and South African Region embarked on innovative training and research programme with key activities centred at Sokoine University of Agriculture in Tanzania. This paper presents the genesis, current initiatives and projections towards Capacity Building for Training and Research in Health of Aquatic Resources in the East and South African Region. It sheds light on key achievements towards workforce development at Post-doc, PhD, MSc, BVM/BSc and Diploma levels; scientific and popular publications in this field; and development of the African Centre for health of Aquatic Resources at SUA. The state of viral, bacterial, fungal and parasitic infections and diseases of socio-economic importance have also been highlighted. It is concluded that, the capacity building for training and research at SUA and its satellite centres at Makerere University, University of Zambia, University of Nairobi and the Institute of Marine Sciences in Zanzibar are key regional footprints for optimising productivity and trade of fish and fish products through enhanced disease management practices.

Community Governance and Decentralization of Fisheries Management in Malawi: Case of Lakes Malawi (South), Malombe, Chilwa and Chiuta

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In this paper, we present findings on the preliminary governance analysis focusing on recent efforts to strengthen community fisheries governance in Lakes Malawi, Malombe, Chiuta and Chilwa. We used a governance analytical framework which highlights the different nature of governance reforms and reflects in particular distinction between deconcentration, devolution and decentralization to assess the co-management programmes implemented in these water bodies. From the analysis, it appears that donor funded programmes on strengthening fisheries governance in these water bodies have been successful. Legally binding bylaws are key to sustainable management of fisheries resources. However, interference by Traditional Authorities and lack of implementation modalities to distinguish self-financing mechanisms by LFMA and mainstream district council revenue collection mechanisms poses a challenge to effective co-management. The inability of deconcentrated agencies in district councils to provide adequate backstopping support is further demotivating the LFMA. This paper concludes that effective co-management demands an enabling environment that provides authority and power to resource users and government to implement co-management. However, there is need for accountability by LFMA to fisheries stakeholders to gain trust and support in implementing co-management.

Aquaculture of the Endemic Tanganyikan cichlid *Boulengerochromis microlepis* – the New Salmon of the Tropics?

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The inland fisheries in African Rift Valley lakes are facing increasing problems due to overfishing, such that novel aquaculture strategies need to be developed, to meet the high demand for food fish. Moreover, it is important to consider future problems of foreign fish introductions, which frequently occur by accidental escape from ponds or cages. Therefore, local fish species are the best candidates for novel aquaculture strategies. While local *Tilapia* species, such as *Oreochromis tanganyikae* in the Lake Tanganyika drainage and *O. andersoni* in the lower Zambezi are already at an advanced stage of establishment in aquaculture, larger predatory species are not yet available, as their diet and breeding issues remain to be solved. The endemic Lake Tanganyika cichlid species, *Boulengerochromis microlepis*, with up to 80cm total length (the largest cichlid in the world), is a highly promising candidate for future aquaculture production in ponds and cages. First trials are underway, but no results concerning rearing, diet and breeding have been published so far.

Here we present first results on the successful rearing of “Nkupi” from small fingerling size to adulthood in a large aquarium, and present an adequate pellet diet that can also be adapted for the use in cage culture. Breeding was also successful in large aquaria in 2017, so that all basics seem to be in place to seriously consider this species as the future salmon of the tropics.

Possible Impacts of Climate Change on the *Chrysichthys nigrodigitatus* Fishery of the Cross River, Nigeria.

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Chrysichthys is a prized food fish in Eastern Niger Delta of Nigeria. The species is commercially very important as it forms the most important freshwater single species of commercial interest. The species is known to be abundant during the rainy seasons though catches are found all year round. This study was aimed to investigate the exact influence of rainfall on the species and its fishery. A twelve month time series was conducted from January 2017 to January 2018. Catches and hydrographic parameters were monitored fortnightly in the middle and lower reaches of the river. Catch abundance occurred between May and September with a peak in July. Catch per-unit effort rose from 1.65kg/unit effort in March to a peak of 31.4kg/unit effort in July. This coincided with the peak of rains. Specific influence of rainfall included habitat expansion and provision of refuge against predation due to increase in depth and flooding to the terrestrial vegetation. Results show that reproductive migration is initiated by rainfall; gravid females were more abundant in the catch after the heavy rains in April. Health indices like condition factor and hepatosomatic index increased from the months of April to June. Gonadosomatic index dropped in the month of May, signifying the commencement of spawning. Most of the fishers in the riverine communities migrated upstream because of flooding. The implication is that changes in the climatic phenomena can lead to adverse impacts for the fishery. Climate change could possibly alter the phenology, that is, annual timing of life history events, of the fish. This could lead to a mismatch of suitable events, with adverse impacts on the reproductive success of the population. We advocate a wide spread domestication of the species as an important adaptation to climate change impacts.

Towards Challenges for Sustainable Fisheries Management and Beyond In Burkina Faso, West Africa

Raymond Ouedraogo, Paul Meulenbroek, Jan Sendzimir, Adama Oueda and Andreas H. Melcher

A number of challenges, including climate change and population growth, threaten the fair and sustainable availability of water and fisheries. In response to threats of chronic water scarcity and episodes of severe drought, since 1950 hundreds of reservoirs were created to provide a dispersed network of water storage facilities throughout Burkina Faso. As fisheries, these reservoirs also became important new sources of food. However, pressures of overfishing, intensive agriculture and sedimentation threaten the services these reservoirs provide. To establish sustainable management of natural and man-made aquatic systems, Burkina Faso requires methods and tools for the assessment of water and river health as well as the environmental impacts on riverside society. However, inland fisheries production has plateaued at the same time that quantity of riverine fish has dramatically declined. Experience made will help to implement activities that are socially, politically and scientifically relevant for improvement of techniques in aquaculture.

GIZ Baseline report for Aqua value chain in Malawi

Ladislao Di Dominica /Baird Chilora

GIZ Malawi

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH supports the German Government in achieving its objective in the field of international cooperation for sustainable development. The Globalvorhaben (Global-Programme) (GV) Fish, implemented by GIZ, is part of the special initiative One World - No Hunger (SEWOH), funded by the German Ministry for Economic Cooperation and Development (Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung, BMZ), which aims at reducing extreme hunger and poverty in selected countries, including Malawi. GV Fish contributes to this objective by implementing sustainable fisheries and aquaculture projects with a focus on artisanal practices. In Malawi, GV Fish is being implemented by The Aquaculture Value Chains for Increased Income and Food Security Project (AVCP). AVCP has as its counterpart the Ministry of Industry, Trade and Tourism (MoITT), with technical co-operation with the Department of Fisheries, Ministry of Agriculture, Irrigation and Water Development, (MoAIWD). The AVCP commenced in January 2018 and will run until February 2022. AVCP's overall objective is to support the development of Malawi's aquaculture sector to increase the availability of fish products and income from sustainably operated small and medium size aquaculture businesses. While fish farmers are the core focus group of the project, the project strives to develop the entire value chain in which these farmers are embedded. This will occur by strengthening capacities of fish farmers, by enhancing fish farmers' organizations and by supporting the institutional framework required for the implementation of sustainable aquaculture practices. According to country size and regional differences in terms of aquaculture potential, primary target areas for intervention have been defined within the framework of a preparatory study, conducted by Imani Development for GIZ in 2017. As an outcome, Blantyre, Salima, Mzuzu and their 75 km radius have been selected. To identify the exact areas of intervention at District level, a base-line survey will be carried out from June until September 2018. The baseline survey adopts a study design combining quantitative and qualitative research methods while assessing 400 fish farmers, 800 consumer households and 100 supply chain actors. The sampling and preparation for the baseline study have been finalized during a participatory process involving GIZ, extension officers from the DoF and the consulting firm Imani Development, in charge of carrying out the survey. The results of the base-line study will be recorded in a final report which will be presented during the PAFFA Conference 2018.

Gis Mapping of Informal Fish Trade Routes Used by Traders between Malawi and Neighboring Countries

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The study focused at mapping of informal fish routes used by fish traders in cross border fish trade between Malawi and neighboring countries. A route labelling method using questionnaire survey and observation as described by Ramming, (2002) was adopted and used for the study where GPS coordinates for boundary entry and exit points were captured and uploaded in ArcGIS as a shape file. GoogleEarth® was used to get points for sources and destinations of fish products away from the data collection sites through marking of placements on all interacting points. The results indicate that fish traders involved in informal cross border trade leave the formal routes when approaching the border sites and use routes that bypass the border sites and rejoin the main route after crossing the official border sites. Fish traders use informal routes because of excessive government protocols for formal cross border fish trade, availability of unmonitored exit and entry points, lack of required travel documents for importing and exporting fish products, and tax avoidance. The study recommends that the Fishery Authorities and Non-Governmental Organizations' (NGOs) in the fisheries sector should facilitate review and amendment of cross border trade related policies that are perceived to be restrictive by fish traders, deploy vehicles to border posts for regular patrols along informal fish trade routes and encourage informal fish traders to form clubs or associations to reduce the cost of licensing with department of fisheries as resources will be poured together.

What Makes Farmers Try New Aquaculture Technologies? Predictors of Adoption Behaviour Among Smallholder Farmers in Kenya, Eastern Africa

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Aquaculture technologies have developed and advanced rapidly in recent decades, but not all technologies have been readily adopted by farmers. Few studies fully capture the complexity of drivers and behaviours which contribute to the adoption of key technologies by fish farmers. In this study, we aim to (1) understand the factors that influence fish farmer's perceptions, attitudes and behaviours towards technology adoption and (2) investigate the relationship between technology adoption and the associated socioeconomic impacts. We present an analytical framework that combines both extrinsic and intrinsic variables influencing farmers' decisions to adopt new aquacultural technologies and apply the framework to technology adoption. We collected data between July 2017 and February 2018 using digitised structured questionnaires installed in Open Data Kit (ODK) and administered to 331 randomly selected smallholder farmers in Kenya. We analysed these data using descriptive statistics and logistics regression. Regression analysis results show that predictor variables including greater than secondary education (OR, 4.46; 95% CI 2.33–8.53; $p < 0.01$), the

presence of diversified on-farm agricultural activities (OR, 3.86; 95% CI 1.14–13.11; $p=0.01$), farm size (OR, 3.39; 95% CI, 1.14–10.04; $p=0.03$), and high productivity status (OR, 2.02; 95% CI 1.20–3.38; $p=0.01$), and participation in extension training (OR, 4.15; 95% CI 1.98–8.70; $p<0.01$) were significantly associated with higher adoption of aquaculture technologies. Similarly, three technology characteristics proxied by increase in yield (OR, 2.34; 95% CI 1.09–5.00; $p=0.02$), ease of understanding (OR, 2.10; 95% CI 1.27–3.48; $p<0.01$) and ease of handling of technologies (OR, 1.84; 95% CI 1.07–3.15; $p=0.02$) were significantly associated with higher adoption of aquaculture technologies. Conversely, farmer's age, occupation and household size had a significantly negative association with adoption decisions. Majority of farmers (80%) stated that technology adoption is significantly associated with increase livelihoods outcomes proxied by increased fish consumption (OR, 4.57; 95% CI 1.36–15.38, $p=0.01$) and increased incomes and profits (OR, 5.40; 95% CI 1.88–15.50). Based on composite scores, farmers decision to adopt new technologies are primarily motivated by perceived usefulness (PU) and perceived ease of use (PEOU) of technologies. In conclusion, fish farmers tend to adopt technologies that are perceived to be more advantageous than others in terms of productivity, profitability, ease of understanding and ease of management; as well as those with greater contributions to the diets of low and medium income consumers. We recommend that future studies aiming to understand the adoption process of aquacultural innovations takes into consideration both extrinsic and intrinsic variables simultaneously rather than separately to better understand the decision-making process.

Analysis of Large-Scale Fishing Effort Allocation and Fishers' Behaviour in Lake Malawi through a System Approach

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In this paper, we analyse the fishing effort allocation among large-scale fishers in the commercial fishery of Lake Malawi. These fishers use pair-trawlers and stern trawlers with diverse exploitation techniques which are modeled on bottom and semi-pelagic trawling regimes depending on the target fish species. Using a system analysis approach i.e. an integrated multi-disciplinary analytical framework where emphasis is put on the interactions (linkages) that exist between the different components of the fisheries, we attempt to identify the biological, economic and social mechanisms which govern the fishers' effort allocation as opposed to the dictates of the existing licensing scheme. The analysis shows that the seasonal dynamics of the whole system is essentially dictated by levels of fishing investment and expected returns, presence of appropriate infrastructure on landing sites and fish marketing opportunities, among others. Although the results are not exhaustive, the analysis also shows that the fishers' individual rationality is in fact "overcome" by a set of collective and individual constraints related to continued illegal fishing practices (IUU fishing), non-submission of catch returns and discretion of the fishery management authority. This explains the common phenomenon of fishers continuously applying for relocation of fishing areas and landing sites.

Impacts of Illegal Fishing Gears on Persistence of Nile Tilapia in Fergussons' Gulf in Lake Turkana, Kenya

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Fishing gears are selective by nature. Well-managed fishery catches most of available species at sizes that promotes persistence which is widely achieved through application of mesh size regulations aimed to protect small fish and target big. The study purposed to find out why Lake Turkana fish populations seemed persisting despite increased use of illegal fishing gears and rejection of mesh size regulations. Total length (TL) data for most commercialised Nile tilapia caught using illegal gill nets of 50.8 mm, 76.2 mm and 101.6 mm and legal ones of 127 mm and 152.4 mm sizes were used in simulating fishing regimes using Thompson and Bell (1934) model in the R package version 1 (Taylor, 2014). Simulation followed fish cohorts from first age at capture (t_c) to maximum age (t_{max}). This assumed that vulnerability of fish to capture (p_{cap}) increases with age and catch at age depends on fishing effort and the p_{cap} . The key results are that yield per recruit (YPR) increases with mesh size though Tilapia's was slightly lower at legal mesh sizes but somewhat optimised at illegal ones. Spawning potential ratio (SPR) and escapement spawning biomass (ESS) were average when very small and very large mesh sizes were considered. In conclusion, small illegal mesh sizes are likely the reason behind persistence since they pose a short vulnerability window to the fish which consequently grows faster past such window and can further replenish the stocks than legalised mesh size. The study recommends further research with a larger scope of the entire Lake Turkana open waters or any other African inland fishery.

Sustainable Aquaculture as an Alternative to Overfishing: Valorization of Local By-Products in the Diet of *Clarias gariepinus* (Burchell 1822)

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Overfishing, aquatic ecosystem degradation and the decrease in supply of stocks and increasing demand for aquaculture affect the availability and cost of fishmeal. Therefore, alternative animal protein sources in aquaculture feeds has become a research priority. In this study, the effects of replacement of fishmeal (FM) with chicken viscera meal (CVM) on growth, body composition and production of *Clarias gariepinus* fingerlings (initial body weight 11.3 ± 0.1 g) was studied for 90 days. Three isonitrogenous (43 % crude protein) and isoenergetic (20 KJ/g) diets were formulated to containing 0% (diet CMV0), 30% (diet CVM30) and 50% (diet CVM50) of chicken viscera meal (CVM), as FM replace. Diet CVM0, without CVM, acted as a control whereas the commercial diet Coppens developed for *C. gariepinus* was used to validate the experimental design. Feed intake value (247.17-262.0 g) was similar in fish fed Coppens, CMV0 and CMV50, and significantly higher in fish fed CMV30 ($p < 0.05$).

Percentage weight gain (range: 1900.0-2008.2%), specific growth rate (3.33-3.40% day⁻¹), protein efficiency ratio (1.95-2.09), yield (98.2-105.0 kg.acre) and annual production (398.4-425.7 kg.acre⁻¹ year⁻¹) were similar in fish fed Coppens, CMV0 and CMV30 diets ($p < 0.05$). Values obtained for these parameters in fish fed CMV50 diets were significantly lower ($p > 0.05$). Food conversion ratio (1.11-1.19) was significantly higher in fish fed CMV50 diets ($p < 0.05$). Body protein content was similar in all the treatments ($p > 0.05$). Lipid content in fish fed with CVM-based-diets was significantly higher, whereas ash significantly decreased ($p < 0.05$). The study demonstrated that up to 30 % of CVM could be incorporated in the diets of *C. gariepinus* without negative effects on growth and whole-body composition. Therefore, we recommended that CVM could be used to partially replace the expensive and imported FM.

The Impact of Inter-Specific Hybridisation on Growth Traits of African Catfish (*Clarias gariepinus*) Burchell, 1822 From Fry to Fingerling Stage

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The long-term sustainability of aquaculture sectors critically depends on the development and use of genetically improved stocks for cost-effective productions. A genetic improvement study was initiated to investigate impact of hybridisation on growth performance traits of African catfish *Clarias gariepinus* (Burchell, 1822). A comparative study was conducted on three breeds (Hybrids, Selective and Pure breeds) of *C. gariepinus* reared from fry to fingerling stage in concrete tanks for a period of three weeks at National Aquaculture Centre, Domasi. A stocking density of 60 fish per cubic metre was used and replicated three times. The results showed a significant difference in growth traits among the three strains, with hybrid strain exhibiting highest rates of growth 1.83g, as compared to selected breed 1.17g and pure breed 1.73g. There was no significance in Feed Conversion Ratio 2:1 among the breeds. The survival rate from fry to fingerling stage was higher in selective breed 80% as compared to hybrids 70%. Inter-specific hybridisation of fishes have been used as a useful genetic improvement tool for aquaculture and stocking programmes for several reasons such as: to increase growth rate, transfer desirable traits between species, combine desirable traits of two species into a single group of fishes, reduce unwanted reproduction through production of sterile fish or mono-sex offspring, increased harvestability, increase environmental tolerances and to increase overall hardiness in culture conditions. Despite its widespread use, there is a general impression that inter-specific hybridization is not a very useful tool for aquaculture. This impression stems from inaccurate reporting of some useful hybrids, limited testing of strains used for hybrids and from early work on salmonids that did not result in hybrids of commercial advantage. Nonetheless, the results from this study imply that inter-specific hybridisation may be an important tool which can be used in Malawian aquaculture industry in order to produce desirable strains of *C.gariepinus* with increased growth rates as compared to the wild or parent strains.

Changes in Haemato-Biochemical and Immunological Parameters and Disease Resistance in *Clarias Gariepinus* Fed with *Moringa Oleifera*-Based Diets Pre and Post-Challenge with Various Concentrations of *Aeromonas Hydrophila*.

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This study investigated the extent of changes in haemato-biochemical and immunological parameters of *Clarias gariepinus* fed with *M. oleifera*-based diets before and after challenge with different concentrations of *A. hydrophila*. *Moringa oleifera* powdered leaves were added to five experimental diets at 0%, 3%, 6%, 9% and 12%, designated D1, D2, D3, D4 and D5, respectively. Each diet was randomly fed to triplicate groups of 45 fish (32.49 ± 0.27 g) for 45 days. There were no significant differences ($P > 0.05$) in WG, FCR and SGR between treatments. There was an increase in WBC, RBC, HGB and HCT with increasing *M. oleifera* levels. No significant changes ($P > 0.05$) were observed in AST, ALT, ALP and LDH levels between treatments. After 45 days, fish from each treatment were injected with varying concentrations (0, 1×10^6 cfu, 1.5×10^6 cfu, 3×10^6 cfu and 4×10^6 cfu ml⁻¹) of *Aeromonas hydrophila*. There was a significant decline in RBC, HGB and HCT of fish in the D1-D3 compared to the D4 and D5 groups. There was an increase in AST, ALT, ALP and LDH in the D1-D3 groups while no significant changes ($P > 0.05$) were observed in the D4 and D5 groups between bacterial concentrations. Survival rate was lower in the D1-D3 compared to the D4 and D5 groups, indicating that immunity was enhanced in fish fed with the highest *M. oleifera* inclusion levels. NBT and lysozyme activities were also lower in the D1-D3 groups compared to the D4 and D5 groups. The enhancement of immunity is attributed to the presence of biologically active compounds with immunostimulatory properties. The phytochemistry of the *M. oleifera* revealed high levels of total polyphenol, total phenols, total flavonoids, carotenoids, vitamins C and E.

Growth performance of Nile tilapia, *Oreochromis niloticus*, Chinese Cabbage and its Economic Benefit in Integrated System

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A study was carried out aimed to evaluate the growth and economic benefit of Nile tilapia and Chinese cabbage under integrated system. A total of nine ponds were used, three ponds treated with feed only, another three ponds with chicken manure only and the last three ponds with chicken manure with supplementary feed. Fish were fed 5% of body weight and the fertilization rate was 30kg/pond for every two weeks. Water from the three treatments was used to irrigate nine vegetable plots. Among these plots three were irrigated with water from ponds treated with feed only, another three plots with water from ponds received manure

only and the last three plots with water from ponds received manure with supplementary feed. Water samples for plankton analysis were collected from fish ponds in all treatments using a bucket with a capacity of 20 litres and filtered using plankton net of 20 µm mesh size and preserved using 4% formalin. Counting of zooplankton and phytoplankton was done using sedge wick rafter under microscope using magnification of x40. Weight of individual fish was measured monthly in each treatment using weighing balance. Growth performance of Chinese cabbage was monitored by measuring diameter and length of leaves using a ruler and counting the number of leaves after every two weeks. Cost benefit analysis was conducted at the end of the experiment using the revenue and variable cost information. The experiment lasted for 6 months. Differences on fish and Chinese cabbage growth performance among the treatments were analyzed using analysis of variance (ANOVA). Results showed that there was significant difference ($P < 0.05$) on growth performance of *Oreochromis niloticus* among the treatments. Fish in ponds received manure and supplementary feed had significantly higher final weight, weight gain, specific growth rate and yield compared with ponds received manure and feed only. Yield from ponds received manure with supplementary feed had twice as much as yield from ponds received feed only and almost three times from those received manure only. However, there was no significant difference on survival rate among the treatments. Four groups of phytoplankton and three groups of zooplankton were recorded from fish ponds. There was significant difference on plankton abundance among the treatments, the highest being recorded in ponds received manure with supplementary feed followed by manure only. Zooplankton was significantly higher in ponds treated with manure with supplementary feed than manure and feed only ($P < 0.05$). Furthermore, results showed that there was significant difference on Chinese cabbage growth performance among treatments. Generally, vegetable plots irrigated with water from fish ponds had significantly higher leave diameter, length, number of leaves and yield compared to those irrigated with stream water ($P < 0.05$). Application of chicken manure and supplementary feed contribute significantly on plankton abundance, fish and Chinese cabbage growth performance; and net profit of integration system.

The Effect of Dietary Incorporation of Cockroach Meal as Protein Source of *Oreochromis Shiranus* Diet

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Cockroach meal can be used as feed for fish and other animals because of its nutritive content. Its alternative protein sources can replace the current high priced and competitive with the humans as they are used either directly or indirectly feed such as fishmeal, and soybeans meal. It have potential as a fish diet and the transformation of edible insects into high quality fish feed in low-input pond culture systems can make a significant contribution to improve fish production. A study was conducted at Lilongwe University of Agriculture and Natural Resources Aquaculture farm from 15th February 2018 to 11th May 2018 to determine the effect of dietary incorporation of cockroach meal as protein source in *Oreochromis shiranus* diet in term of growth rate, the survival rate of *Oreochromis shiranus* and to examine the effect of incorporation cockroach meal to the formulated diet on water quality. There was a

significant ($P < 0.05$) difference in total weight gain of the fish among the treatments. The fish in 25% Cockroach meal showed higher weight gain (24.17 ± 0.98) as compared to other treatments and it was followed by a treatment given 20% Cockroach meal which showed higher weight gain of (20.94 ± 1.45) and then Control treatment of Soybean meal indicated the lower gain weight of 18.29 ± 1.10 . The mean apparent feed conversion ratio (AFCR) of 4.2% was recorded in 25% Cockroach meal followed by 5.1% Cockroach meal then 5.3% in the control treatments. The morning mean temperature ranged from 23°C to 28°C and from 25°C to 30°C for those recorded in the afternoon, across the treatments. The mean water pH taken in the morning and in the afternoon from the tanks ranged from 6.0 to 7.5 and from 6.84 to 6.85 respectively. The dissolved oxygen ranged from 5.96mgL^{-1} to 6.26mgL^{-1} and Ammonia ranged from 0.06 to 0.73mgL^{-1} across the treatments.

The Effects of Feeding Moringa Oleifera Leaf Meal on Growth Performance of *Oreochromis shiranus* in Semi-intensive Systems

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In the face of climate change and the pressure to meet an ever growing demand for fish and fish products, fish farmers in Malawi have turned their attention to plant protein sources for their fish production. The fish and fish products consumption is hovering around 4Kg/person/year instead of recommended 13Kg/person/year by FAO (2014). Malawian fish farmers are failing to satisfy the fish demand on the market. All fingers are pointing at the scarcity of fish feed as the main culprit due to exorbitant fish feed prices on the market which is mainly caused by the competition for similar feedstuffs with different production systems and human consumption. When drought strikes crop fields, no farmer is willing to share the little he harvests with his fish; not even maize bran or the protein laden and precious Soybean meal. That's how far climate change is manifesting itself in Malawian aquaculture despite all the potential it has. As such, a study aimed at evaluating the effect of substituting soybean meal with Moringa oleifera leaf meal on growth performance of *Oreochromis shiranus* in chicken manure fertilized tanks was conducted at LUANAR. Methodologically; Nine 200 litter tanks were used to raise a mixed sex population of *Oreochromis shiranus* fingerlings. Body Weight, length and water parameters data were collected fortnightly. SPSS Version 20 was used for data analysis. ANOVA was performed and there were no significant differences among the treatments ($P < 0.05$) in growth performance throughout the experimental period. For survival rate in which there were significant differences among treatments, Tukey test was used as post hoc. Specific growth rate (SGR) was not significantly different ($P < 0.05$) between the treatment containing Soybean meal (T2) at $0.57 \pm 0.11\%/ \text{day}$ and the combination of soybean and moringa (1:1) (T3) at $0.57 \pm 0.12\%/ \text{day}$. These treatments were significantly different to the treatment containing moringa only (T1) at $0.62 \pm 0.07\%/ \text{day}$. Survival rate differed significantly ($P < 0.05$) T2 recorded; 88.89%, then T1 (66.67%), T3 recorded 50% survival rate. Feed Conversion Rate (FCR) did not differ among the treatments. T1 was 1.29 ± 0.11 , T2 was 1.67 ± 1.37 while T3

1.39 ± 0.63. Temperature, ammonia and pH were within recommended ranges. Turbidity ranged between 6.6 and 16.02cm. These were not significantly different ($P>0.05$) in all treatments. This study helps us to conclude and recommend the use of moringa oleifera leaf meal for raising *Oreochromis shiranus* in semi-intensive systems solely or as a supplement substituting soybean meal as there were no significant differences in growth performance of fish raised on these diets and the water quality was not adversely affected.

The larval fishery on *Limnothrissa miodon* in the Congolese Waters of Lake Tanganyika: impact on exploitable biomass and the value of the fishery

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Declining catches of freshwater clupeids in Lake Tanganyika have recently led to widespread illegal fishing on the clupeid larvae with mosquito nets. The present paper examines whether this larval fishery could have a negative impact on the exploitable biomass of the clupeid *Limnothrissa miodon* and whether the sale of clupeid larvae is actually causing economic losses for the fishermen. The beach seine fishery on *L. miodon* larvae in the coastal zone of DR Congo was surveyed during a cruise in May 2013 from the north to the south of Lake Tanganyika. The local women fishing with their own gear were interviewed, their catch sampled, and their fishing effort evaluated. Based on catch sampling, the annual yield of larval fishery on the 17 fishing sites surveyed was about 24.5 tons, worth of US\$1.5 kg⁻¹. If these fish, now harvested as larvae, were allowed to grow to the average size in the lift-net catches, they would have annually produced 620 tons of fish. Applying a price of US\$3.5 kg⁻¹ for adult fish, and subtracting the value of larvae sold, this indicates that the current income of US\$36800 from the larval fishery, caused a US\$2.1 million loss for the lift-net fishery, thus accentuating the problems facing the fishing community.

Effect of Binding Agent on Stability and Nutritional Availability of Formulated Feed for Tilapia

Mohammed Elsheikh Mohammed Ahmed

Efficiency of various natural binding agents' viz., Wheat Flour (WF) starch, Cassava Flour (CF) starch, Ripe Banana Flour (RBF) starch and Ladies Finger Flour (LFF) gum were studied in relation to pellets water stability and retention of protein and lipid in beakers. Out of various diets that were tested, the highest pellets water stability of 96.75% was observed for the control diet containing (WF) starch, whereas lowest (93.5%) was seen for the diet containing (RBF) starch. However, there were significant different ($P<0.05$). Highest retention of the lipid (97.88 %) was observed for the control diet containing (WF) starch, whereas lowest (93.87%) was seen for the diet containing (LFF) gum. In terms of retention of the protein the highest value of

95.48% was observed for the diet containing (RBF) starch, whereas lowest (91.25%) was seen for the diet containing (LFF) gum. On the sinking rate of pellets of all the four diets measured in plastic aquariums had water column 30 cm, the diet 3 containing (RBF) starch had best sinking rate of 7.03 cm/sec and finally diets 1 containing (WF) starch which recorded 7.73 cm/sec. However, there were no significant differences ($P>0.05$) among Treatments. In the interim, the binding agents of (WF), (CF), and (RBF) and (LFF) are recommended for fish farmers in feed formulation.

Effect of Lipid Levels on Reproductive Performance of *Oreochromis Karongae* (Trewavas 1941)

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Oreochromis karongae, though it has good growth performance, has a major constraint of low fecundity. As such, a study on the influence of dietary lipid level on reproductive performance of *O. karongae* was conducted at Bunda Fish Farm. Fish were reared in 12 hapas for 86 days at a ratio of 2:1 (female and male) with four treatments replicated three times and fed four diets formulated to contain 8.28%, 10.17%, 12.09% and 14.05% levels of lipid. Sampling was done every two weeks and different reproductive parameters like absolute and relative fecundity, individual egg weight and diameter were determined. At the end of the experiment, *O. karongae* fed 10.17% and 12.09 % lipid had the highest absolute fecundity (237.5 ± 6.50 and 271.3 ± 26.19 , respectively) as compared to fish fed on 8.28% and 14.05% lipid levels (90.3 ± 46.3 and 143.7 ± 30.8 , respectively). However, there was no significant difference between fish fed on 14.05% and fish fed the other lipid levels for absolute fecundity. Higher number of spawns were observed in fish fed on diets containing crude lipid of 10.17 %. Thus, we can assume that diets of 10.17 % lipid performed better and also is not costly as those of 12.09 % or 14.05 % lipid. It was also found that the size of eggs depended on the number of eggs spawned by the female fish, as the number of eggs increased, the weight of eggs and mean egg diameter decreased. There were no significant differences ($p>0.05$) among treatments in terms of relative fecundity. The above findings unveiled that diets containing at least crude lipid of 10 % should be fed to broodstock for optimum reproductive performance of *O. karongae*.

Aquaculture and Mari-Culture Development in Malawi: Gaps, Constraints And Unmet Needs

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Though there is great potential, the development of aquaculture and mari-culture in Malawi continues to lag behind though it is a sure and reliable alternative to the dwindling quantities

of fish from capture fisheries. Other studies have revealed that the volumes of fish caught from capture fisheries have been dropping every year. Realising this challenge government of Malawi formulated different policies and ratified some international frameworks and policies whose objectives are to promote intensive fish farming methods in aquaculture and mari-culture. However there are several gaps, constraints and unmet needs in aquaculture and mari-culture development in Malawi as highlighted below. A Study was conducted to explore gaps, constraints and un met needs in aquaculture and mari-culture development in Malawi. The study used FGDs, IDIs) and a SITAN as data collection tools. Respondents included 8 aquaculture clubs and 13 individual smallholder fish farmers. In total the study had 42 respondents from five EPAs in Mangochi and Balaka districts respectively. Data was being analysed on a continuous basis using tally sheets. The study documented the following as some of the gaps, constraints and unmet needs affecting the development of aquaculture and mari-culture in Malawi. (1) Lack of Capacity: Fish pond construction requires special expertise of which many smallholder fish farmers lack capacity ranging from knowledge and lack of financial muscle as well as equipment. (2) Extensive Pollution and Unreliable water supply: Upland agricultural activities in some cases pollute the water in the ponds with chemical fertilisers, pesticides and other pollutants. (3) Lack of fingerlings and feeds: Smallholder fish farmers lack fish multiplication technologies and improved feeds. It is a fact that despite its economic and social importance, aquaculture development in Malawi is facing several challenges as such the government and its development partners should reinvigorate their efforts in the improvement of aquaculture and mari-culture development.

Malawi Lake Fisheries Value Chain and Post-Harvest Losses Assessment

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This paper presents the findings from a qualitative and quantitative value chain and post-harvest study conducted in the four lakes of Malawi, Malombe, Chilwa and Chiuta. The study, which took place in stages between December 2015 and March 2018, has the following key points and recommendations: Malawi's fishing industry directly contributes US\$ 1.2 billion to the gross domestic product (GDP). Fish is also an essential part of the Malawian diet, providing over 60% of the national dietary animal protein and 40% of the total protein supply. With a national GDP of US\$ 6.3 billion in 2017 (GoM, 2018), fisheries represent 7.4% of the economy's value added, compared with 19.7% for agriculture and forestry in 2016 (World Bank). The total value of the fisheries sector is six times the value when landed at the beach. This value of US\$ 1.2 billion does not include many ancillary economic activities, such as *mandazi* bakers, small market stalls, providers of ice and other products that support the fisheries industry, shops, restaurants, and bars, operating at beach landing sites. The assessed value provides a strong case for Malawi government to invest in the fisheries sub-sector by strengthening governance, surveillance, field extension, research, monitoring, and infrastructure.

The total quality and physical economic loss depends on the annual catch, but in 2017 the loss was estimated to be valued US \$174 million (13% of the total assessed value) – which is almost 20 times higher than the previous estimate of US\$ 10.5 million. The total economic losses are highest at the beach node (20%) and lowest at the market node (8%). It is counterintuitive that the losses are lower at the market node since the quality losses are highest at this node.

However, almost all fish (regardless of quality) is consumed in Malawi and it is likely that the lower quality fish is either given away as payment for services or it is mixed in and “hidden” within bundles of better quality fish at the market node. Problems that contribute to the lost value include: poor communication of market information; poor handling of fish on boats, at landing sites, and in trade in markets; lack of grades and standards; seasonality of fish supply; poor processing technologies and practices; poor packaging and storage of processed fish; lack of ice and containers for handling fish catch on boats; and poor transportation infrastructure. Based on the results it is recommended that on-board handling should be improved to reduce post-harvest losses that occur due to poor handling in the boat and that the Department of Fisheries capacity to support and uphold fish processing standards. Additionally there is need to pilot test alternative methods for fish preservation, such as salting and icing, for species and other forms of fish based products such as fish oil and powder for species such as Usipa and Matemba, whose production comes in surges during peak seasons. Reduction of post-harvest losses and diversification of fish products would therefore further enhance the economic contribution of the fisheries sector to Malawi’s economy.

Involvement of Women in Sustainable Aquaculture Development Of Nigeria

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Despite the immense fish biodiversity of Nigeria, there is a still a wide gap between supply and demand of fish, thus leading to high prices of fish products which make them unaffordable to the common man. Of recent, though women are becoming increasingly involved in aquacultural practices especially homestead culture of African catfish *Clarias gariepinus*, the sector (especially artisanal fisheries) is still male-dominated. The age-long traditional and marginal role of women as marketers and processors and financiers of fish need to change to direct fish producers for sustainable development in the sector. This paper highlights the factors affecting effective participation of women in direct fish production in Nigeria and calls for increased access to credits, inputs and land to potential women investors. Various constraints faced by women in fisheries livelihoods include restricted access to credit, inadequacy of education, dearth of infrastructural facilities, low participation in decision-making due to apathy for women in African setting, land tenure system, traditional beliefs and taboos, lack of access to information through extension services, poor cooperative society formations. The author emphasized the need for attitudinal changes in a patrilineal society like Nigeria by the men folks towards participation of women in the male-dominated profession like fisheries. Women should be regarded as equal partners in sustainable development of the fisheries sector. The author advocated culture fisheries for Nigerian women because of the less risky, less-laborious and more environment-friendly nature of fish farming.

Perception of Consumers on the Fish Raised in Cages (Case Study in Mangochi District)

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It has been noted that religion and tribe influences preference of consumers on fish species. This work wanted to find out if there are other social-demographic characteristics that influence consumer's preference levels on fish species other than religion and tribe. This work found that social-demographic characteristics like tribe, religion, education level and marital status have an impact on consumer's preference over fish species. This work also found that family size and sex of consumers do not influence consumer's preference on fish species. The work also wanted to see if the consumers are able to differentiate the characteristics of the caged fish from wild fish. The work found that caged fish and wild fish differ in terms of color, smell, freshness, test and fat content. Data for the research was collected using a questionnaire. As the data analysis procedure, cross tabulations in SPSS were made to show preference levels of the consumers based on their social-demographic characteristics.

Comparative Study of the Weight Gain Performance of Two Tilapia Strains in Western Democratic Republic Of Congo

Joachim Kuzimbila Yongo

Tilapia is one of the main fish in Africa (Carlos Lietar, FAO, 1984) However, despite the potential of exploitation this fish, breeding seems not yet mastered in sub-Saharan Africa. The West of the DRC specifically in the provinces of Congo-Central ex Bas-Congo, Kwango and Kwilu (from the dismemberment of the former province of Bandundu) tilapia is the main species farmed, but with low weights average at harvest, 48 g to 6 months at the farmer and 80 g to the Kiyaka Station. Compared with the frozen tilapia sold in the DRC and imported from China or Thailand with an average weight of 250g, the following questions would find answers: The low weight of Tilapia to the West of the DRC would be due to a genetic degeneration of the local strain. The low weight of Tilapia to the West of the DRC would be due to bad breeding system. To answer the question of whether the low weight of tilapia to the West of the DRC was due to a genetic degeneration or simply the wrong system of breeding, we have introduced a new strain of tilapia that we compared the performance of gain weight in the same conditions with the local strain. Both strains were fed on basis of the internal are the leaves of banana trees combined with cassava and Lucaena in the respective proportions of 70, 25 and 5% with a complement of 25 kg/ha of concentrated feed (18% PD) and 50 kg/ha of the dung chickens every 10 days, and we have achieved the middleweight of the order of 83,34. 149,12 and 182,28 g respectively at 3, 6 and 9 months with the local strain. As the introduced strain, we have obtained the results from 85,94 g to three months, to 6 months 150,18 g and 218,22 g at 9 months.

Statistical analysis (Z-test) has shown that there is no significant difference between the local strain and the strain introduced in what concerns gain weight at different ages. At the end of our study it is clear that nutrition would be the main factor limiting the performance of strains of tilapia as a result, the growth of fish farming in sub-Saharan Africa will leave the management of nutritional standards of fish breeding.

An Overview of Seed Production; Systems and Status for Malawi's Aquaculture

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Fisheries and aquaculture remain important sources of food, nutrition, income and livelihoods for hundreds of millions of people around the world. In Malawi capture fisheries stocks have been dwindling especially for specific species over the past years. Fish Farming has thus been taken to be a life saver for the shortage in animal protein supply. Successful fish farming relies on well-established hatchery operation systems for quality fingerling production. Several indigenous species of fish found in different localities are still dependent on wild seed supply because there is still lack of understanding of their breeding behaviours. This paper is a result of a review conducted to assess the status of seed production in Malawi. Among others the review reports the major fish species cultured in Malawi with *Oreochromis shiranus* recorded to be the most dominant, Pond based system as the most commonly used production system in Malawi, levels of fingerling production for small scale, medium, commercial and for some government institutions. The review also identified the major challenges faced in seed production and the potential for the further development of the seed production industry in Malawi.

The Effect of Caterpillars (*Imbrasia Belina*) as Dietary Protein Source on Growth Performance of *Tilapia Rendalli* (Boulenger, 1897) Raised in Concrete Ponds.

Richard Makanda

A study was conducted at LUANAR on potential of caterpillar (mophane) worms (*Imbrasia belina*) as feed ingredient for partial/whole replacement of fishmeal as protein source in fish Diets from December, 2014 to April, 2015. A CRD with 4 Diets: Caterpillar meal (*I. belina*) Treatment 1, Fishmeal made from Usipa (*Engraulicypris sardella*) Treatment 2, mixture (Fishmeal, Caterpillar meal and Maize bran) Treatment 3 as feed ingredients varied while Treatment 4 was subjected to Fertilization (Control) aimed at determining fish growth performance, survival, water condition and whole body composition at 30%CP. Final weights differed significantly ($P<0.05$) between supplementary Treatments and Control, but did not differ ($P>0.05$) among supplementary Treatments with $32.68\pm 1.52\text{g}$, $30.34\pm 1.41\text{g}$, $30.45\pm 0.67\text{g}$ and $20.84\pm 0.57\text{g}$ of Treatments 1, 2, 3 & 4, respectively. Condition Factor significantly differed ($P<0.05$) for Treatment 4, but did not differ from other Treatments ($P>0.05$). Weight – Length relation was better ($P>0.05$) among supplementary Diets but poor ($P<0.05$) in Treatment 4. Survival rate was highest ($P>0.05$) in all Treatments. Whereas Salinity ($P<0.05$), measured water quality parameters did not differ significantly ($P>0.05$) among the Treatments. Final whole body composition significantly differed ($P<0.05$) among all Treatments. Similarity showed in Moisture content ($P>0.05$) between *I. belina* and mixture Diets, fertilization and fishmeal based Diets. Crude protein was similar ($P>0.05$) for *I. belina* and mixture Diets, but strongly differed ($P<0.05$) for fertilization and fishmeal based Diets. Ash ($P>0.05$) was similar for single Diets, but varied ($P<0.05$) for mixture and Control Diets. Crude Fiber appeared similar ($P>0.05$) in fishmeal and fertilization only, but varied ($P<0.05$) between *I. belina* and mixture Diets. Meanwhile, variation ($P<0.05$) was indicative of all Treatments in Fat and Gross Energy contents. Conclusively, *I. belina* is a viable partial/complete replacement of fishmeal fed at 5% body intake.

Evaluation of Growth and Survival Rate of Goldfish Fry (*Carassius Auratus*) Fed on Different Zooplankton Feed Forms.

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The study evaluated the effects of feeding different forms of zooplankton on the growth and survival of goldfish fry at the University of Eldoret fish farm and aimed at determining the effects of feeding different forms of zooplankton (live, frozen and dried form) on growth of and survival of goldfish fry. One-week old goldfish fry (0.03mg and 0.8 cm initial weight and length respectively) were studied in nine plastic tanks (100 liter) with 40litres water full at a stocking density of one larva per liter to determine the suitability of frozen, dried and live zooplankton as their diet. At the end of the four weeks' study, the mean weight of fry fed on frozen, dried and live zooplankton diet were 578mg, 308mg and 773mg respectively. Fry fed on live zooplankton recorded the highest growth rate ($p < 0.05$) as compared to those fed with dried and frozen zooplankton diets. The weight of the fry fed on live, frozen and dried zooplankton diet forms differed significantly ($p < 0.05$). Treatment where fry was fed live diets recorded 100% survival while frozen diet and dried diet had survival rates of only 11% and 61% respectively. The study shows superiority of live zooplankton diet over preserved diets for goldfish fry rearing in terms of growth and survival rates. Therefore, live zooplankton diet form exhibited the best growth and thus would be preferable as goldfish fry feed due to ease of collection and direct feeding without loss of nutrients because of preservation.

Implementation of Solar-Powered Hatchery Technologies to Improve the Supply of Chambo (*Oreochromis Karongae*) Fingerlings for Rural Farmer In Malawi

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In recent years aquaculture production in Malawi has increased to about 12,217 tonnes. However, over 50% of these yields come from commercial farms despite a representation of more than 15,000 active fish farmers at present. Mass aquaculture production of affordable fish contributes to food security but one of the major bottlenecks for farmers to improve their yield is the scarcity of sufficient viable fingerlings, specifically for the highly valued Chambo.

Thus, one of the major goals of the project “Ich Liebe Fisch” was to establish technologies which improve significantly the stable supply of viable fingerlings to farmers that want to grow fish for food and the market. To achieve this goal, the project has provided a solar powered hatchery which is designed to support intensive production of Chambo offsprings. The prototype of the hatchery was set up in March-April 2018 at the fish farm of Bunda which plays an important role in providing training sessions for these new technologies. The presentation will introduce the applied technologies and will report about the implementation of this approach for a mass production of fingerlings. Additionally, it will also make a case for the adoption of solar-power hatchery facilities in Malawi.

Constraints and Opportunities of Artisanal Fish Farming in Rural High and Low Altitude Areas of South Kivu Province (DR Congo)

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This study was conducted in two agro-ecological areas (high altitude and low altitude) of South Kivu province (Eastern DRC). The aim of this study was to identify the strengths and weaknesses of fish farming and in particular (i) to draw up the fish farmers socio-economics' profile, (ii) to describe the fish farming practices and finally (iii) to characterize the types of ponds management and the fish feeding systems.

A participatory survey coupled with interviews was conducted with 265 fish-farmers distributed in these two agro-ecological zones. In addition to these interviews, field observations have also focused on 576 fish ponds in the area.

Results obtained at the end of these investigations revealed that fish farming is mainly practiced by men (79.5%) aged on average 44.3 ± 10.7 years without any management structure and generally for subsistence and a small share of production is directed towards commercialization. In these two areas, fish farming is practiced in monoculture on reduced areas and is limited to farmers who 98.9% are confronted with many constraints including the lack of management structures, difficulties in finding good quality fry, the lack of financial and land capital, the reduced number of fish ponds, the lack of quality food and the non-sexing of fish.

Beyond these constraints, these areas offer many opportunities for sustainable development of fish farming since 77.2% of fish consumed are imported from outside and these fish- farmers practice agriculture and livestock farming in addition to fish farming. On the other hand, about 53% of the ponds are built on their private properties. Thus, the optimization of fish production requires the consideration of these potentials in order to integrate fish farming with agricultural and animal production.

Sex Reversal in Fish: A Case Study of Tilapia Culture in Nigeria

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Aquaculture is very important because of the continuous decline in fish landings from the wild. Tilapia is the favorite species for aquaculture in many parts of the world, only second to carp by volume. However, tilapia culture is faced with the problems of early sexual maturity and high fecundity. These challenges in tilapia culture can be overcome through sex reversal. The use of hormones (steroidal and nonsteroidal) for sex reversal is popular. The use of hormone above the optimal dose usually results in the mortality of the fry. Nevertheless, the use of botanicals is therefore been advocated to address the challenges posed by the use of hormones. In this paper, we reviewed the methods of sex reversal, effect of dose on hormone effectiveness, importance of sex reversal in tilapia as well as sex reversal in fish treated with methyltestosterone (MT). This paper also reviews the case studies of sex reversal in fish. In this paper, we concluded that botanicals should be used for sex reversal, in order to overcome the environmental and health challenges associated with the use of hormones.

Resource Use Efficiency in Tilapia Production in Malawi

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Self-sufficiency in fish supply can be achieved by increased investments in aquaculture, and improving the productivity and efficiency of fish production in Malawi. However, the aquaculture sector has not shown significant growth in terms of production and productivity. This study determined resource use efficiency and determinants of tilapia production and sources of production inefficiency using survey data collected from tilapia farms in Zomba and Dowa. The stochastic frontier approach with the application of a flexible translog production function and an inefficiency model were used in the estimation of the production efficiency. The empirical results show that seed, fertilizer input, and pond size have significant positive effects on tilapia output whilst labour had significant negative impact on tilapia output. The returns to scale show that on average production is done under the decreasing returns to scale. Indices of resource use show that tilapia producers grossly under-utilized feed, fingerlings, fertilizer, and pond size while labour on the other hand, is over-utilized. Generally, the variation in tilapia production in the sampled areas is primarily as a result of technical inefficiency on the part of tilapia producers. The results further show that the average technical efficiency of tilapia is 66 percent indicating that the tilapia producers have a yield gap of 34 percent. Inefficiency model reveals that sex of producer, age, household size,

access to extension, training, access to credit and region dummy are major factors influencing the efficiency level of tilapia producers. The study suggests the need for policies to address sources of technical inefficiency highlighted by the study and improving farm-specific efficiency factors by widening access to extension, training fish farmers, empower women tilapia producers, widening access to credit and financing sources. In addition, government should train more fish farmers in fingerling production to ensure fingerlings availability and accessibility by producers.

Effect of Different Biofilters on Performance of Nile Tilapia (*Oreochromis Niloticus*) In a Small-Scale Recirculating Aquaculture System

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Most recirculating aquaculture systems (RAS) use aerobic biofilters to maintain water quality for fish production. The implementation of anoxic biofilters would lower aeration costs, water usage and concentration of all nitrogenous wastes in the effluent water. The aim of our study was to compare the effects of aerobic and anoxic biofiltration on Nile tilapia performance and water quality in a replicated recirculating aquaculture system. The experiment consisted of two treatments; RAS1 with conventional aerobic biofilters and RAS2 with anoxic biofilters in three replicates. Three biofilters were operated as aerobic biofilters and three were operated with anoxic biofilters without aeration. The two RAS systems consisted of 18, 500 L tanks stocked with 900 Nile tilapia each (56 ± 2.5 g). Water samples were collected across all the recirculating aquaculture units and fish growth was monitored biweekly. Median test was used to compare the growth of fish and water quality parameters in the two systems. All the water quality parameters except dissolved oxygen were not significantly different between the treatments ($p > 0.05$). Most water parameters were within recommended limits for growth and survival of Nile tilapia except ammonia. The concentration of ammonia was slightly higher in RAS2 (2.58 ± 0.76 mgL⁻¹) compared to RAS1 (2.43 ± 0.87 mgL⁻¹). There were no significant differences in mean weight gain of tilapia (77.47 ± 17.2 g, 69.25 ± 14.2 g) between RAS1 and RAS2 respectively. A comparison of growth performance indices (specific growth rate, feed conversion ratio and survival rate) showed no differences between the two recirculating aquaculture systems. The results confirm that anoxic biofilters can substitute aerobic biofilters because the biofilters did not negatively affect growth of tilapia. Besides, they can be appropriate in Africa where power outage is common.

Is the Culture of Exotic Fish Species the Answer to Low Fish Productivity? A Case Study on the Use of Exotic *Oreochromis Niloticus* in Zambia

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The study was conducted in the Copperbelt and North – Western Provinces which represented the urban and rural strata respectively. A total of two hundred and forty farmers were randomly sampled from the farmer registers kept by the Department of Fisheries (DOF) in the Ministry of Fisheries and Livestock (MFL), Zambia. The main objective of the survey was to determine the productivity of the exotic fish species *Oreochromis niloticus* in relation to other indigenous fish species (*Oreochromis andersonii*, *O. machrochir* and *Tilapia rendalli*). Correlation analysis showed that stocking density was positively, though weak, correlated ($r = 0.31$, $N = 292$, $P < 0.05$) with yield with a higher stocking density associated with higher yield. Since the correlation coefficient was lower than 0.5, regression analysis was not performed. Sex reversed fingerlings gave almost double the yield (5.5 tons/ha/year) compared with mixed sex fish (3.8 tons/ha/year). Productivity was highest in those farmers using commercial feed (6.4 tons/ha/year). There was no evidence to show that farmers who were using *O. niloticus* were getting more than those farmers using *O. andersonii* since the productivity of the farmers culturing the non – indigenous *O. niloticus* (4.7 tons/ha/year) did not differ significantly from those farmers using *O. andersonii* (4.6 tons/ha/farmer). Therefore, management was more important than germplasm in fish production. There should be deliberate efforts to promote *O. andersonii* both at production and consumption levels in order to create demand for the fish species. Genetic studies should be conducted to establish the genetic variability and strains of the indigenous fish species in Zambia. Furthermore, there is an urgent need to establish gene banks for the most indigenous fish species to conserve the genetic resources for aquaculture and capture fisheries.

Theme 4: Biology, Ecology and Behavior

Morphology of Alimentary Canal and Feeding Habits of African Sicklefish, *Drepane Africana* (Osório, 1892) of the Nigerian Coast at Niger Delta

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The African sicklefish, *Drepane africana* is an economically important food fish from Nigerian marine waters. Knowledge on its dietary composition will reveal the foraging status and also provide information for adequate management of the resource in the Nigerian marine environment. This study describes the morphology of alimentary canal, dietary composition, trophic level, feeding strategy and feeding intensity of *D. africana* off the Nigerian coast at Niger Delta. 1,443 specimens collected from April, 2013 to September, 2015 were grouped into three sizes classes and examined. Morphology of their mouth, teeth, gill rakers, stomach and intestine were studied. Feeding intensity was determined using vacuity index while primary and secondary indices were used to analyse the diet. The mouth of is terminal and highly protrusible, the jaws have bands of small teeth which are smoothly conical and setiform; gills have few, small and spaced rakers. The gill rakers of juveniles have micro filaments which could enhance filter feeding. Oesophagus is short, muscular and distensible; stomach is large and flask-shaped; intestine is short. The overall vacuity index was 157 (10.9% specimens examined); adults had the highest vacuity index (13.2%) while the sub adults had the lowest value (6.0%). Based on index of relative importance, amphipods (36.0%) were major food of juveniles, followed by copepods (32.1%). Polychaetes (34.0%) were major food of sub-adults followed by shrimps (22.8%) and echinoderm (17.6%). Polychaetes (29%) were also major food of adults followed by shrimps (22.7%), fish (18.2%) and echinoderms (15.6%). The estimated dietary trophic levels for the juveniles, sub adults and adults were 3.2, 3.9 and 4.2 respectively. *D. africana* is a carnivorous benthic feeder.

Direct and Indirect Effects of the Growth of Aquaculture Sector in Africa – Economic, Environmental, Ecological, Genetic and Biodiversity Aspects as well as Some Implications for the Future of the Industry and the Aquatic Fauna.

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Aquaculture is a growing sector globally, and after a slow start Africa is now moving forward, especially with large scale commercial operations. Examples of the rapid growth of these from Zimbabwe, Kenya, Ghana and Zambia are investigated, and lessons on policy and legislation that can be learned from other countries such as New Zealand and Chile are examined. Most aquaculture operations in Africa are farming the Tilapias, and with Africa being the original indigenous home of most of these species, there are ecological, genetic and biodiversity aspects to be considered from the development of aquaculture and the concomitant

introduction and escape of farmed fish. The introduction of disease in wild fisheries and long term deleterious genetic effects of hybridization and homogenization of species across the continent are discussed, and the mechanisms of how we have arrived at this situation are reviewed. Some possible mitigating strategies have been identified and are presented.

How Social Evolution Changes Behavioural Repertoires in African Cichlids, a Comparison Using Highly Quantitative Computational Behavioural Decomposition

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In order to realise the potential of the –omics age to revolutionise our understanding of social evolution, we must develop quantitative, rigorous, and standardised approaches to analysing social behaviour. Techniques like computational behavioural decomposition provide such a framework, yet so far have been restricted to model systems. Here I will present my lab's work employing advanced computational algorithms and behavioural decomposition to quantify and compare social behaviour among African cichlids within the cichlid tribe Lamprologini. These species are ecologically almost identical, yet vary dramatically in their social structure and behaviour, and are therefore highly amenable to examining how selection acts on behavioural elements in the transition to sociality, and the mechanisms underlying this change. We use machine vision and machine learning approaches to generate highly-quantitative measures of the kinematic structure of social behaviours. We test how social evolution has altered both social behaviours and the functional significance of potentially conserved behavioural elements, measuring the kinematic structure of the behaviour itself and the effect behaviour has within its social network. We aim to create entire behavioural repertoires for every species using t-SNE embedded behavioural spaces, Markov chain analyses of the transitions among different behaviours, and extended Markov chains to examine the effect on other individuals, mapping these differences on to the genomic and transcriptomic datasets available for this group. With this approach, our group aims to bring behavioural analyses up to the quantitative standard of modern molecular techniques, generating a powerful and data-rich behavioural tool for comparison with equally data-rich –omics approaches.

Infestation of *Oreochromis niloticus* (L) By *Saprolegnia* Spp. (*Saprolegniasis*) in a Commercial Cage Culture System in the Northern Lake Victoria Basin, Kenya.

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The infectivity and role of the OOMYCOTA; *Saprolegnia* sp. were investigated during a reported *Oreochromis niloticus* fish diseases outbreak causing massive mortalities in the cage culture systems in the region of the Northern Lake Victoria in November 2016 to November 2017. Several fish cages with dimensions ranging from 3m³ to 6m³, and stocked with 3,500 – 12,500 fingerlings were inspected. Mortality in cages ranged from 10 - 51.6% in the worst affected cages. The prevalence of infection ranged from 16.3 - 23.7%. The epidermal tissues; the head, mouth, skin, caudal areas, fins and the eye of the fish were severely invaded by the fungus. Some specimens (n = 8) from one of the cages which were taken for further

Laboratory analysis, had a mean length of 75 mm and ranged between 42.0-131.0 mm, had white or gray patches visible as cotton wool spreading on the entire surface. Microscopically, the new hyphae appeared to be growing up through the old or empty sporangium. The digital images of the specimens were also taken for documentation. The aetiological agent *Saprolegnia* sp leads to full blown clinical signs on fish that is physically challenged by stress and environmental stressors, including pollution. They also determine whether or not mortality will occur. The paper suggests prophylactic measures to reduce the risk of infection in the cages.

Phylogeography of *Oreochromis shiranus* (Boulenger 1897) in the South-Eastern Catchment of Malawi

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The Lake Chilwa-Chiuta catchment represents the headwaters of the east flowing Rovuma drainage system that empties in the Indian Ocean and the only part of Malawi that falls within the Coastal East Africa Freshwater Faunal Region. Lake Malawi catchment lies within the Zambezi Region. *Oreochromis shiranus* is an endemic tilapiine species represented in both catchments by its two subspecies. Analysis of 272 individuals of putative *O. shiranus* at nine microsatellite, 44 D-loop and 36 ND2 loci respectively from five sites was done to unravel historical connectivity between the catchments for informing proper conservation practice. *Oreochromis shiranus* populations from all sites studied have considerable levels of genetic diversity at both mitochondrial and microsatellite loci obtaining between 9 and 49 alleles per locus and overall mean heterozygosity, $H = 0.76$. Nucleotide frequencies were 0.313 (A), 0.348 (T/U), 0.11 (C), and 0.23 (G) with transition/transversion rate ratios of $k1 = 22.88$ (purines) and $k2 = 11.61$ (pyrimidines) and overall bias of $R = 6.768$, where $R = [A * G * k1 + T * C * k2] / [(A + G) * (T + C)]$. The species showed a clear pattern of spatial dispersion of lineages across the two geographic regions implying restricted gene flow and/or sequence conservation. No significant differences ($\alpha = 0.05$) were observed in base composition across sequences implying incomplete lineage sorting due recent divergence. The dichotomy of gene pools detected suggests that these could be cautiously interpreted as distinct management units with each catchment independently considered for conservation and management needs.

Migration of Silver Catfish, *Chrysichthys nigrodigitatus*, of the Cross River, Nigeria: a Myth or a Reality.

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Chrysichthys nigrodigitatus is a prized food fish of commercial importance in Eastern Niger Delta. The species is abundant during the rainy season months of April to October and hence the fishery can be severely affected by climate change impact. There is a growing concern on its conservation through domestication. As our own contribution towards the quest for the domestication of this species, we embarked on study of the migration pattern of the species. The objective was to identify the migration route and pattern, if any, and to proffer management advice. A total of 908 specimens of *C. nigrodigitatus* was tagged and released from January to July 2017 at two sites in the Cross River separated by a distance of 88km. The tagging was done using nylon monofilament. So far a total of 44 specimens have been recaptured, representing 4.45 % of the total fish tagged and released. Highest number of recaptured fish was recorded in the months of April and May. A correlation of the rainfall data with number of recaptured fish shows that more specimens were recaptured during the rainy season. Two were recovered in the months of November and in 2018, four more specimens were recovered in the lower Cross River. The two seasons' data show that all recaptured fish were either around the point of release or some distance far away from the point of release. So far there is no evidence of movement to and fro the two geographical regions. The study shows that *C. nigrodigitatus* engages only in local wanderings and not directed migration.

Ecology and Behaviour of Fish under Different Hydrological Regimes and Its Impact on Tana River Delta Fisheries, Kenya.

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Tana River is Kenya's longest watercourse emptying into the Indian Ocean via one of the country's largest and biodiversity rich wetlands. The delta's fisheries is a characteristic of tropical floodplains, with abundance and species distribution is influenced by seasonal flooding while inter-annual trends in water volume and timing may also affect the floodplain's productivity (Lindholm et al. 2007). As water volume increases it rises and spills over the banks of the main channel and spread across the floodplain, an explosion of primary production in the shallow flooded areas occurs. These are critical spawning habitats for fishes and serve as important nurseries for larval and juvenile stages, providing better refuge from predators, higher food abundance, and more suitable temperatures than the main channel. As the flood recedes, the adult and juvenile fish retreat to the main channel while some become trapped in the seasonal water bodies. These distinct temporal and spatial trends in fish species abundance have a particular significance in fisheries and livelihood strategies. This study aims at investigating characteristics of floodplain wetlands fish community and how this impacts fisher-folk utilisation in different hydrological regimes in Tana River Delta. The presentation will show how fish community are affected by changing hydrology in the floodplain wetlands and its effects to fisheries and livelihoods (the roles of seasonal and inter-annual variations in

flooding). National, local and customary fisheries governance structures and their effects on fish populations will be presented.

New Divergence Ages Provide Novel Insights into the Biogeographic Origin of the East African Cichlid Radiation (EAR)

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Several of the most prominent examples of adaptive radiations are found within the African Great Lakes, all part of the East African cichlid radiation (EAR). Not surprisingly, great effort has been paid into the reconstruction of the evolutionary and biogeographic history of cichlids, often however resulting in highly contradicting divergence age estimates. Based on a comprehensive dataset encompassing representative taxa (N=180) of almost all recognized cichlid tribes and ten mitochondrial genes we present new divergence age estimates (BEAST) for the major cichlid lineages and especially for those of the EAR. We carefully re-evaluated both fossil and geological calibration points and moreover included the recently described fossil †*Tugenchromis pickfordi* as a calibration point. Our results estimate the onset of diversification of the EAR to the Late Eocene/Early Oligocene. The divergence age of the MRCA of several Tanganyika cichlid tribes is estimated substantially older than the oldest estimated maximum age of the Lake Tanganyika, a result which supports the 'Melting-pot Tanganyika' hypothesis. Further the onset of the Lake Malawi cichlid radiation is estimated to coincide with the first record of lacustrine conditions of the Lake Malawi suggesting that the precursor lineages of the Malawi species flock survived multiple severe lake level changes. Age estimates based on our mitochondrial dataset are largely compatible with those obtained from a nuclear dataset (117 taxa, four nuclear loci). Further, we recognize several novel mitochondrial lineages within the EAR, i.e. *Orthochromis* sp. “Lufubu”, *Haplochromis vanheusdeni*, and a monophyletic clade for the *Lamprologus* of the Lower and Central Congo drainage. Finally, preliminary phylogenetic reconstructions based on an extensive nuclear DNA (ddRAD) data set recovered all those lineages, but in some cases with different phylogenetic positions within the EAR.

Contribution of the Length's Measurement Unit in Estimating Fulton's Factor Condition.

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Fulton's condition factor (K) is generally used to determine the health and well-being of fish in its habitat. It is obtained by the relation $K = W/L^3$. It has been found that in use, the length is often expressed in centimeters or millimeters. The objective of this study was to test the importance of length's measurement unit on the value of Fulton's condition factor in *Clarias anguillaris* of Peelé reservoir, Burkina Faso. The condition factor was calculated in two ways. At first the

length values were expressed in centimeters and in a second time they were expressed in millimeters. The results show that value of Fulton's condition factor was very influenced by unit of measure of length. So when the length was expressed in centimeters K was higher than one (1) while it value was lower than one when length was expressed in millimeters.

Keys words: Fish size, factor condition, *Clarias anguillaris*, man-made lake, Burkina Faso

An Insight in the Understudied Diversity of Monogenean Parasites Of Freshwater Fish in South Africa

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Monogeneans (Platyhelminthes) are a diverse parasitic group with approximately 5500 species from 750 genera known worldwide. In Africa, 470 species from 35 genera have been described from fish hosts. Given the high diversity of freshwater fish species in Africa (more than 3000 spp.), one can expect a similar diversity for their monogenean parasites. The present study aimed to contribute to the limited knowledge on the diversity of monogenean parasites of freshwater fishes in South Africa. From March 2012 to February 2017, various fish species from the Cyprinidae, Claridae, Mormyridae and Cichlidae were collected during field surveys at 10 localities from four provinces (Limpopo, North-West, Northern Cape and KwaZulu-Natal) of South Africa. Collected hosts were screened for the presence of monogeneans and any found were fixed in glycerin-ammonium picrate for morphometric analyses and in ethanol for molecular characterisation. *Clarias gariepinus* was collected from nine localities, and hosted 15 monogenean species, of which four belongs to *Gyrodactylus* von Nordmann, 1832 representing new species. *Oreochromis mossambicus* and *Tilapia sparmanii* were infected with two *Enterogyrus* Paperna, 1963 species, both constituting new host records. *Pseudocrenilabrus philander* was parasitised with two known *Gyrodactylus* species of which one is a new host and new geographical record. *Petrocephalus wesseli* and *Marcusenius macrolepidotus*, hosted specialist mormyrid monogeneans of the genus *Bouixella* Euzet & Dossou, 1976, including two new species. New species of *Gyrodactylus* were found from small cyprinids *Enteromius paludinosus* and *Labeo altivelis*. The present findings indicate that detailed investigations on monogeneans in South Africa can significantly increase our knowledge on the distribution and diversity of these economic and ecological important fish parasites in Africa.

Fish Species Packing and Partitioning in the Okavango Delta, Botswana.

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Tropical floodplain fish populations fluctuate at spatio-temporal scales. Since these fisheries are a major source of rural livelihoods, there is need to assess the nature and extent of these fluctuations. Understanding the variability in these systems will contribute to comprehensive

management of these resources. Therefore, the main of this study was to assess the seasonal dynamics of floodplain fish community, by investigating their seasonal dynamics, drivers and processes. Data were collected using standard methods between 1999 and 2009 from the main channel and two connected lagoons in the delta's panhandle. Various analytical tools (e.g. CCA, SIMPER, cluster, ANOVA, etc.) were used to assess fish community dynamics. SIMPER analysis revealed differences between lagoon and channel fish communities. Results also showed that lagoons had significantly higher fish biomass than the river channel habitat, but had significantly ($p < 0.05$) smaller fish. CCA revealed that similar fish species were structured along different environmental gradients in different habitats. PCoA, cluster analysis and regression techniques revealed significant inter-specific associations along the seasonal hydrograph, especially at decreasing floods in both habitats. One conclusion from this study is that floodplain fish communities are driven by stochastic and deterministic processes and that floodplain fish assemblages are dynamic, persistent, stable and heterogeneous. This is incongruent to the static oriented paradigms currently used in their management. The best management approach of these systems, therefore, is to manage them for resilience, persistence and heterogeneity, which fits the balanced exploitation regimes traditionally used in them. This study contributes knowledge to floodplain fish ecology and enhances management of this resource for the benefit of socio-economically impoverished riparian communities.

Life-history Traits of the African Lungfish, *Protopterus aethiopicus* and Influence of Environmental Variability on the Traits in Lake Baringo, Kenya

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Information on life-history traits of African lungfish, *Protopterus aethiopicus* (Heckel, 1851) and possible influence of environmental variability on the traits is limited in Lake Baringo, Kenya. Yet this information is important for evaluating commercial potentials of the fish stock and its exploitation status. This study examined these factors in an attempt to bridge the data gaps and understand the *P.aethiopicus* fishery in Lake Baringo. The study was based on random samples taken from monthly catches landed by artisanal fishermen in Lake Baringo between June 2011 and December 2012. Estimates of growth, mortality and relative yield per recruit of the species were obtained from the monthly length-frequency data. The length-weight relationship is expressed by the equation $W = 0.0016 \times TL^{3.2225}$ for 2011 and $W = 0.0007 \times TL^{3.3979}$ for 2012. Length at sexual maturity was 88cm and 91cm for males and females respectively. There was a significant difference in the gonadosomatic index (GSI) of the two sexes. Specific fecundity varied from 0.799 in December 2011 to 3.87 in June 2011. The relationship between body length and fecundity was $F = 5E-05 \times TL^{4.1618}$ ($r^2 = 0.4728$), while that between fecundity and weight was $F = 3359 \times TW - 1726.5$ ($r^2 = 0.5345$). The von Bertalanffy growth function (VBGF) estimates were: $L_{\infty} = 146.32$ cm; $K = 0.34/\text{yr}$ and $t_0 = -0.3149$ years. Natural mortality rate (M) was 0.547/yr. Total mortality coefficient (Z) was estimated as 0.78/yr and the exploitation ratio ($E = F/Z$) was 0.295. The recruitment pattern was continuous throughout the year. There was a correlation of; pH, conductivity alkalinity, hardness and total dissolved solids with gonadosomatic index. On the other hand secchi depth and hardness had a significant difference on specific

fecundity. Presence of all maturation stages throughout the year is an indication that *P.aethiopicus* is a continuous spawner. The results can be interesting for management and conservation programs of this valuable species in Lake Baringo.

Effects of Fluctuating Water Volumes on Growth Performance of *Tilapia rendalli* (Boulenger, 1897) Fingerlings

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Optimum water quantity is crucial for fish survival, growth and reproduction. However, climate change has brought about erratic rains and fluctuating water volumes in fish ponds. This study was conducted to investigate the effects of fluctuation of water volumes on growth performance of *Tilapia rendalli*. One hundred eighty fish samples of *Tilapia rendalli* with mean weight between 2.90 ± 0.10 g and 3.15 ± 0.08 g were randomly stocked in 4 Treatments and replicated three times. Water in Treatment 1 (T1) and Treatment 4 (T4), were maintained at constant volumes throughout the study period, while the volumes were fluctuated in Treatment 2 (T2) and Treatment (T3), every after twenty-one days. Water quality, growth parameters and survival were determined according to the standard procedures. The data collected were analysed using ANOVA and Duncan's multiple Range Test was used to separate the means. The highest final average weight was noted in T1, with an average weight of 6.75 ± 0.22 g followed by T2, T3 then T4. Final weight in T1 was almost 1.5 times higher than that of T4 and was significantly higher than that of T3, and T4 ($P=0.000$). T1 showed a lower feed conversion ratio of 1.49 ± 0.26 followed by T2, T3 then T4 with 1.83 ± 0.03 , 3.81 ± 0.28 and 4.19 ± 0.97 respectively. Ammonia content was significantly higher in T4 with average readings of 0.19 ± 0.02 mg l⁻¹, followed by T3, T2, then T1 with an average readings of 0.18 ± 0.04 mg l⁻¹, 0.09 ± 0.01 mg l⁻¹ and 0.07 ± 0.02 mg l⁻¹ respectively. However, there were no significant differences on survival rates of fingerlings in all treatments. These findings show that optimum water level is a crucial factor if optimal survival and growth of fingerlings is to be achieved. Apart from that the results show that fingerling survival cannot be significantly affected with water volume reduction to 60%.

Monogenean parasites of cichlids in the Congo Basin: species inventories, next-generation sequencing and invasion biology

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More than half of all species on Earth are parasites. This species richness, the interactions with their host (a “living niche”) that lead to unique speciation mechanisms, and their role in host speciation and ecosystem functioning, render parasites excellent model organisms for research on a range of biodiversity-related topics. Nevertheless, parasitological research on cichlids, themselves established model organisms in biodiversity science, is relatively rare. For the past decade, we have been studying monogeneans infecting cichlids in the Congo Basin. These mostly ectoparasitic flatworms are ideal targets in evolutionary parasitology: they only require a single host species throughout their lifecycle and are allegedly quite host-specific, ensuring an often close relationship with their host species. Some groups of cichlid parasites are more species-rich than their host taxa. Indeed, in Lake Tanganyika, we discovered that cichlid lineages sometimes harbour radiations of host-specific monogeneans. We have described over 40 new species, while co-phylogenetic analyses allowed for hypothesizing which diversification mechanisms were involved. We also studied the diversity of monogenean cichlid parasites in rivers and small water bodies throughout the Congo Basin, resulting in several species descriptions. Moreover, this served as a baseline to study whether and how this fauna is influenced by the introduction of non-native Nile tilapias, and by pollution. In addition, using Illumina next-generation sequencing technology we sequenced the mitochondrial genomes of some cichlid-infecting monogeneans, offering a resource for phylogenetics and marker development. In summary, this talk strives to offer some perspectives on combining two groups of model organisms in biodiversity science: cichlids and parasites, and on collecting policy-relevant information from this host-parasite system, particularly regarding the assessment of anthropogenic impact.

Parasite Species Richness of Fish from Fish Ponds and Fingerling Sources in Central Ethiopia: It's Implication on Aquaculture Development.

Marshet Aduugna Mitiku

This study was conducted from October 2016 to January 2017 from Koftu Lake, Sebeta ponds and selected private fish farms in Wonchi area, Ethiopia. The main objective was identifying the major parasites of *O. niloticus* to the lowest possible taxa, quantitatively determining the prevalence, mean intensities and mean abundances of parasites and calculating parasite diversity in the three study sites. A total of 302 *O. niloticus* were examined using conventional parasitological examination procedures. From the sampled fish, 11 different genera of parasites were identified in the three study sites. One genus of Protozoa, one genus of Monogenea, unidentified larvae of Cestoda, four genera of Digenea, two genera of Nematoda, one species of Acanthocephala and one genus of Crustacea were recorded. The overall prevalence of parasites of *O. niloticus* covering all study sites was 83.4%. The prevalence of parasites in Koftu Lake, Sebeta ponds and private fish farms were found to be

100%, 71.0% and 82.2% respectively. There was statistical significant difference ($p < 0.05$) between the study sites in overall prevalence and mean intensity of the parasite infestations. Koftu Lake and Sebeta ponds have higher diversity indices and show the same community similarity coefficient. Values of prevalence, mean intensity and diversity of the parasites were especially high in Koftu Lake and there is a need to design control strategies especially when fingerlings from the lake are used for stocking in other water bodies and intensive and small scale fish farms. Two digeneans, *Clinostomum sp.*, *Euclinostomum sp.* and one nematode, *Contracaecum sp.* were identified as possible health risk for humans.

Pelagic Fish Species in Lake Tanganyika: Potential of Parasites as Tags for Host Population Structure and Historical Events

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Lake Tanganyika is the deepest of the African Great Lakes with one of the most diverse fish assemblages. While dozens of studies focus on this lake's cichlids as famous model organisms, our knowledge about the economically important species is still poor. The fishing effort is concentrated mainly in the lake's pelagic zone with two clupeids (*Limnothrissa miodon*, *Stolothrissa tanganicae*) and four latid species (*Lates angustifrons*, *L. mariae*, *L. microlepis*, *L. stappersii*) as dominant targets. Additionally, cichlid species including members of the tribe Bathybatini can be found as valuable catch on fish markets. Surprisingly, almost nothing is known about their parasite fauna. We examined the abovementioned host taxa for the presence of parasites to answer the following questions: which parasites infect the dominant fish species in the pelagic zone of Lake Tanganyika? Can parasites potentially help to reveal their hosts' population structure or historical events? Samples of 14 host species originated from localities throughout Lake Tanganyika including all three subbasins of the lake. Parasite species identification was based on the sclerotised structures. Molecular characterisation was conducted using nuclear and mitochondrial markers with different rates of molecular evolution. In general, a decrease of parasite host specificity in the lake's pelagic zone was documented in all examined fish taxa. In total, four monogenean parasite species (Platyhelminthes) of three different genera were identified combining morphological as well molecular data. The parasite population structure inferred from morphometric data and from part of the COI gene shows no north-south gradient. Recent demographic expansion in species infecting clupeid and cichlid hosts was detected and could be linked with paleogeographic reconstructions and climate changes, respectively. We aim to use genomic data in future studies, hypothesizing that the phylogeography of these parasites can reflect historical events that are too recent to be inferred from host genetics.

Life History Divergence along an Aridity Gradient in African Annual Fishes: An Experimental Study

R. Blažek, M. Polačik, M. Vrřilek, M. Reichard

Extreme environments induce extreme adaptations, as exemplified in African annual *Nothobranchius* fish inhabiting temporary pools of East African savannah. Unpredictable conditions of *Nothobranchius* habitats are directly associated with their adaptations and life history trade-offs. Hence, phenotypic traits of some populations might be associated with different selection pressure determined by population specific lifespan expectancy (duration of their temporal habitats). Populations from the drier area of species distribution are expected having faster life strategy than their conspecifics in wet regions. To test whether population-specific lifespan expectancy predicts the rates of demographic and reproductive aging we used common garden experiment with F1 generation of imported natural populations of African annual fishes of four species. Each species was represented by two populations; from dry and wet regions. Analysis of several phenotypic traits confirmed that populations from dry region have shorter lifespan and faster fertility decline. Intraspecific divergence in life span was not associated with divergence in early life history (rapid growth, maturation). Variability across four study species suggests that a combination of different life-history traits conformed with or contradicted the predictions for each species. These findings demonstrate that variation in life span and functional decline among natural populations are linked, genetically underpinned, and can evolve relatively rapidly.

Safety Analysis of Fresh *Diplotaxodon* Fish Species (Local Name; Ndunduma) Under Ice Storage

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The quality deterioration of fresh fish species in the tropics is a complex event that requires multiple analyses to define acceptability, this is imperative for prediction of safety of the fresh product during distribution. Consequently, changes in microbial, chemical and sensory also known as Quality Index assessment (QIM) changes of *Diplotaxodon* species under ice storage were evaluated for a period of 28 days. The shelf life of *Diplotaxodon* species was estimated to be 24 days. The level of pH ranged from 6.4 on day 0 to 6.6 on day 28. Total volatile basic nitrogen (TVB-N) levels increased over time, reaching levels above 30.1 mg/100g by the end of the storage period. Protein and moisture content range were 60.14-55.65%, and 89.89-80.57% respectively. Ash remained constant at 12.70 % for the entire storage period. Total Viable Counts followed a lag, exponential phase and ranged from 2.4×10^3 to 3.9×10^8 CFU/g

(muscles), 4.2×10^4 to 8.1×10^8 (intestine), 3.0×10^2 to 5.8×10^5 (gills). On rejection point, TVC were 2.7×10^7 , 6.9×10^8 and 3.4×10^5 for muscles, intestine and gill respectively. The overall Quality Index scores showed a decrease in quality with storage time and showed a strong linear regression correlation coefficient ($R^2 = 0.9803$). The results have demonstrated that *Diploaxodon* fish species have can remain safe for consumption with the aid of ice. However, there is a need to implement good manufacturing practices during storage to enhance product safety.

Geometric Morphometrics Reveals Morphological Variations Among Native Populations Of The Nile Tilapia (*Oreochromis Niloticus* L.) In Ethiopia and Uganda

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The Nile tilapia (*Oreochromis niloticus*) is a native fish species to the Eastern Africa. Due to its economic and ecological importance, this species has been the focus of several studies. Due to its high phenotypic plasticity and local adaptations, The Nile tilapia is able to thrive in habitats from lowland warm water environments to cooler water bodies located at high altitudes in the region. Previous studies employing traditional morphometric methods have shown existing morphological variations among populations and the identification of 7 subspecies. However, studies employing the modern geometric morphometrics are few and restricted to few populations. We hypothesised that morphological variations revealed by geometric morphometrics method are informative of the roles local adaptations and phenotypic plasticity play in shaping these variations. To test this hypothesis, we analysed the shape of 499 individuals from 12 native populations in Ethiopia, Kenya and Uganda. A tps file was created using tpsUtil v.1.74 from Images of fish taken using a standard platform. From the tps file, landmarks were digitized using tpsDig v.2.16. the data was then exported to MorphoJ v.1.6d for multivariate analysis by using Procrustes superimposition. The Procrustes coordinates were then analysed using PCA and CVA. The results revealed that pronounced shape variation was observed on the head region. Additional variations were also noted in the caudal fin region. Populations were observed to form clusters according to the PCs. The CVA revealed that the Uganda and Ethiopian populations separated with the Ugandan population showing more variability. The variations observed in morphology among the population, therefore, can be attributed to the local adaptations to the various environmental pressures faced by the populations. The separate clustering of the Ethiopian and Ugandan populations might suggest their close genetic relatedness.

Spatial Variation In Condition Factor And Growth Patterns Of *Labeobarbus Altianalis* (Boulenger, 1900) Along River Nyando, Kenya

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Continuous monitoring of riverine fish communities is a requirement. Knowledge on condition factor of the existing fish species provides a basis for appropriate intervention strategies. This

study is aimed at determining the spatial variation in condition factor and growth of *Labeobarbus altianalis* and further correlates it with selected water quality parameters along River Nyando. Three sites S1 at the upper region; S2 at the mid region and S3 at the lower region closer to the river mouth were sampled. Fish sampling was done using an electrofisher and the sampled fish identified in the field. The length and weight of *L. altianalis* were taken in the field to the nearest 0.1 g at every sampling point physico-chemical parameters were taken *in-situ* in triplicates. There were significant differences in the TL among the sampling locations (One-Way ANOVA; $F = 6.1212$, $df = 2$, $P = 0.034$). According to post-hoc DMRT, fish sampled from site S1 had the highest SL followed by those in S3 while mean TL at S2 was the lowest. Total weight varied significantly (One-Way ANOVA; $F = 3.001$, $df = 2$, $P = 0.044$) among sites in tandem with variation in TL and TW. There were significant differences in condition factor among stations (One-Way ANOVA; $F = 19.923$, $df = 2$, $P = 0.0001$). Based on post-hoc DMRT, fish at site S1 had the highest Kn (1.38 ± 0.25) followed by Kn at S3 (1.06 ± 0.12) and the least Kn was reported at site S2 (0.85 ± 0.11). The differences could be attributed to food items consumed and influence of dissolved oxygen, pH and Turbidity.

Reproductive Biology and Diet of Two Elasmobranches species – *Carcharhinus amboinensis* and *Carcharhinus limbatus* in the Coastal Waters of Sierra Leone

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The reproductive biology and diet of two elasmobranches species *C. amboinensis* and *C. limbatus* in the coastal water of Sierra Leone were studied. During the research, 100 fish samples including 64 females and 36 males were studied for a period of five months between March – July at two locations, Tombo (western rural district) and Goderich (western urban district). Data collected from the fish samples were analyzed for gonadosomatic index, hepatosomatic index and stomach content analysis. Results obtained indicated that *C. amboinensis* reached maturity at total length of 195cm for male and 198 to 223cm for females, while *C. limbatus* reached maturity at total length of 135 to 180cm for male and 120 to 190cm for females. The breeding period falls between April and August. Gonadosomatic index was higher for females with a peak in early rains. Stomach contents analysis revealed preponderance of worms, crabs of all kinds, shrimps, gastropods, cuttlefish, bristle star and fishes were found in some of the sampled species. The calculated relative gut length shows that *C. amboinensis* and *C. limbatus* are exclusively carnivorous. Sex ratio was significantly different from 1:1; there were however more females than males among the samples collected.

The *Marcusenius moorii* (Günther, 1867) (Teleostei: Mormyridae) from the Congo basin: a complex of species

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Within the Congo Basin, *Marcusenius moorii* currently contains two junior synonyms: *M. lambouri* (Pellegrin, 1904) and *M. moorii longulus* (David & Poll, 1937) (Boden et al., 1997). Nevertheless, new fish collections from the Yangambi Biosphere Reserve (YBR) and the Okapi Wildlife Reserve (OWR) revealed two groups of specimens similar to, but yet different from, *M. moorii*. Thus, 8 counts and 30 measurements were taken on 154 specimens of *M. moorii*, its two junior synonyms from the Congo Basin and Syntypes of *Mormyrus lepturus*, the two groups of recently collected specimens, and *M. intermedius* and *M. kanninginii*, including their type specimens. In addition, a genetic analysis of the mitochondrial gene *cytb* has been executed. This study shows that the first group belongs to *M. lambouri*, which thus represents a valid species with *M. moorii longulus* as its junior synonym. *Marcusenius lambouri* differs from *M. moorii* by its high number of lateral line scales, its short pectoral fin length and its elongated body. The second group revealed to be a new species for science, *M. sp. 'lilanda'*, which can be distinguished from its congeners with 8 circumpeduncular scales by its short and high caudal peduncle, its rounded head with a terminal mouth, its short and compressed body and several meristic differences. Cytochrome b DNA results also confirm the species status of these two groups of specimens. *Marcusenius lambouri* is widely distributed in the Middle Congo. However, the distribution of *M. sp. 'lilanda'* is limited to some affluents of the more upstream part of the Middle Congo. Nevertheless, the presence of *M. moorii* remains confirmed for the Middle and Lower Congo basin. In addition, while *M. intermedius* is new species for the YBR, *M. sp. 'lilanda'* seems locally extinct in the reserve, which unfortunately reflects the significant anthropogenic impacts even within its borders.

Production Of Sterile *Oreochromis Shiranus* Using Herbal Product

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Reproduction is highly risky and energetically demanding to both male and female fish. Moreover, the likelihood that any particular breeding attempt will succeed – that is, that it will produce surviving offspring – may depend upon prevailing conditions in the physical, biotic and social environment, as well as upon the potential breeder's physical and physiological condition. Investment of energy into reproduction results in slow growth, low quality flesh, because it eliminates the cessation of somatic growth that accompanies sexual maturity. In an attempt to overcome this, fish meant for aquaculture production should be sterilized. This will prevent fish from investing massive amounts of energy into gonad production. In sterile fish, where the gonads do not develop, this energy can be utilized for growth instead of reproduction, meaning that sterile fish grow faster and have better feed conversion ratios than non-steriles; this has large implications for the economic viability of a given fish farm. In addition, sterile fish reduce the risk of inbreeding, overpopulation in a culture facility and prevents the genetic problems which escaped farmed fish may have on wild populations. There is a range of methods that can be used to sterilize fish such as triploidization, hybridization, and generation of new lines via advanced biotechnological techniques, temperature, hypoxia, radiation etc. Most of these proposed methods require expensive materials and expertise. Therefore this calls for an interest in formulating a herbal product that will be administered to fish to produce sterility. This method will be easy to be applied by farmers and requires no expertise since a certain dosage will be administered through feed. It is expected that the herbal product will efficiently induce sterility in both male and female fish specifically the *Oreochromis shiranus*.

Poster Presentations

Theme 1: Fish Systematics Biodiversity Research and Data Management

Taxonomy and Systematics of the Haplochromine cichlidae, *Pseudocrenilabrus multicolor* in Kenya River System

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The genus *Pseudocrenilabrus* is widely distributed in Africa, ranging in the north from Egypt to Sudan, across eastern Africa and part of eastern Congo basin, down to South Eastern Africa and Namibia in the west. The Genus currently constitutes 3 valid species; *P. philander* in south Africa; *P. multicolor* in the Nile River system and *P. nicholsi* in congo river basin. *P. multicolor* constitutes two subspecies, one colonizing the area downstream lake albert in the Nile river system (*P. multicolor multicolor*) -the Egyptian Mouthbrooder and the second (*P. multicolor victoriae*)- dwarf Victoria mouthbrooder known to occur in Lake Victoria basin. Considering this distribution patterns, only one sub-species is known to occur in Kenya (*P. multicolor victoriae*), in the Lake Victoria basin. More recently however, collections of this genus have been made in eastwards flowing rivers of Kenya, where they had not been documented before, namely; Tana, Athi and Ewaso Ng'iro systems. These collections have so far been classified as *Pseudocrenilabrus multicolor* with no specification of subspecies, it is suspected therefore to belong to a different sub-species than the Lake Victoria fish and a taxonomic study is currently

underway to ascertain this. This current study proposes undertaking a rigorous systematic assessment to compare these new collections to other sub-species of *Pseudocrenilabrus* in order

to find out if it constitutes a new sub-species and describe variability. Preliminary results from this assessment shows great difference in the morphology of these group of species in Kenya, in comparison with the dwarf Victoria mouth brooder. A total of 364 specimens from National Museums of Kenya, Ichthyology Section have been used in this study; from Lake Victoria system (194 specimens), Athi system (79), River Tana system (45) and Ewaso Ng'iro system (46). A total of 19 and 16 morphological measurements and meristic counts, respectively, have been carried out and will be analyzed using Multivariate statistical methods involving principal components.

Phylogenetic Relationships of Alestidae (Ostariophysi, Characiformes): Updates with Complete Character Sampling for *Petersius Conserialis*.

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The family Alestidae is a monophyletic unit widespread in the freshwaters of Africa and represented by one genus with five species in South America. A previous phylogenetic hypothesis, based on 200 morphological characters, included the monotypic genus *Petersius*. However, morphological data of the species were restricted to alcohol-preserved specimens and radiographs. Thus, more than 25% of the characters were coded as missing to that taxon. Although *Petersius* was proposed as basally positioned in the cladogram of the Alestidae, it was mentioned that a better evaluation of the relationships of the genus utilizing information from cleared and stained specimens were required. Recently, new material of *Petersius conserialis* became available and specimens were cleared and stained for the present study. The missing 55 characters of the original matrix of Zanata & Vari were scored and re-analyzed. Thus, the morphological phylogenetic hypothesis was updated, with a complete data matrix for *Petersius*. The study focused on the phylogenetic relationships of *Petersius* as well as rearrangements that take place in the phylogeny.

Species diversity in the genus *Labeobarbus* (Cypriniformes: Cyprinidae): the case of the Kalumengongo and Kalule Nord rivers in the Upemba National Park (Upper Lualaba, DR Congo, Africa)

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Eight valid *Labeobarbus* species are known from the Upemba National Park (UNP), but recent sampling in the Kalumengongo and Kalule Nord rivers revealed numerous specimens that could not be readily identified. A total of 57 and 152 specimens of these two rivers, respectively, were studied morphologically, with 16 meristic and 29 measurements taken on each specimen. The typical mouth phenotype diversity was documented according to the following groups: *Labeobarbus*-mouth phenotype (L) specimens, with a well-developed mental lobe; *Varicorhinus*-mouth phenotype (V) specimens, with a keratinized outer cutting

edge on the lower jaw; and several intermediate-mouth phenotype (I) specimens. Finally, based on a subsample of these specimens phylogenetic relationships of mitochondrial haplotypes were inferred using COI and Cytb. For the Kalumengongo, morphological results enabled unambiguous identification of three species: *L. gestetneri* (I), *L. upembensis* (V) and *L. sp. 'kalumengongo'* (L). Moreover, two groups of intermediate-mouth phenotype specimens, one highly similar to *L. upembensis* the other to *L. sp. 'Kalumengongo'*, were identified. In contrast, the mitochondrial data recovered only *L. gestetneri* constituting a separate lineage. For the Kalule Nord six species were identified morphologically, all of which are new to science, but only three mitochondrial lineages could be identified: (i) *L. sp. 'kapepe'* (V), (ii) *L. sp. 'kalule'* (L) and (iii) one containing the four remaining species, i.e. two with a L-, one with a V- and one with I-mouth phenotype. Furthermore, within the last lineage, two groups of intermediate-mouth phenotype specimens, one similar to the *Varicorhinus*-, the other to one of both *Labeobarbus*-mouth phenotype species, were also identified. Based on presented results, both rivers harbour a largely endemic *Labeobarbus* fauna. Both border the UNP and are thus prone to anthropogenic impacts such as selective subsistence overfishing. Hence the need to envision ways for conservation and sustainable management of this unique fish fauna.

Predictive Model for Descriptions of Freshwater African Fish Species in a Historical, Political and Biogeographic Context

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We present a prediction on African freshwater fish species, except Madagascar, that still have to be described and how long it will take. We reviewed literature of currently valid species descriptions, recording: author(s), publication year, country and continent of the first author institution, type-locality ecoregion, conservation status and classification. Subsequently, estimated the number of species remaining to be described and simulated scenarios to reach that. We draw an accumulation curve of species description by year (1758 to 2018), extrapolated under logistic model curves using Jackknife₂ as carrying support (K, expected species number), current species as initial population, varied growth rate in each curve to simulate discoveries scenarios, and searched breakpoints using piecewise linear regression. We recorded 3,207 species, 413 genera, 56 families and 24 orders. Representatives are: orders Cichliformes (33%), Siluriformes (17%), Cypriniformes (16%), Characiformes (11%) and remaining (23%); families Cichlidae (34%), Cyprinidae (16%), Nothobranchiidae (9%), Mormyridae (7%),

Mochokidae (7%), and remaining, with less than 100 species (27%); genera *Enteromius* (231), *Haplochromis* (209), *Synodontis* (129), *Labeobarbus* (119), *Aphyosemion* (104) and remaining, with less than 100 species (338); first authors Boulenger (19%), Poll (8%), Pellegrin (5%), Trewavas (4%), Günther (3%), and Regan, Greenwood and Daget (2% each) described species until mid-twentieth century, and 288 the remaining (55%); continents of first authors Europe (84%), North America (11%), Africa (4%), and Asia, South America and Central America together (1%); countries England (1,136), Belgium (460) and France (381), USA (361) and other nations (840); conservation status NE (37%), LC (37%), threatened (7% VU, 3% EN and 3% CR), and DD plus NT (13%); ecoregions Congo (33%), Zambezi (18%), Lower Guinea, Nilo-Sudan and East Coast (13% each), and remaining totaled 10%. We estimated 9,571 species, considering currently 3,207, remain 6,364 to be described. Logistic models with $r = 0.025$ and 0.025 were closer to a sigmoid. We estimated 1890 (± 362 species) and 1970 (± 2199 species) decades as breakpoints on real accumulation curve. We provide recommendations considering countries different histories.

Anthropogenic Impacts On Water Quality And Macroinvertebrates Distribution Of Toho Lake, South-West Benin

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Toho Lake is a water body in Benin strongly submitted to anthropogenic activities. An appreciation of the impact of these anthropogenic activities on the water quality and the distribution of the macrobenthic organisms of Toho Lake was conducted. Nine physico-chemical parameters were measured and benthic organisms were collected from May to August at 8 stations with an Eckman grab. The auto-organizing map (SOM) of Kohonen was used to determine the similarity between stations on the basis of the environmental variables collected. Benthic structure were performed using four indices of biodiversity (species richness, relative abundance, Shannon-Weiner and Pielou' equitabiliy indices). Abundance-biomass Comparison (ABC) indices, Difference in Area by Percent (DAP) and Shannon-Wiener Equitability Proportion (SEP) were used to reveal ecological stress in the lake. In total, 23 species of macroinvertebrates gathering into 18226 individuals and divided into 4 classes (Insects, Gastropoda, Achaeta and Arachnids) were inventoried. The insects (with 20 species representing 91% of the specific richness and 99.01% of the total individuals) have largely dominated the group of this fauna with one species, *Enithares* sp. (Notonectidae family). Only one species of Mollusk Gastropoda, *Thiaridae Melanoïdes* sp. has been collected. Water transparency (40-90 cm), water temperature (26.50 - 30.3 °C), conductivity (213-350 mS/cm) and dissolved oxygen (1.75-6.06 mg/L) varied significantly in time whereas depth (0.60 - 1.68 m) showed spatial variation. Three clusters were discriminated by SOM analysis and have revealed stresses on the organisms. The feeble values of Shannon and equitability indexes

obtained have confirmed the scarcity of the water body in benthic organisms. The ABC, DAP and SEP indices have largely supported the impacts of anthropogenic activities on the distribution of macroinvertebrate species dominated by few taxa that showed to be indicators of the ecological status of the ecosystem observed.

Molecular Phylogenetic Analyses of Selected Catfish

E Zhang

Lake Turkana is the world's largest permanent alkaline isolated lake located in Kenya, with its far northern end crossing into Ethiopia. It is home to about 50 fish species, 11 of which are endemic. The current taxonomy of these fish species leaves much to be desired, and fish species diversity of this lake is not well known. This thesis is the first attempt to sort species identification of catfishes from three genera (*Auchenoglanis*, *Schilbe* and *Chrysichthys*) in Lake Turkana based on molecular (CO1 and *cyt b* gene) and morphological data. Its main conclusions reached are as follows: (1) the currently recognized *A. occidentalis* is a species complex including many distinct species; (2) the Niger River basin harbors two species of *Auchenoglanis*, one of which occurs in Lake Turkana, as well as *A. biscutatus*; (3) *A. sacchii*, whose type locality is Lake Turkana, is likely a valid species, but not endemic to this lake; (4) *Chrysichthys auratus* is confirmed based on molecular evidence to occur in Lake Turkana where the species diversity of the genus is currently underestimated; (5) incipient speciation in *Schilbe uranoscopus* is revealed by two sympatric mtDNA lineages in Lake Turkana. All these findings not only highlight a need to conduct in-depth studies on the taxonomy of catfishes from this lake, but also deepen our understanding of its fish diversity and evolution, particularly sympatric speciation. This thesis was built up on accurate data, authentic and detailed information and rigorous or evidence-focused literature, rigorously structured and organized in a scholarly or scientific format. This means that the student has already mastered the basic theories and methods of taxonomy, and relevant skills or techniques

Functional diversity of stream fish communities in the Republic of Congo: do Afrotropical freshwater systems conform to mainstream lotic conceptual models?

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The historical focus of research on temperate freshwater systems has resulted in a large data gap in the tropics, particularly in Afrotropical regions. As most conceptual models have been developed in temperate systems, their applicability to Afrotropical waters is uncertain. The aim of this study is to use trait and diversity information from freshwater fish assemblages to characterize the functional ecology of lotic communities in an Afrotropical region. Secondly,

we aimed to test conformity of these systems to aspects of gradient (River Continuum Concept, Patch Dynamic) and landscape (Riverine Habitat Template) conceptual models. Sampling of fish communities was undertaken at eighty-two sites in coastal and inland locations in the Republic of Congo. Abiotic data included measurements of stream morphology, landscape variables, water quality and habitat integrity. Landscape data were modelled using ArcGIS, and biotic-abiotic relationships were analysed using Non-Metric Multidimensional Scaling. Functional traits were assessed using a Principle Component Analysis, and trait diversity calculated using functional trait-space occupation, functional evenness and divergence. Trait-environment relationships used RLQ and 4th Corner methods to show significant relationships between function and environment.

Preliminary results indicate that functional diversity increases with species richness along the longitudinal gradient from first-order streams within both inland and coastal basins, however functional diversity remained consistent between upstream and lowland sites. Habitat preference, feeding and swimming mobility traits were associated with both local and broad-scale environmental variables, where broad physiographic differences between sampled ecoregions also influence taxonomic and functional structure. As with diversity and taxonomic structure, the functional composition of fish communities changed across the longitudinal gradient of the basins with an almost complete species turnover. Functional trait and environment patterns documented in this study only partly confirm established theoretical assumptions and show unique patterns that may assist in developing a greater understanding of responses and vulnerabilities of fish assemblages to environmental modification in Afrotropical systems.

Spatial Variation in Condition Factor and Growth Patterns of *Labeobarbus altianalis* (Boulenger, 1900) Along River Nyando, Kenya

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Continuous monitoring of riverine fish communities is a requirement. Knowledge on condition factor of the existing fish species provides a basis for appropriate intervention strategies. This study is aimed at determining the spatial variation in condition factor and growth of *Labeobarbus altianalis* and further correlates it with selected water quality parameters along River Nyando. Three sites S1 at the upper region; S2 at the mid region and S3 at the lower region closer to the river mouth were sampled. Fish sampling was done using an electrofisher and the sampled fish identified in the field. The length and weight of *L. altianalis* were taken in the field to the nearest 0.1 g at every sampling point physico-chemical parameters were taken in-situ in triplicates. There were significant differences in the TL among the sampling locations (One-Way ANOVA; $F = 6.1212$, $df = 2$, $P = 0.034$). According to post-hoc DMRT, fish sampled from site S1 had the highest SL followed by those in S3 while mean TL at S2 was the lowest. Total weight varied significantly (One-Way ANOVA; $F = 3.001$, $df = 2$, $P = 0.044$) among sites in tandem with variation in TL and TW. There were significant differences in condition factor among stations (One-Way ANOVA; $F = 19.923$, $df = 2$, $P = 0.0001$). Based on post-hoc

DMRT, fish at site S1 had the highest Kn (1.38 ± 0.25) followed by Kn at S3 (1.06 ± 0.12) and the least Kn was reported at site S2 (0.85 ± 0.11). The differences could be attributed to food items consumed and influence of dissolved oxygen, pH and Turbidity.

Eye-Opening Discoveries on the Blind Congo Minnow *Caecobarbus geertsii* Boulenger 1921, An Enigmatic Fish Under Threat

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The Congo blind minnow occurs in some cave formations of the Lower Congo basin (DRC). Although three isolated cave zones occur in this area, *C. geertsii* was considered only to occur in the Mbanza-Ngungu area, the north-eastern zone. Recent explorations of two caves in the south-eastern zone, the Nkyende area, situated about 50km south of the Mbanza-Ngungu area,

led to the discovery of new *Caecobarbus* populations. These populations show some clear morphological differences with specimens from the Mbanza-Ngungu area, e.g. in pectoral fin shape, dorsal fin base length, head width and barbel lengths. Moreover, genetic analyses on the mitochondrial COI gene show a genetic distance of 1.4-2.1% between the populations of the two areas. The population from the Nkyende area may therefore constitute a distinct species. As early as 1937, the Belgian colonial authorities placed *C. geertsii* on the list of fully protected animals. Furthermore, due to threats to its habitat and its limited geographic range, it is listed as vulnerable on the IUCN Red List of Threatened Species. In addition, it is currently the only African freshwater fish species, and the only cave fish, placed on the CITES list, thus restricting its international trade. Nevertheless, severe declines in the major *C. geertsii* populations of the Mbanza-Ngungu area have been noted during the last decade. Indeed, anthropogenic impacts such as siltation resulting from deforestation for agriculture, water extraction for irrigation, habitat destruction due to artisanal mining, loss of cave sites that have been converted to quarries etc. threaten these populations. According to our observations, 65-75% of the total estimated number of ca. 8,000 *C. geertsii* specimens appears to be currently lost. These severe population declines and the possible discovery of a new species highlight the need for a change of statuses and the urgent need for in situ protection measures.

Towards a Collaborative Ichthyological Network Between Africa and South America

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South America stands out as the most diverse continent in the world for freshwater fishes, with about 5,100 species. On average, two new freshwater species have been described per week in the past two decades, with estimates of additional 4,000 species still awaiting discovery. About 4,000 fishes are also reported for marine waters off South America, and new species are regularly discovered in different habitats such as the deep sea and rocky shores. This fascinating diversity inspired generations of European and North American naturalists who started visiting the continent almost immediately after its “discovery” in 1492, leading to significant advances in taxonomy, biogeography, phylogenetic relationships and ecology during that period. The seeds for a more internationally independent ichthyology were sown only by the end of the XIX Century, with the establishment of important fish collections in South American museums. The last decades of the past century witnessed an exponential increase in the number of South American ichthyologists, which are now responsible for the bulk of ichthyological research. Africa and South America share an impressive and historically connected fish diversity that is still only partially understood. Fishes on both continents are threatened by similar impacts, especially high deforestation rates, hydroelectric dam construction, pollution, and unmanaged fisheries. South American and African countries also share close cultural and historical ties. Therefore, strengthening the scientific collaboration between ichthyologists of both continents seems to be a natural development, and will help to mitigate the taxonomic impediment still faced by most African and South American countries, providing a better understanding of the diversity and evolution of their mutual fish fauna. The establishment of a more effective collaborative ichthyological network between both continents would also provide tools for the development of more sustainable strategies for managing relevant natural freshwater resources.

Extinction Risk of African Forage Fishes of the Order Clupeiformes (Teleostei)

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The Clupeiformes includes about 400 species of generally small, schooling fishes such as herrings, sardines and anchovies. They are typically ecologically important forage fishes that serve as a vital trophic link between zooplankton and larger predators. Additionally, these species are often important to commercial fisheries, and can be taken in large quantities to support industrial, artisanal and recreational fisheries. Despite the ecological and commercial importance of clupeiform fishes, population information and conservation efforts are lacking globally and in Africa. This knowledge gap may be attributed in part to a tremendous overlap in distribution variance coupled with relatively indistinguishable morphological characteristics among taxonomically problematic species. This project aims to address the currently known conservation status, data gaps and the symptoms of extinction risk for clupeiform fishes in African waters using the widely accepted Categories and Criteria set forth by the IUCN Red List of Threatened Species. Using primary literature and expert knowledge, global species-specific assessments have been completed for 72 of the 74 marine and freshwater species known to occur in African waters (16 assessments are not yet published). The species accounts provide a comprehensive analysis of significant aspects such as: geographic distribution, habitat preference, life history traits, as well as past and present threats. Of the 74 species reported for the continent, 47 are marine and 27 are freshwater; ten species have been assessed as Data Deficient, three were assessed as Vulnerable and two species have not yet been assessed. Overall, marine species appear to be more impacted by high fishing pressure and freshwater species appear to be more impacted by habitat degradation and alteration. These completed assessments should be applied to guide future regional conservation initiatives and fishing practices in Africa.

A Preliminary Survey of the Fishes of the N'Djili River (Pool Malebo Ecoregion): Biodiversity and Distribution in a Heavily Urbanized System.

Modimo Yoko Myriam

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A preliminary study of the diversity and distribution of fishes in the N'Djili River basin was carried out between December 2015 and June 2016. The N'Djili River flows through the mega-city of Kinshasa and was for the first time investigated to estimate fish biodiversity in both human-impacted and non-impacted sections of the river and its tributaries. To date, 41 fish species have been identified and of these, 9 appear to be confined to tributaries, 23 to the main channel and the remaining 9 are shared between the two biotopes. This preliminary study indicates that despite heavy urbanization the N'Djili remains an important source of fish diversity in the region. Subsequent studies are planned to further characterize the impact on species abundance and composition of heavily impacted and relatively pristine regions of the river.

Length-weight Relationship and Condition Factor of *Papyrocranus (Notopterus) afer* (Günther, 1868) and *Lates niloticus* (Linnaeus, 1762) of river Jong, Sierra Leone.

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The length-weight relationships and condition factor 'K' of 46 specimens of *Lates niloticus* (Linnaeus, 1762) and 92 specimens of *Papyrocranus (=Notopterus) afer* (Günther, 1868) were studied for 6 months (August, 2016 - February, 2017). The results of the study were described by the formula: $\text{LogW} = -1.5089 + 2.6634\text{TL}$ and $\text{LogW} = -1.7988 + 2.7005\text{LogTL}$ respectively. A positive correlation coefficient r of 0.7904 exists between the length and weight of *Lates niloticus* while that of *Papyrocranus (Notopterus) afer* (Günther, 1868) was 0.6995. The b value (growth pattern) of *Lates niloticus* was 2.66. A T-test showed that the value was not significantly different from 3 at $P > 0.05$ while the b value of *Notopterus afer (Papyrocranus afer)* was 2.70. A T-test also showed that the value was not significantly different from 3 at $P > 0.05$. The “ b ” value for the two species showed negative allometric growth. Growth with respect to weight for *L. niloticus* in the dry and rainy season was $b > 3$ (positive allometric growth) while for the length $b < 3$ (negative allometric growth). The results obtained for *N. afer* for both dry and rainy season indicated that growth was in favour of the body weight ($b > 3$, positive allometric growth) while for the length $b < 3$ (negative allometric growth). Condition factor (K) of 0.575 and 0.520 was recorded for *N. afer* during the rainy and dry season respectively while K values of 1.23 and 1.03 were recorded for *L. niloticus* in the dry and rainy seasons respectively. In both seasons for the species, growth appeared to correlate positive with condition factor (K).

Anal-Fin Muscle Complex: A Promising Anatomical Feature on the Resolution of the Phylogentic Delimitation of Alestidae and Its Genera (Teleostei: Characiformes)

Priscilla Boera

This study presents the first documentation of the status of the River Malewa fishery, a major river draining into Lake Naivasha and, to relate the status of the current commercial fishery to information on potential yields so as to identify whether or not there is a scope for better management and utilization of the resource (River Malewa fishery). Six sampling sites were selected from the upper catchment area of the Malewa river system to the lower catchment as it drains into Lake Naivasha. An integrated assessment of water quality to all sites, including the collection of fish communities, physical habitat and chemical information to assess river Malewa conditions was conducted. Electrofishing was conducted at pre-determined points along River Malewa and its tributaries and water quality data collected at the same locations that were marked and recorded using GPS system. The Malewa River System was found to be significantly more dendritic than other systems in the catchment, with headwaters and tributaries rising at arrange of altitudes. pH, temperature, conductivity and TDS values were observed to increase downstream. Four (4) different species – *Oncorhynchus mykiss* (Rainbow trout), *Clarius theodare* (Snake catfish), *Barbus amphigramma* (Barbus) and *Poecilla reticulata* (Guppy) – were captured along the Malewa river system. The rainbow trout was abundant

upstream nearer the source of the river where water temperatures were cooler, but decreased in numbers with decreasing altitude, increasing pH, water temperature, conductivity and turbidity. The other species were more abundant downstream. At the same time, there was an observed significant increase mean size of trout going downstream whereas, increase in mean sizes for the other fish species was found to be inconclusive. Exploitation of *Barbus* (*B. amphigramma*) spawning migration up the River Malewa by fishermen using dipnets was found to be short-lived in the 80's. It can be concluded (inconclusively) that at the present time, the fish population of River Malewa cannot support a productive fishery. To re-establish the fishery of the 80's, sustainable development must be addressed at the catchment scale if it is to be effective in providing social and economic benefits from a riverine fishery.

Anatomy of the Cephalic Myology of *Brycinus Macrolepidotus Valenciennes, 1850* (Characiformes: Alestidae)

Priscilla Boera

This study presents the first documentation of the status of the River Malewa fishery, a major river draining into Lake Naivasha and, to relate the status of the current commercial fishery to information on potential yields so as to identify whether or not there is a scope for better management and utilization of the resource (River Malewa fishery). Six sampling sites were selected from the upper catchment area of the Malewa river system to the lower catchment as it drains into Lake Naivasha. An integrated assessment of water quality to all sites, including the collection of fish communities, physical habitat and chemical information to assess river Malewa conditions was conducted. Electrofishing was conducted at pre-determined points along River Malewa and its tributaries and water quality data collected at the same locations that were marked and recorded using GPS system. The Malewa River System was found to be significantly more dendritic than other systems in the catchment, with headwaters and tributaries rising at arrange of altitudes. pH, temperature, conductivity and TDS values were observed to increase downstream. Four (4) different species – *Oncorhynchus mykiss* (Rainbow trout), *Clarius theodare* (Snake catfish), *Barbus amphigramma* (Barbus) and *Poecilia reticulata* (Guppy) – were captured along the Malewa river system. The rainbow trout was abundant upstream nearer the source of the river where water temperatures were cooler, but decreased in numbers with decreasing altitude, increasing pH, water temperature, conductivity and turbidity. The other species were more abundant downstream. At the same time, there was an observed significant increase mean size of trout going downstream whereas, increase in mean sizes for the other fish species was found to be inconclusive. Exploitation of *Barbus* (*B. amphigramma*) spawning migration up the River Malewa by fishermen using dipnets was found to be short-lived in the 80's. It can be concluded (inconclusively) that at the present time, the fish population of River Malewa cannot support a productive fishery. To re-establish the fishery of the 80's, sustainable development must be addressed at the catchment scale if it is to be effective in providing social and economic benefits from a riverine fishery.

Polychromatism in the Ichthyofauna of the N'Sele River (Pool Malebo Ecoregion, DR Congo)

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During an ichthyofaunal survey of the fishes of the N'Sele River, two instances of polychromatism or of cryptic species were encountered. Specimens seemingly belonging to the cichlid species, *Tylochromis lateralis*, and the distichodontid species, *Distichodus affinis*, were collected that differed markedly in pigmentation patterning with respect to other specimens assigned to those species. The molecular “barcode” (COI) was used, in conjunction with standard morphometric measurements and meristic counts, to taxonomically resolve the status of the individuals in these two cases.

Population Genetic Structure of *Nothobranchius Melanospilus* from Eastern Tanzania

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The coastal region of south-eastern Kenya and eastern Tanzania is an important hotspot of biological diversity with high occurrence of endemic species. This region exhibits the great species diversity of *Nothobranchius* fishes, a killifish genus that distributed across large part of central and eastern Africa. *Nothobranchius* fishes are small and evolved a strategy to reside in temporary pools formed during the rainy season. Their life cycle is annual and adults die when the habitat desiccates. Resistant eggs undergo diapause during the dry season and persist in the dry mud until a next inundation of the pools. The most common and geographically widespread species of *Nothobranchius* present in the floodplains of coastal river systems in eastern Tanzania is *N. melanospilus*. We used a set of 10 microsatellite loci for a sample of the over 250 individuals from 11 populations and subset of individuals for analysis of mitochondrial gene sequences to describe its population genetic structure. Some studies have shown the role of large rivers as the major barriers to *Nothobranchius* dispersal in particularly dry regions. Our data are used for testing this hypothesis in a region with more humid climate and longer rainy season.

Theme 2: Aquatic Resources Conservation and Management

Impacts of Mini-Hydropower Dams on Stream Fishes of Rwenzori Mountains, Uganda

Aventino Kasangaki

The Rwenzori Mountains are situated within the western arm of the East African Rift system giving rise to several streams and rivers. River Mubuku is the primary glacier-fed river originating from Mt Rwenzori in Western Uganda. The river currently supports a cascade of three hydropower dams located in its lower-reach sections between about 1800 m and 1400m above sea level. Through a combination of field sampling and review methods, fish fauna of rivers draining Mt Rwenzori on the Ugandan side was assessed for dam impacts of existing hydropower dams and potential impacts of proposed hydropower dams. Currently three hydropower dams are operational on river Mubuku (1,2, and 3), and one on river Mpanga while several are under construction or are proposed on the remaining rivers such as Nyamugasani, Nyamwamba, Rwimi, Ndugutu, and Sindila. Fish species richness recorded between about 1000m to 2600 m above sea level is about twenty with the possibility of more species downstream as the rivers drain into Lakes George, Edward and Albert. Of the recorded species, two are Albertine Rift endemics (*Labeobarbus ruwenzorii*, and *Platypanchax modestus*) while the Brown Trout (*Onchrychus mykiss*) is introduced. High altitude species such as *L. ruwenzorii* and *Amphilius jacksonii* are the most impacted by hydropower dams in the River Mubuku drainage where the river has been dissected by three weirs constructed across the river. In addition, migratory species are unable to move above the weirs resulting in habitat contraction. Dam construction techniques or designs that include fish passages and ladders are recommended for the continued connectivity along the river gradients for continued survival of migratory species.

Aquaculture of the endemic Tanganyikan cichlid *Boulengerochromis microlepis* – the new salmon of the tropics?

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The inland fisheries in African Rift Valley lakes are facing increasing problems due to overfishing, such that novel aquaculture strategies need to be developed, to meet the high demand for food fish. Moreover, it is important to consider future problems of foreign fish introductions, which frequently occur by accidental escape from ponds or cages. Therefore, local fish species are the best candidates for novel aquaculture strategies. While local *Tilapia* species, such as *Oreochromis tanganyikae* in the Lake Tanganyika drainage and *O. andersoni* in the lower Zambezi are already at an advanced stage of establishment in aquaculture, larger predatory species are not yet available, as their diet and breeding issues remain to be solved. The endemic Lake Tanganyika cichlid species, *Boulengerochromis microlepis*, with up to 80cm total length (the largest cichlid in the world), is a highly promising candidate for future

aquaculture production in ponds and cages. First trials are underway, but no results concerning rearing, diet and breeding have been published so far.

Here we present first results on the successful rearing of “Nkupi” from small fingerling size to adulthood in a large aquarium, and present an adequate pellet diet that can also be adapted for the use in cage culture. Breeding was also successful in large aquaria in 2017, so that all basics seem to be in place to seriously consider this species as the future salmon of the tropics.

A Close Analysis of Major Causes of the Loss of Fish Fauna and Diversity in Lake Malawi.

Dickens P. Mahwayo,

GS Foundation

A study was conducted to explore and analyse major causes of the loss of fish fauna and diversity which includes a declining catch of traditional fishery in Lake Malawi. A qualitative prospective mixed method cohort study which involved interpretative literature review, focus group discussions, key informant interviews and in-depth interviews was carried out consisting a randomly selected sample of 62 respondents from Sengabay, Msaka, Chembe, Bolera, Moto, Kadango and Chikulo fishing beaches in Salima and Mangochi respectively. Data analysis in the study which was carried out between March 2014 and November 2017 was being analysed on a continuous basis using tally sheets. The study documented the following as some of the major causes of the loss of fish fauna and diversity in Lake Malawi. Destructive and illegal fishing, Extensive Pollution due to excessive feeding and agricultural activities, over exploitation of fisheries resources/Overfishing, introduction of Exotic Species and Climate Change effects. It is a fact that despite its economic and social importance, the Lake Malawi fish fauna is exposed to many manmade threats. Malawi's economy is agro and natural resource based hence majority of Malawians relies on income derived from agriculture and natural resources which include fisheries as such the government and its development partners should reinvigorate their efforts in the protection, management and conservation of the fish fauna of Lake Malawi which is highly diversified.

Preliminary Data on the Ichthyofauna of the Couffo Basin in Benin

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To date, the ichthyofauna of the Couffo basin is poorly known. Lake Ahémé, which is drained by the Couffo basin, is located in a network of waterbodies, i.e. the Lake itself, the Ahô Chenal, and a coastal lagoon complex. This complex is currently degraded due to eutrophication and poor fishing practices. Faced with this situation, and in view of the socioeconomic importance of the waterbodies that make up the complex, the government of Benin has decided to rehabilitate them through implementation of the Intercommunal Rehabilitation Program of Lake Ahémé and its channels (PIRA) and the establishment of an economic development zone. The main component of this program is the dredging of the involved waterbodies with as major goal the recovery of its fish populations and thus its production. However, dredging is a procedure that will profoundly disturb its aquatic fauna. Samplings were carried out in 2013-2014 all-over Lake Ahémé to obtain an inventory of its fish fauna prior to the implementation of the PIRA program. However, despite harbouring a very poorly known fish fauna, the Couffo River (190 km) was not taken into account. To remedy this situation, an inventory of the current ichthyofauna of the Couffo has been initiated in order to be able to evaluate the impact of dredging on its fish diversity. A preliminary study, conducted on the river's estuary between April and May 2018, based on experimental and small-scale fishing, has made it possible to record 50 native and one introduced species, *Oreochromis niloticus*. The most species-rich families are the Cichlidae (7 species), Alestidae (4) and Gobiidae (3). Twenty three species (45%) are typically of marine or estuarine origin. Two species, *Polypterus endlicheri* Heckel, 1849 (Polypteridae) and *Mastacembelus cryptacanthus* Günther, 1867 (Mastacembelidae), not known from the Mono Basin, i.e. its western neighbouring basin, were also caught.

Socio-Economic Factors Influencing Nile Perch (*Lates Niloticus* (L.)), Overfishing in Lake Victoria Tanzania

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Fishery sector play a vital role in contributing directly to food and livelihood security especially in developing countries. In Tanzania, the role of fishing is realized through its employment contribution to majority fishers particularly Nile Perch fishers in Lake Victoria which is major fish export and has high commercial value. However, with the presence pressure of fishing there evidence that Nile Perch fish is overfished. This study was conducted to investigate the socio-economic factors influencing Nile perch (*Lates niloticus* (L.)), overfishing in Lake Victoria Tanzania. Primary data were collected by randomly selecting Nile Perch fishers and interview them with the use of questionnaires to 268 respondents from three districts with 12 fish landing sites in Mwanza. The study employed Probit model in analysis and found that, significant factors which influence Nile perch overfishing are; quantity of Nile Perch per trip (catch per trip), time that the fishing vessel has been used (age of the fishing boats), gillnet mesh size, mode of propulsion and hours spent to reach the fishing ground. The study recommends that, quantity of Nile Perch catch per fisher (Quota restrictions), time to time inspection and monitoring of fishing boats used, the Nile Perch slot size and size of mesh gillnets should be well

monitored. In addition, restriction policy on the fishing grounds and fishing education should be emphasized.

Mapping for Conservation of Native Tilapia Resources in East Africa Using Smartphone Application Technology

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East Africa is the major hotspot for diversity of native *Oreochromis*, the genus that dominates the \$5b+ global tilapia farming industry. These unique populations may contain genes for disease resistance, environmental tolerances etc. valuable for improvement of farmed tilapia strains. However, they are threatened by invasive exotic tilapia strains stocked from fish farms, which often outcompete native strains or genetically swamp them through hybridization. Research indicates that exotics are now found in many water bodies in East Africa, but assessing or ameliorating the threat has been hampered by lack of species identification capacity and difficulty in archiving and accessing distribution data. We aim to facilitate identification of remaining populations of native tilapias in Kenya and Tanzania, mapping distributions of introduced and invasive species, using smartphone application technology, and build the capacity for this to be monitored and sustained through local agency and citizen science approaches. We will build links between fish biology researchers and biological database managers, develop sustainable data management plans, and build capacity in the archiving and analysis of data through local and global platforms. We will work to ensure that this process will inform policy on zonation of strains used in aquaculture and on importation and distribution of non-native species.

Assessment of Physicochemical Surface Water Quality Parameters of Awhum Stream, Udi Local Government Area, Enugu State, Nigeria.

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The surface water samples of Awhum stream were assessed for physicochemical quality. The parameters examined comprised colour, temperature, pH, turbidity, electrical conductivity, TDS, TSS, hardness, salinity, nitrate, oil and grease, BOD, DO, sulphate, iron, chromium, manganese, lead, copper, zinc and cadmium. The results were as follows: Colour (7.5 – 9.2PtCo Units), Temperature (26.3 – 26.7oC), pH (6.62 – 6.57), Turbidity (2.18 – 2.73NTU), Electrical Conductivity (27.86 – 28.04µS/cm), TDS (19.5 – 19.6mg/l), TSS (0.91 – 1.13mg/l), Hardness (25.17 – 27.05mg/l), Salinity (0.00218 – 0.00224ppt), Nitrate (0.002 – 0.014mg/l), Oil and Grease (<0.01), BOD (0.04 – 0.1mg/l), DO (9.48 - 10.21mg/l), sulphate (0.03 – 0.06mg/l), heavy

metal content in water samples ranged from 0.92 – 0.93mg/l with the average of 0.926±0.008 for Iron; 0.03 – 0.07mg/l with the mean of 0.05±0.03 for Manganese; 0.026 – 0.0028mg/l with the mean of 0.027±0.001 for Copper; 2.751 – 2.882mg/l with the mean of 2.8165±0.09 for Zinc; whereas Chromium, Lead and Cadmium concentrations were equipment detection limits of Chromium = 0.001, Lead = 0.01 and Cadmium = 0.002 respectively. All the physicochemical parameters were in agreement with standard limits prescribed by WHO and NSDWQ, except Iron which was slightly higher than the recommended standard limit by WHO and NSDWQ. The study area is relatively pristine environment, with no significant anthropogenic activities that impacts negatively on surface water qualities, as human settlement is about 4km away from the Awhum stream. Consequently, the water is ideal for thriving of aquatic resources, particularly fish. Thus, it can be harnessed carefully for aquaculture purposes, with very low risk of associated contaminants problems often associated with food fish cultured in polluted or contaminated water sources. In order to maintain this environment congenial, rearing of cattle and other anthropogenic activities already observed to be gradually encroaching on Awhum stream, should be curtailed. This recommendation is aimed at avoiding contamination of the stream by faecal matter and pollutants associated with other human socioeconomic ventures, such as manufacturing concerns. Also, the Awhum stream as currently constituted in terms of its physico-chemical parameters could be used as a baseline reference standard to evaluate pollution changes that anthropogenic activities might have impacted in similar water bodies within the area.

Impact of Dredging on the Ichthyofauna of the Lowlands: Comparison of the Reproduction Parameters of *Sarotherodon Melanotheron* Populations (Rüppell, 1852) of Dredged Lowlands and the Coastal Lagoon at Togbinin Southern Benin

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The sampling between June and September yielded 428 specimens (230 for lagoon and 198 for shallows) on which breeding parameters were determined; monitoring monthly measurements of the physicochemical parameters of the water. In the long run, only the depth differs between the two environments (Prof lag = 1.57 m, Prof bottom = 6.2 m) ($p < 0.05$). The absolute fertility obtained in the lagoon (1,552 eggs) did not differ from that of the lowlands (1,468 eggs) ($p > 0.05$). The sex ratios obtained are not different from the unit (lagoon $p = 0.99204$, lowlands $p = 0.7113$). The first sexual maturity sizes of females and males are respectively 6.51 cm and 7.17 cm for the lagoon and 15.32 cm and 10.65 cm for the dredged bottomlands. The ovarian diameter revealed the size of the eggs in the shallows (0.17 cm) compared to the lagoon (0.11 cm). Ultimately, dredged water bodies will only serve biodiversity.

Trophic Structure of a Clear Water River in the Brazilian Amazon: Spatial-Temporal Dynamics of Resources Used By Rheophilic Fish in the Brazilian Amazon

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Differences in environmental characteristics within a spatial and temporal scale may influence consumption of food resources by rheophilic fish in rivers in the Amazon Basin. Thus, a comparative experiment was carried out to investigate the spatial-temporal dynamics in the use of food resources and the trophic structure of fish assemblages in two sections of the Teles Pires river, a clear water river in Brazil. We sampled two distant sections about 430-km apart. The upper section (6 sample points) was characterized by a low number of rapids, slower stream velocity, relatively lower margins and presence of more lakes and tributaries than the lower section (7 sample points). Fish specimens were collected using a sequential set of gillnets with different sized meshes, during falling, low water, rising and high-water periods. The fish used a variety of food resources, with an autochthonous diet predominating in the assemblages of both sampled sections. However, there was variation in the proportion of use of this type of resource between the sites. The trophic structure also presented spatial variation. In the upper section, piscivorous, detritivores and herbivores predominated. In the lower section, the trophic structure was predominantly composed of piscivorous, herbivorous and insectivorous fish. The trophic structure presented low temporal variability in both samples. In the upper section, detritivores presented variation in biomass ($p= 0.040$) with lower biomass in the high water compared to other periods. In the lower section, omnivores presented numerical variation ($p= 0.030$) with lower abundance in the high water compared to rising period. The results obtained in this study showed that the two studied sections of the Teles Pires river are functionally distinct with low temporal variability in the trophic structure, which can be explained by variability in environmental characteristics.

Development and Effects of the Gillnet Mesh Size Regulation on Lake Victoria, Uganda. The Case of The Nile Perch Fishery

Mpomwenda Veronica

The five-inch gillnet minimum mesh size regulation was one of the earliest measures used to regulate and manage the major fisheries in the Lake Victoria fisheries in East Africa since the beginning of the twentieth century. However, there has been no study conducted to show the development of the Nile perch fishery in relation to the minimum mesh size regulation the lake. This study examined the development and effects of gillnet mesh size regulation on the Nile perch fishery, focusing mainly on motorized and paddled fishing vessels using gillnets. The study used data from Frame and Catch Assessment Surveys for the period 2005 to 2015. Linear regression analysis was conducted to determine the effect of mesh size composition on the catch length in the different vessel categories with reference to the five-inch minimum. Results indicated that the mesh sizes in the different categories had a significant effect on fish length, average quantity and fish price for the two vessel categories. Motorized vessels in the Nile

perch fishery over the same period increased by 390%; where > 90% had gillnets above the five-inch benchmark. Paddled vessels, on the other hand, indicated no increase in numbers, however, there was a shift to smaller mesh sizes contributing to > 60% in 2015. On the contrary, Catch rates showed declines in motorized vessels than their counterparts. The study concludes that mesh size restriction alone is not effective in ensuring the sustainability of the fishery and recommend a combination of management measures coupling gear size restriction and effort regulation.

Prospects and Constraints in Culturing Mangrove Whelks (*Thais coronata* - Lamarck, 1816) in the Niger Delta, Nigeria.

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The mangrove whelk *Thais coronata* commonly known as rock snail is a mollusc species of the Niger Delta. The species occurs in the inter-tidal zone of the region where it is harvested. Its meat provides a source of cheap protein in the coastal towns and villages. Rock Snail is a good species for aquaculture, it grows up to 5cm in length and are dirty grey in colour. They are found in saline waters, like the other mangrove whelks such as *Thais callifera* (Lamarck, 1822) and *Thais forbesi* (Dunker, 1847). The settlement and distribution of *Thais coronata* is determined by the presence of suitable substrates. Knowledge of the breeding habits, larval development and behaviour of the whelks is important for culture purposes. The availability of *Thais coronata* seeds is seasonal. This could mean that the breeding cycle of this species is not all year round. There are no established culture methods for the cultivation of *T. coronata* in the Niger Delta. Culture technique for whelks in Asia and the Americas that can be adopted in the Niger Delta includes; artificial spawning in hatcheries, culture of the juveniles in earthen ponds and raising of the juveniles in designated sea bed, also known as sea ranching. Rock snail is a brackish water species found in prop roots of mangrove and other surfaces in the Niger Delta. The mangrove swamps is the region considered suitable for the culture of this species. The aquaculture of Rock snail is to meet the following objectives; to quickly produce large amounts of rock snail meat to bridge the gap in fish demand, produce gainful employment in rural area and exchange commodity to increase national wealth. The prospects for the culture of this species include; availability of the species, potential exchange commodity, environmental factors etc, while the constraints include; environmental degradation mainly oil pollution, poor infrastructure development of the Niger delta area, inaccessibility to loans and credit facilities etc. Innovative culture techniques practiced in other parts of the world could be adopted in the Niger Delta to culture these species.

Mapping of Oreochromis Species in Kenya

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Oreochromis is a large genus of tilapiine cichlids endemic to Africa. They are important for fisheries and in particular aquaculture, accounting to about 80% of Kenya's freshwater. In Kenya seven species of genus Oreochromis are known Oreochromis hunteri, O. esculentus, O. jipe, O. leucostictus, O. niloticus, O. spilurus and O. variabilis. Before 1950s the distribution of these species were known. However, introductions of species from basin to basin begun to complicate the formerly clear delineation. In the early 2000s the Kenya government begun to push aquaculture as a viable economic activity countrywide, through the Economic Stimulus Program (ESP). This saw the Nile Tilapia, O. niloticus, proliferated in every region and hydrological system. The source of this tilapia was mostly from hatcheries of the Fisheries Department around the country, one of which contains doubtful identified fish. Ichthyology Section of the National Museums of Kenya had previously identified fish from Sagana Fish Farm in Central Kenya as a hybrid between the Nile Tilapia and the Sabaki Tilapia, O. spilurus, which occurs naturally along the upper Tana River catchment (including R. Sagana). These hybrids have been observed around the country in ponds and in rivers (due to escapes from ponds). This study will involve mapping out of distribution of Oreochormis species around the country from museum collections and field expeditions in areas where aquaculture has been known to occur. The results will reveal areas where natural strains occur, hybridization zones and possible consequences including extinctions.

Genotoxicity of sub-lethal concentrations of ZnO-NPs on Heterobranchus longifilis and ameliorative potentials of ascorbic acid

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Zinc oxides nano-particles are used in the production of most commercial and medicinal goods, but their potential toxicity on aquatic organisms as a result of their ability to bio accumulate in animals tissues cause genetic disorder. This study investigated the toxicity of ZnO-NPs on H. longifilis and the ameliorative potentials of ascorbic acid (AA) on micronucleus (MN) frequency and DNA quality of ZnO-NPs-exposed fish. Juveniles H. longifilis were exposed to sub-lethal concentrations (6.00, 8.00, 10.00, 12.00 mg/l) of ZnO-NPs for 60 days. Fish were treated with varying concentrations (50.00, 250.00, 500.00, 1000.00 mg AA/kg diet) for 30 days to ameliorate the toxicity. After each experiment, the MN abnormalities and DNA quality were evaluated. The commonest abnormalities recorded in the tissues of ZnO-NPs-exposed fish are micronucleated, binucleated, multinucleated, altered, echinocyte cells, kidney-shaped and

deformed nuclei. However, the groups ameliorated with 500 mg/kg diet of ascorbic acids recorded little or no abnormalities. A dose and time dependent increase in MN induction and frequency occurred compared to control, but decreased significantly ($P < 0.05$) as the concentration of ascorbic acids increased. There were highest MN induction and frequencies in the liver (38.23%) than gills (26.32%) and blood (24.61%) of ZnO-NPs-exposed fish, with the lowest MN induction and frequency in the liver (10.21%), gills (1.76 %) and blood (1.61%) of the group fed on diet with 500 mg/kg diet. DNA quality reduced with increasing concentrations and exposure periods but improved in fish fed 500 mg/kg AA diet. The results of the findings indicated that ZnO-NPs are toxic to *H. longifilis* but 500 mg/kg of AA was able to neutralize the toxic effects of ZnO-NPs and minimize MN induction and DNA damage in *H. longifilis*.

A Conceptual Framework for the Integrated Management of Fish and Fisheries in Lake Tana, Ethiopia: DPSIR as a Tool to Support Decision and Policy Makers

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Lake Tana has a remarkable and conservation-worthy assemblage of fish species, which are of great value to the local fisheries. However, due to anthropogenic impacts, the fish species and attributes of the lake fisheries are threatened. Hence, management of these resources is important. A better understanding of the cause-effect relationships between human activities and environmental components is vital for optimum management of the resources. The Drivers-Pressure-State-Impact-Responses (DPSIR) framework is a useful tool to describe these links in a meaningful way to managers and policy makers. Despite its potential, application of DPSIR is virtually lacking in developing countries like Ethiopia. This paper assesses the potential of the DPSIR framework and uses it to comprehensively describe the available knowledge in the lake catchment. Rapid population growth and the economic transformation are the main driving forces of various pressures. Due to these pressures, degradation of the fish population, water quality, wetlands and forestland is intensifying, which is detrimental to the socio-economic state and health of the local inhabitants. Optimal multi-level responses (including family planning, policy revision and proper implementation, construction of wastewater treatment plants, restoration and subsidizing) are developed as feedback to the driving forces, pressures, state changes and impacts. This study aims at providing policy makers a better understanding of the lake catchment in order to bridge the gap between science and decision-making.

Effects of Angling on Improved Knowledge of Fishes in Two Communities in South-West Nigeria

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The activities of children involved in angling were examined in this study with the aim of documenting the indigenous knowledge transfer of angling by the children and the possible effect of angling on fish conservation and food security. Structured questionnaires were purposively administered to forty – six children fishing on Ogunpa stream, Ibadan; Opa, Alagbon, and Okoko streams in Ile – Ife area. Fish samples were collected from the children; these fishes were identified and preserved in 70% alcohol. The results revealed that 69.2% of the respondents learnt angling skills from friends or relations, while 30.8% acquired angling skill by observation and trials. Among the respondents 46.2% have transferred the angling skill to a friend or brother (usually younger). The results also showed that the respondents knew the common (Yoruba / local) names of the fishes they caught. The most abundant fish species collected was *Barbus occidentalis*, - reported as Isin. Other fish species caught were Ojiji (*Malapterurus electricus*), Aro (*Clarias angularis*) Epia (*Tilapia zillii*) and Mota (*Brycinus longipinnis*). The study revealed that 41.1% of the respondents were able to catch fishes by other methods apart from angling. The catches were either sold or eaten by the children. 7.1% of the respondents have some form of aquarium. The study concludes that the children transferred the indigenous knowledge of angling to peers informally. The children's knowledge of the (local) names of fish species caught is very fundamental in fish conservation and should be harnessed in creating the awareness of conservation – sustainable use of natural resources – in the children

Effects of Aquatic Vegetation Removal by Fishers on Fish Populations in Lake Chilwa, Malawi

Elliot Watson Lungu

This study was conducted to test the effect of removing emergent aquatic vegetation by fishers on the abundance and size-distribution of economically important fish species in Lake Chilwa, Malawi. Fish samples were collected using seine nets and fish traps from three distinct habitats: (1) vegetated sites, (2) unvegetated sites and (3) sites from which vegetation had recently been cleared by fishers. Sampling vegetated sites required different methods than the other two habitats, which means comparisons among habitat must be made cautiously. There was no evidence that the total abundance of fish differed among habitats, but clearing vegetation appears to create habitat that is occupied by smaller individuals of *Oreochromis shirana chilwae* and *Clarias gariepinus* than vegetated sites. *Clarias gariepinus* at vegetation removal sites were also in worse condition (Fulton's K) than in other habitats. Because this study was conducted during the recovery dry season, and while the lake was recovering from drying completely in 2012, we hypothesize that reduced food availability may explain smaller body sizes and reduced condition where vegetation was removed. The findings suggest that the current prohibition on cutting vegetation is justified, and that a broader, integrated analysis of the consequences of vegetation removal may be warranted.

The Occurrence of Pansteatitis in Fish from Two Impoundments within the Olifants River System, South Africa: An Update

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Pansteatitis (yellow fat disease) has become a concern in some South African freshwater systems, and has been identified as the leading cause of the declining Nile crocodile population along the Olifants River. High prevalence levels were recorded for some fish species from impoundments within this river system. This disease leads to solidification of adipose tissue, resulting in a reduction of metabolic processes of these tissues and over time resulting in animals becoming lethargic. The pathogenesis is linked to a diet high in polyunsaturated fats and the deficiency in vitamin E which play an essential role as an antioxidant. Pansteatitis was first diagnosed from a number of *Oreochromis mossambicus* (Mozambique tilapia) at Loskop Dam in 2012. Over time the prevalence and severity of this disease became more evident within the tilapia and was also diagnosed in other species such as *Labeo rosae* and *Clarias gariepinus* within this impoundment. Minor signs of this disease were also recently recorded from different fish species in Flag Boshielo Dam, downstream from Loskop Dam. Studies by other researchers indicated the occurrence of pansteatitis in *C. gariepinus* in the Olifants Gorge just before the river enters Massingir Dam in Mozambique. During the current study, signs of steatitis lesions were observed in the mesenteric fat, as well as within fat associated with the muscle, liver, eyes and brain. Prevalence statistics indicates that pansteatitis is more prevalent among larger fish which is indicative of long term exposure to certain drivers within the system. To date no distinct factor has been identified, as it appears to be the result of many different chronic factors. The cause of this disease is thought to be associated with degradation of water quality from pollution derived from effluent of sewage, agricultural and industrial discharge as both these impoundments are on the impacted Olifants River.

Theme 3: Fish and Food Security in the 21st Century

Strengthening Pond Aquaculture among fish farmers of Western Uganda

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This paper presents the findings of a study whose purpose was to assess the performance of pond production systems in order to design modalities to improve incomes of fish farmers in Western Uganda. It was conducted through a semi-structured questionnaire survey in eight districts and covered 104 respondents and Key Informant Interviews with key persons. An estimated 20.6% of ponds were abandoned majorly due to failure to generate profits especially after the first production cycle. There was lack of local sources of fish seed so fish farmers obtained their supplies from Kampala and lakes; whereas others stocked once and depended on their natural multiplication while in ponds. There was limited knowledge of on-farm feed mixing among farmers so they depended on feed sourced from feed suppliers which was sometimes not of good quality resulting into poor harvests and low growth of fish. Most small scale farmers who did not receive aid from government programmes and some who run short of recommended feed used local materials such as yam leaves and food remains. On average, the fish farmers made losses on tilapia only ponds of Shs (-2,683,654) and catfish only ponds of Shs (-1,507,236) but made gross profit on mixed tilapia and catfish ponds of Shs 6,604,203 per production cycle. The study recommends that fish farmers should be trained and supported to produce on-farm mixed feeds, only supplementing with manufactured feeds to ensure quality and minimise costs. Farmers should also be equipped with knowledge and skills in pond management and addition value to fish in order to improve the shelf life and enable access to distant markets.

Effect of Yeast (*Saccharomyces cerevisiae*) Products on African catfish (*Clarias gariepinus*) Production

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The intensification of aquaculture operations is often accompanied by stress due to suboptimum environmental conditions resulting from overcrowding and overfeeding. To keep up with demand for aquaculture products, the suboptimal environmental conditions associated with intensive aquaculture operation will likely continue. Hence, the importance of including bio-active ingredients (such as yeast products) in formulated aquaculture diets to enhance the performance, health and immunity of aquaculture species under suboptimum environmental conditions. The purpose of this study is to examine the effects of yeast (*S. cerevisiae*) products (unextracted and hydrolysed yeast) on the production of African catfish (*C. gariepinus*). African catfish ($11.77 \pm 0.05 \text{ g fish}^{-1}$, $100 \text{ 857L tank}^{-1}$) were fed ad libitum with iso-

nitrogenous and iso-lipidic diets supplemented with either 0% yeast product, 3% unextracted yeast or 0.3% hydrolysed yeast for 56 days. The feeding trial was carried out in a flow-through aquaculture system (9 circular tanks of 857 L capacity each) and were supplied with freshwater from a deep well. At the termination of the feeding trial, growth, feed utilisation, somatic and haematological indices were assessed. There was no significant difference ($P > 0.05$) observed in the final weight (63.63 ± 2.57 g fish⁻¹), feed conversion ratio (1.30 ± 0.04), specific growth rate (3.12 ± 0.08 % day⁻¹), protein efficiency ratio (1.67 ± 0.05) and survival (90.67 ± 2.54 %) of the catfish fed the experimental diets. Similarly, the somatic indices (K-factor, 0.8 ± 0.04 ; hepatosomatic indices, 0.91 ± 0.18 and viscerosomatic indices, 10.83 ± 0.87) and haematological parameters were not significantly different ($P > 0.05$) among the catfish fed the experimental diets. It could be inferred that under optimum rearing condition, yeast products (at current level of inclusion) do not enhance the growth performance nor haematological parameters of African catfish (*C. gariepinus*). Histological analysis of gut morphology as well as microbiological analysis of gut microbiota profile are ongoing.

Effect of Fertilization with *Tithonia Diversifolia* (Hemsl.) on Zooplankton Productivity and Zootechnical Performance of Fingerlings of *Oreochromis Niloticus* (Linnaeus, 1758)

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The effect of fertilization with *Tithonia diversifolia* on the productivity of zooplankton and the growth performance of fingerlings of *Oreochromis niloticus* were investigated between May and October 2014 at the IRAD of Foumban in order to contribute to the improvement of the production of the fishes.

A total of 513 fingerlings with an average weight of 8.89 ± 0.91 g, were randomly distributed into six ponds of 85 m² previously equipped with compost crib occupying 5% of the surface area. Each randomly selected pond was administered weekly doses (3.75; 5 and 6.25 kg) of *T. diversifolia* previously chopped. At the end of the study, the highest biomass of zooplankton were obtained with the highest dose (6,25kg). But the growth performances of *O. niloticus* and its productivity were significantly higher with the dose of 5kg.

The dose of 5kg of *Tithonia* proved most convincing to improve the production of *Oreochromis niloticus*.

Aquaculture Development in Nigeria: Challenges and Opportunities in Nigeria Aquaculture Industry

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Aquaculture is widely recognised and promoted as a source of income, employment and food supply hence its potential as a tool for development in developing nations including Nigeria. A mapping study of operators in Lagos and Ogun States aquaculture industry was conducted. A total of 5,103 operators (hatchers and farmers) were enumerated and characterised. The industry was dominated by African catfish production, mainly operated by male (81.6% and 92.3% in Lagos and Ogun States respectively). Catfish table-size operation was the main engagement (53.8% and 48.4% in Lagos and Ogun States respectively) in the industry, followed by hatchery operation (20.7% and 35.11% in Lagos and Ogun States respectively) with few operators engaged in enterprise mix. Borehole and river/ stream are the main sources of water for operations. Large proportion of the farmers utilised feed from more than a source (imported and locally-produced) for production. Operations are mainly financed from personal savings (88.27% and 85.5% in Lagos and Ogun States respectively). Cost of feed was the largest recurrent production cost accounting for more than 60% in table-size operation. The most common sales terms were cash on delivery. High cost of feed input and insufficient fund and/ or lack of access to fund are perceived to be the most severe constraints to aquaculture production. Therefore, to further tap the potential of the Nigeria aquaculture industry for economic growth, provision of funds and easy access to credit facilities as well as local production of affordable high quality feed requires urgent attention.

Assessing Quality and Acceptability of *Bagrus Meridionalis* (Kampango) Smoked Using Agricultural By-Products

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This research was on assessing the quality and acceptability of Kampango (*Bagrus meridionalis*) fish smoked using agricultural by-products/residuals through analysis of nutritional composition and sensory quality of the product, realizing the direct quantity of tree (for fish smoking) population decline. The central **aim** was to assess potential of using maize cobs and pigeon pea dry plants as a source of fuel wood for smoking fish. Six treatments were administered, namely; smoking fish using hard wood, smoking fish using maize stovers (maize cobs after removing grains), smoking fish using pigeon pea dry plants, smoking fish using a mixture of hard wood and stovers, smoking fish using a mixture of hard wood and pigeon pea dry plants, and smoking fish using a mixture of stovers and pigeon pea dry plants. From each treatment, a fish sample was collected, for proximate analysis to determine nutritive value in terms of crude protein, crude fat, moisture and ash. Comparatively, the like tests were done with a fresh fish sample. Organoleptic testing seconded up on smoked samples to investigate the impact of the smoking fuels on colour, taste, moisture and odour. Both proximate and sensory analysis reveal that, there were no significant differences in overall acceptance of fish

samples smoked using dry wood as well as maize cobs, but both of them were most liked and accepted followed by smoked using pigeon pea dry plants. However, the acceptance was significantly lower in fish samples smoked using the rest of combinations of fuels and the lowest in fish samples smoked using “maize cobs and pigeon pea dry plants”. This research realized potential food (smoked fish) security and resilience through alternative measure to smoking fuel which breeds directly, resilience to climate change, by encouraging use of wastes and enforced reduction on use of wood.

Production of Sterile *Oreochromis Shiranus* Using Herbal Product

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Reproduction is highly risky and energetically demanding to both male and female fish. Moreover, the likelihood that any particular breeding attempt will succeed – that is, that it will produce surviving offspring – may depend upon prevailing conditions in the physical, biotic and social environment, as well as upon the potential breeder's physical and physiological condition. Investment of energy into reproduction results in slow growth, low quality flesh, because it eliminates the cessation of somatic growth that accompanies sexual maturity. In an attempt to overcome this, fish meant for aquaculture production should be sterilized. This will prevent fish from investing massive amounts of energy into gonad production. In sterile fish, where the gonads do not develop, this energy can be utilized for growth instead of reproduction, meaning that sterile fish grow faster and have better feed conversion ratios than non-steriles; this has large implications for the economic viability of a given fish farm. In addition, sterile fish reduce the risk of inbreeding, overpopulation in a culture facility and prevents the genetic problems which escaped farmed fish may have on wild populations. There is a range of methods that can be used to sterilize fish such as triploidization, hybridization, and generation of new lines via advanced biotechnological techniques, temperature, hypoxia, radiation etc. Most of these proposed methods require expensive materials and expertise. Therefore this calls for an interest in formulating a herbal product that will be administered to fish to produce sterility. This method will be easy to be applied by farmers and requires no expertise since a certain dosage will be administered through feed. It is expected that the herbal product will efficiently induce sterility in both male and female fish specifically the *Oreochromis shiranus*.

Assessment of the impact of climate change on fish production in Lake Chilwa

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The study was conducted at Lake Chilwa which covers Zomba, Machinga and Phalombe districts in the southern region of Malawi. It was conducted to understand how climate change has impacted on fish production in the Lake. Data on fish production from the lake, rainfall, ambient temperatures of the lake and lake water levels was collected for 30 years and more. The temperatures of the lake, rainfall and water levels were used as predictors of the

model whereas fish catches was used as the dependent variable. Data were entered through SPSS and analysed using linear regression model. From the model analysis, descriptives were produced that explained the data. On the other hand ANOVA table was produced which was used to test the hypothesis. Model summary, correlations and coefficients describing each predictor's contribution to the model were produced. The results indicated that there is no significant statistical difference on how climate change has impacted on the production of fish in Lake Chilwa as the ANOVA table showed a sig. of 0.060 which is greater than the 0.05 alpha level. The model summary again showed that the coefficient of multiple determination R^2 is 0.304 which shows that about 30.4% of the variation in total fish catches of the lake is explained by the model. This further means that despite climate change not significantly impacting on fish production in the lake, 30.4% of the variations in fish production is attributed by the predictors that are contributing towards the climate change model. The study further found out that ambient temperatures of the lake made a stronger unique contribution to explaining the dependent variable unlike the other predictors (rainfall and lake water levels). Based on the findings, it can be concluded that climate change has not had a significant impact on the production of fish in Lake Chilwa. The study further concluded that the use of rainfall probabilities alone is not a sufficient tool in predicting the water levels of the lake as there are several contributors to the Lake's water levels. The study also concluded that rainfall and water levels of the lake have a negative correlation. The study recommended that there is need to enhance community awareness as well as resilience to climate change adaptation so as to effectively enhance the mitigation of the impacts of climate change in fisheries. It also recommended that there is need to enhance knowledge of the community on the climate of the area for effective management and utilisation of the fishery. It further recommends that fishers should be catching fish in line with the biology of the fish (mesh size, fishing effort etc.) so as to ensure sustainability of the fishery

Fishing techniques used in Kisangani and its surroundings (DRC)

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The present work aimed at the identification, understanding and improvement, the fishing techniques used in Kisangani and its surroundings. These techniques are very diverse. They depend on the area of fishing and the target species. Majority of fishing tools used are traditional and artisanal, rarely modern. The most observed are the creels, the mosquito nets, the gill nets. Fishing in Kisangani and its surroundings is a really daily activity. Previous studies carried out in the same area showed that more than 90% of the fishermen had fishing as the main cash generating activity Fishing provides survival means to many households in the different areas and villages. The use of this fishing equipment in Kisangani has profoundly modified the prospects and the conditions of progress of fishing, because recent data on the halieutic production showed a decline. With the view to gain reliable information that can help identify areas of intervention in order to initiate the process of fish species protection and fishing development in the Kisangani area and surrounding, studies, surveys and sensitisation have been carried out for the monitoring of activities in this sector. These studies allowed us to segregate between friendly environmental fishing techniques and those destroying fish

habitats in order to raise the awareness of the concerned factors for the respect of the State established rules.

A model for achieving Continuous Improvement and Innovation (CI & I) in the freshwater aquaculture sector of North West Province, South Africa

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The aquaculture sector remains recognised as the significant alternative contributor in reducing hunger and creating employment globally. A number of species-related interventions and investments have been practised for over a decade and seldom on improving thinking and action of the resource owners or managers. The principle of Continuous Improvement and Innovation (CI & I) provides a solution to this gap. Freshwater aquaculture emerging farmers meet regularly to assess their current performance, identify a clear need and set targets to achieve outcomes effectively and efficiently. Their thinking, decisions and actions are based on the principle and process of Continuous Improvement and Innovation (CI & I) consisting of eight steps. The aquaculture emerging farmers are equipped with appropriate tools, technologies, resources and expertise. The results indicated improved project management skills, communication skills, team work, formal project registration, secured funding, sales, market, confidence, enjoyment and satisfaction from the process. Therefore improving and innovating can be regarded as basics of life and there are real needs and opportunities to improve and innovate in all aspects of life such as businesses, organisations, industries and communities. The information gathered will be used to support rural fish commercialisation and profit making and enhance local economic growth potential.

Investment in Agro-Business for Employment Generation and Poverty Alleviation for Unemployed Youths in Nigeria

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In recent times, the rate of youth unemployment and poverty in Nigeria has risen to unprecedented level. One of the ways most seriously considered by the Federal Government to reduce unemployment and poverty in Nigeria has been agricultural development. Agriculture is the mainstay of a majority of the people in the rural areas. However, it is observed that the present day youths are shying away from Agriculture and have the high rate of unemployment in the rural areas. To reduce poverty and create employment opportunities, the different communities in Nigeria should establish Agricultural production estate and processing zones. This will boost food production and create employments for the youths. This paper highlights strategies for engaging unemployed youths in Agricultural

production and processing. It also examines how efficient Agro-business can be used to solve poverty problems among the youths, provide income and food in the local areas and Nigeria at large.

Role of Village Savings and Loan Associations on Fish Farming - A Case Study of Malosa Epa In Zomba District

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Smallholder Fish farmers have poor access to credit and financial services due to fewer financial lending institutions. The study was conducted in Malosa EPA, in Zomba District Southern part of Malawi, with the main objective of assessing the role of Village Savings and Loan Association (VSLA) on smallholder fish production. The specific objectives were: to determine fish production levels of members and non-members of the Village Savings and Loan Associations, to identify socio-economic factors affecting fish production, to determine profitability of fish farming among members and non-members of VSLAs and to identify constraints to performance of VSLAs. A semi-structured questionnaire was administered to 40 fish farmers of which 20 were VSLAs members and 20 non-members of VSLA. Mean production levels, multiple regression model, Gross margins and Return on Investment analytical tools were employed in the study. In the study area, fish farmers belonging to Village Savings and Loan Associations were profitable with gross profit of MK42, 293 per 0.4 ha of fish, while the gross profit for non-members was MK26, 392 per 0.4 ha of fish. The returns on Investment for fish for members was found to be 67% and for non-members was found to be 48%. The study also found that sex, education level and extension contact, at p-value of 0.005 significantly affect fish production except age. Lastly, the study unveiled the constraints affecting the performance of VSLAs of which lack of extension services was the major constraints. The study recommends that farmers should be encouraged to join VSLAs as they positively and significantly contribute to increase in fish production since the loans and share-outs members generate are used as capital to buy farm inputs such as feeds and pesticides. Lastly, the study also recommends that VSLA service providers' e.g. CADECOM and government should increase the number of the VSLA groups so that they reach more smallholder farmers in the country.

The Role of Self-Recruiting Species (Srs) in Rural Community Farmer Managed Fish Ponds. A Case Study of Selected Districts Of Central Region Of Malawi

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There is an abundance of organisms that grow in a pond in addition to the stocked fish. These are known as self-recruiting species. The aquatic biodiversity of ponds that is useful to humans includes plants, fish, amphibians, reptiles, molluscs, crustaceans and insects. The role of these miscellaneous aquatic organisms harvested from fish ponds of small scale fish farmers has long been overlooked and neglected in rural based aquaculture communities where it is not often easy to resource inputs as aquaculture requires capital investments. Evidence suggests that self-recruiting species have considerable potential as cost-effective food-based strategies to enhance micronutrient intakes. The relative abundance of self-recruiting species has not been quantified due to lack of promotion or identification. In Malawi, the rural aquaculture practice is yet to tap on the potential of some of the self-recruiting species. Accurate information on the contribution of self-recruiting species is not available because what is produced by rural fish farmers is consumed by them or bartered locally. The contribution of the self-recruiting species to the nutrition and economy of the rural household has not been determined. There is limited information on nutrient composition of the self-recruiting species and their consumption. Not enough attention has been paid to these self-recruiting species and their potential in aquaculture development. This study will generate data so that the SRS are fully utilized by characterizing the role of self-recruiting species of farmer managed ponds in rural communities and to develop management approaches that enhance their production. The study will also help to generate advocacy, awareness and nutrition education on the role of SRS thereby increasing diet diversity and strengthening micronutrient intake. The study will identify and quantify the diversity of SRS from fish ponds. It will also determine their role in the context of house nutrition and food security.

Aquaculture Investment Models: Commercialization of Smallholder Pond Based Aquaculture Out grower Models in Zambia

Yapasa project team

The aquaculture sector has high potential for job creation and improved incomes in rural Zambia. The Yapasa project aims to create jobs for rural youths through development of the aquaculture sector among other value chains. The sector is dominated by smallholder farmers with low production and productivity levels attributed to limited availability and access to quality inputs and limited entrepreneurial and technical skills. The out grower model was developed to enable young farmers to access quality inputs, receive skills training and facilitated access to market from an off taker as embedded services almost as an incubator. Identification of a motivated out grower operator to establish and run the scheme was required. The operator mobilized local youth, provided land for the ponds, trained them in technical and basic business skills, and aggregated the fish for sale to market. As the model matures and the youths gain more experience and establish their respective enterprises they will move off the common land and establish ponds on their own land. The off taker will create linkages between the farmers and input suppliers. Increased productivity and productivity

dictated a more structured approach to marketing of the fish. The mine canteens and the retail stores in Solwezi want to source fish locally but with stringent requirements, demanding further investment in processing, packaging, quality management and transportation. Yapasa has collaborated with other development players to support the offtaker to invest in processing capacity to access these formal markets within their locality. The processing facility will create opportunities for processing of many more fish, stimulating expansion and copying of such outgrower schemes, as well as other products like poultry and horticultural products. Results: 77 farmers participated in the pilot each with one 300m² pond stocked at 6 fingerlings/m² Average yield was 500kg per pond giving the young farmer a net income of \$500 per pond Productivity improved tenfold, from 1.5 MT/ha to 16.7 MT/ha, more in line with commercial farmers due to use of quality inputs and improved skills Participating farmers are expanding their number of ponds while new farmers coming on board The off taker is expanding the out grower scheme to a total of 150 farmers in the next year One commodity trading company is already replicating the out grower model in the same locality Zambia's 80,000 MT annual fish deficit can be met in the medium to long term by improving productivity of the estimated 14,000 smallholder fish farmers and new entrants through improved access to quality inputs, skills development and farmer organization. The market is dispersed and therefore to facilitate functional input and output markets requires business models that organize farmers. The out grower model in the Zambia context has been proven to deliver that value.

Effects of Feeding Frequency on Growth, Feed Utilisation and Survival of *Oreochromis Shiranus*

Thokozani I. Msonkho

An experiment was conducted for fifty six days to evaluate the efficacy of feeding frequency on growth performance and survival of *Oreochromis shiranus* fingerlings. A total of 240 fingerlings were stocked in twelve hapas (1×1×1 m³) at the rate of 20 fingerlings/happa. The happas were divided into four treatments on the basis of feeding frequency 2 times per day (T1), 3 times a day (T2), 4 times a day (T3) and 5 times a day (T4) respectively, having three replications. Fingerlings were fed with Bunda Fish Farm diet (29% CP). The water quality parameters were monitored found to be within suitable range for proper growth of *O. shiranus*. At the end of the trial period, significant variations ($P < 0.05$) were observed among the treatments and Treatment 3 showed the best performance in case of all parameters studied such as weight gain (WG), feed conversion ratio (FCR) and specific growth rate (SGR). The final body weight and specific growth rate (SGR) were significantly higher in Treatment 3 ($P < 0.05$) in this comparison with the specific growth rate ranging from 0.931 ± 0.0611 , 0.966 ± 0.0655 , 1.269 ± 0.0482 and 0.963 ± 0.0484 in Treatments 1,2,3 and 4, respectively. Similar responses were also observed for Apparent Feed Conversion Ratio and the best AFCR were obtained in Treatment 3 (2.795 ± 0.122), that showed significantly different among the treatment means ($P < 0.05$). Treatment 1 had an AFCR of 4.680 ± 0.419 , treatment 2 had 4.472 ± 0.377 and Treatment 4 (4.146 ± 0.227). There was no significant difference among treatment means ($P > 0.05$) in terms of survival rate and water quality parameters, this implies that feeding frequency had no effects on survival and water quality parameters. The study suggests that feeding frequency of four times daily is sufficient for *Oreochromis shiranus*.

Impact of Farm Africa in Promoting Fish Production in Freshwater Ponds in Lake Victoria Basin Kenya.

Z. Shitote

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Aquaculture has grown rapidly in Kenya over the last one decade and plays an increasingly important role in national fish supply. Freshwater fish account for close to 98% of Kenya's reported aquaculture production. Kenya is now ranked 4th major producer of aquaculture in Africa. Kenya's Vision 2030, together with other policy frameworks recognizes aquaculture as a source of food security, poverty reduction, and employment creation. Lake Victoria in eastern Africa is suffering from overfishing, leading to dwindling wild fish stocks. This paper examines the impact of Farm Africa in promoting production of freshwater fish in ponds in the Lake Victoria basin. It further, discusses the strategies of Farm Africa in transforming aquaculture in the lake Basin to increase production for food security and livelihoods. A Cross-sectional and longitudinal Survey research design was adopted for the study. Stratified sampling was used to select fish farming households. Key informants were selected through purposive sampling method. Data gathering was through multiple methods; where primary and secondary data were collected. Data analysis made use of descriptive statistics, where numerical and non-numerical summary of data were used. Chi-Square was used to test the independence between variables. Spearman rank order correlation coefficient was used to test relationship between fish farmers ranking of various variables affecting them. The results were Nile tilapia the most freshwater fish is becoming scarce due to overfishing. Catfish farming is least preferred in Lake Victoria basin. Farm Africa provides, technical training, best management practices, fish feed formulation, marketing, business plan development, hatchery management and value addition for increased income. It also link farmers to various service and credit providers for sustainable fish production. It is anticipated that the study findings will spur other development partners in fish value chain in Africa to increase promotion of aquaculture production for sustainable development.

The Potential of Earthworm (*Eisenia foetida*) in the Replacement of Conventional Proteins Sources in the Diets of Nile Tilapia (*Oreochromis niloticus* L.) Production in Kenya. A Review.

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Fishmeal is the main conventional protein sources of fish feeds globally. In Kenya, *Rastrineobola argentea* which is locally known as *Omena* and the freshwater shrimp *Caridina nilotica* are the commonly used protein sources in Nile tilapia (*Oreochromis niloticus* L.) production. This is due to their nutritional quality and palatability properties. However, the high demand and scarcity for fishmeal has escalated its price to levels below break-even point. Various non-conventional animal and plant protein sources have been tested on fish feeds

with varying success. The limited success is mainly attributed to the cost factor and in most cases to incomplete essential amino acids for animal and plant ingredients, respectively. Among the non-conventional protein sources which have been tested with relatively promising results is earthworm (*Eisenia foetida*) thanks to its high protein levels, proper amino acid profile, high reproduction and growth rate and ease to culture. However, there is limited information of the utilization of the worm as protein source in fish feeds in Kenya. It is against this backdrop this paper reviews the potential of using; earthworm (*Eisenia foetida*) to replace the conventional protein sources in fish diets. This was achieved by reviewing the main conventional protein sources for fish in Kenya i.e *Rastrineobola argentea* and *Caridina nilotica* then describing the commonly tested non-conventional protein ingredients in Kenya with their associated limitations. Finally the paper evaluates the nutritional properties and culture potential of earthworm (*Eisenia foetida*) for its suitability in fish feed production in Kenya.

Commercialization of Fish and Their Consumption Rate by the Population of Uvira, South Kivu, DR CONGO

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This study was conducted in three major markets in the city of Uvira, South Kivu province of the Democratic Republic of Congo for 4 months, from the beginning of February until the end of May 2016. Its objective was to systematically inventory all species of fish sold according to their nature in the three major markets of Uvira by comparing their rate of consumption by the population with other sources of animal protein sources. The accelerated method of participatory research was used to gather information from the different target groups. A total of 20 vendors and 180 households were surveyed. The study found that the fish marketed in the different markets of the city of Uvira come from different origins: in addition to fresh fish from the different landing beaches of this environment, there are processed fish (smoked, salted and dried) imported from several other localities in the neighboring territory of Fizi. The most commercially marketed fish in the markets of Uvira are *Lates stappersii* (adult and juvenile), *Stolotrisa tanganycae* (adult and juvenile) and *Limnothrissa miodon*. These fish with an average unit price of 500 Congolese francs are accessible on the stock exchange of the majority of households of which 85% use less than 1000 Congolese francs for the purchase of fish than meat.

Theme 4: Biology, Ecology and Behaviour

Character Convergence in Two Clades of Rapids-Dwelling Cichlids: The African *Teleogramma* and the American *Teleocichla*

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Thirty years ago, in the description of a new genus of American cichlids, Kullander proposed the name *Teleocichla* to emphasize the parallelism in morphology with the African *Teleogramma*. In fact, many morphological characters are shared between the two groups, possibly related to their dwelling habits in rock bottomed rapids. Phylogenetically, however, they are relatively far from each other: *Teleocichla* considered a valid genus, but embedded in the clade of pike-cichlids (the paraphyletic genus *Crenicichla*); *Teleogramma* within the riverine clade of Chromidotilapiines. Common specializations hypothesized to be related to rheophilic behaviour comprise the strong elongation of the body, extreme reduction or absence of supraoccipital and parietal crests, absence of microbranchiospines, cheek without scale cover anteriorly, lateral line continuous or separate (disjunct) by only one or two scale rows, elongation of the median rays of the pelvic-fin, and usually more caudal than pre-caudal vertebrae. Other modifications on the morphology of the species of *Teleogramma* and *Teleocichla* seem to be associated to feeding and protection in fast-flow stretches of the lower Congo basin and some Amazonian tributaries, respectively. All *Teleogramma* species show cryptic coloration with rocks, strong oral teeth and lower pharyngeal jaw bearing papiliform teeth to feed on encrusted invertebrates. Species of *Teleocichla* show similar appearance of the feeding apparatus, but some species possess cryptic coloration with rocks and others with sandy substrate of marginal areas. Two recently-described species of both genera (*Teleogramma obamaorum* and *Teleocichla preta*) reveal a remarkably convergent morphology and behaviour: both have robust body shape, lacking the typical dorsoventral body depression, both have strong molariform teeth on the robust lower pharyngeal jaw to feed on hard-shelled invertebrates, and overall dark coloration for camouflage among dark rocks or shadows.

Biodiversity, Ecology, Casting and Sustainable Management of the Ichthyologic Fauna of Ulindi, Kimbi, Lwama and Lwiko Rivers at East of the Democratic Republic of the Congo.

Gabriel Mukabo Okito

The present study will take place in the Democratic Republic of Congo, respectively in the province of South Kivu in the territories of Fizi, Mwenga and Shabunda on the one hand and in the territory of Kabambare in the province of Maniema on the other hand mainly in the Ulindi, Kimbi, Lwama and Lwiko rivers in an area between 03° 57 ' South and 28 ° 45' East (Prigogine, 1978), Doumenge (1990) and Wilson & Catsis (1990). It will take place for three years, from October 2017 to December 2020. Its main objective is to carry out a systematic inventory and

to study the ecology of the ichthyofauna of the Ulindi River basin and to identify the diversity of fish species as well as the fishing practices for exploitation sustainable. Fishing trips are carried out on the rivers Ulindi, Kimbi, Lwama and Lwiko as well as in their tributaries (once a month). The fishing technique that uses the different gear are used gillnets in the same area and during the same season or the same period of the year. Gillnets (mesh size 8, 10, 12, 15, 20, 25 and 30 mm between nodes), hawk net, hooks, dip nets and trap nets were used for fish collection. In the laboratory, all the meristic characteristics, the various measurements and observations will be made on each fish. To have a good knowledge on the presence, the abundance and the availability of the food potential in these aquatic environments, the analysis of the stomach contents of the fish will be carried out according to different methods (Lauzanne 1975). This will allow us to determine the diet and feeding activity of the fish in these rivers. The statistical analysis will consist firstly in the analysis of variance (ANOVA) of the physicochemical parameters of the waters between the different harvesting stations by the Fisher test and secondly, in the principal components analysis. (ACP), Correspondence Factor Analysis (CFA), diversity and genetic structure calculation including the differentiation indication (index) and the haplotype diversity index will be applied to genetic and morphological data.

Unmasking philopatry of a giant Amazonian catfish

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Philopatry (natal homing) is characterized by the return of adult individuals to their area of origin (born) to breed. Although this behavior is well known for diadromous species such as

salmonids, it is still poorly documented for potamodromous species. Recently, otolith $^{87}\text{Sr}:^{86}\text{Sr}$ analyses (LA-MC-ICPMS) revealed a > 8000km-long migration with natal homing for *Brachyplatystoma rousseauxii* in Madeira River Basin. The catfish breeds in the Andean piedmont with juveniles drifting to nursery areas in the Amazon River estuary and going back when adults. Unfortunately, philopatry was not confirmed for the main channel of the Amazon River due to the homogeneity of $^{87}\text{Sr}:^{86}\text{Sr}$ values throughout the river (from Andes to estuary). However, two chemical markers, one from the Andean region (Se: Ca) and another from the estuarine region (Sr: Ca) were allowed to clarify natal homing through scanning X-ray fluorescence microscopy (SXFEM). We hypothesized that if *B. rousseauxii* performs philopatry we should detect: i) Selenium in the core of the otolith corresponding to birth in the Andes, ii), Strontium up to 2-3 years old as juvenile due young phase in the estuary; iii) Selenium in the border again, when the adult returns to the breeding area to confirm homing. To test our hypothesis otoliths with known $^{87}\text{Sr}:^{86}\text{Sr}$ profiles (LA-MC-ICPMS) from Upper Madeira and Upper Amazon Rivers were evaluated. All of them showed elemental patterns consistent with natal homing behavior: low Sr:Ca and high Se:Ca in the core of the otoliths, elevated Sr:Ca and low Se:Ca up to about 4 year-old confirming estuary habitats up to 2 year-old, and then low Sr:Ca / high Se:Ca, when it returned to the Andes for breeding. Our results also highlight the potential of SXFM techniques to investigate philopatry for migratory fish species.

Fundamental Thermal Niches of Three Coexisting Annual Killifish Species from Shallow Temporary Waters

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The knowledge of organisms' thermal niche provides invaluable information for fundamental ecological issues, such as the impact of climate change on ectotherm populations and the potential coexistence of ecologically similar species. In this study, we examined fundamental thermal niches in three coexisting annual killifish species of *Nothobranchius* spp. from southern Mozambique. They commonly occur in a single ephemeral pool with subtle microhabitat preferences and high trophic niche overlap. Accordingly, we hypothesized that disparate thermal requirements of the three congeneric species are candidate niche component, which facilitates their local coexistence. We measured their preferred body temperatures (T_{pref}) lower (LB_{Tpref}) and upper (UB_{Tpref}) limit of preferred body temperatures in the horizontal thermal gradient (16-38.5°C). Additionally, we recorded water temperatures at three water bodies in Mozambique with the co-occurrence at least two killifish species to obtain information about the daily range of environmental temperatures, which fish experience in the wild. The species slightly varied in their mean T_{pref} but not in UB_{Tpref} and LB_{Tpref} . *Nothobranchius furzeri* maintained lower mean T_{pref} (25°C) than *N. orthonotus* (28°C) and non-significantly different T_{pref} from *N. pienaari* (23°C). The daily range of temperatures in all temporary pools enabled killifish to thermoregulate at least for part of the 24-hour day

cycle. Our results suggest that sympatric killifish have not segregated their thermal niches which is supported by their similar UBT_{pref} and LBT_{pref}. Similarities in thermal niche suggest that they are inherited from common ancestor or killifish are adapted to similar thermal conditions. According to thermal profiles in their habitat, examined species have space for thermal niche differentiation by increasing UBT_{pref}. However, usually slow evolution of T_{pref} precludes its adaptation to their habitat.

Life History Divergence along an Aridity Gradient in African Annual Fishes: An Experimental Study

R. Blažek, M. Polačik, M. Vrtílek, M. Reichard

Extreme environments induce extreme adaptations, as exemplified in African annual *Nothobranchius* fish inhabiting temporary pools of East African savannah. Unpredictable conditions of *Nothobranchius* habitats are directly associated with their adaptations and life history trade-offs. Hence, phenotypic traits of some populations might be associated with different selection pressure determined by population specific lifespan expectancy (duration of their temporal habitats). Populations from the drier area of species distribution are expected having faster life strategy than their conspecifics in wet regions. To test whether population-specific lifespan expectancy predicts the rates of demographic and reproductive aging we used common garden experiment with F1 generation of imported natural populations of African annual fishes of four species. Each species was represented by two populations; from dry and wet regions. Analysis of several phenotypic traits confirmed that populations from dry region have shorter lifespan and faster fertility decline. Intraspecific divergence in life span was not associated with divergence in early life history (rapid growth, maturation). Variability across four study species suggests that a combination of different life-history traits conformed with or contradicted the predictions for each species. These findings demonstrate that variation in life span and functional decline among natural populations are linked, genetically underpinned, and can evolve relatively rapidly.

Recording Mormyrid Electric Organ Discharges

Carl D. Hopkins

Because electric organ discharge (EOD) waveforms of mormyrids often have species-specific characteristics, they have emerged as an important source of comparative data for the taxonomic study of these fishes. Ideally, recording EODs of mormyrid specimens should be incorporated into fish collection field protocols in Africa. Here we discuss methods of recording these signals on relatively inexpensive equipment and introduce Mormyr-o-scope: a new, free, user-friendly Windows OS application specifically designed for recording these signals along with relevant metadata.

Distribution of Branchiuran Fish Parasites in the Limpopo River System, South Africa

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Fish parasitological surveys conducted from 2000 to 2018 from different localities in the Limpopo River System revealed the occurrence of three branchiuran species from three genera. These include endemic species *Chonopeltis inermis*, *Dolops ranarum* and the alien *Argulus japonicus*. Branchiurans were recorded from the skin, fins, mouth cavity and branchial chamber of various freshwater fish species. Standard methods were followed for parasite fixation and preservation. *Argulus japonicus* and *D. ranarum* were recorded from *Cyprinus carpio* (alien), *Oreochromis mossambicus* (native) as well as *Clarias gariepinus* (native) and appears to be generalist parasites. In addition, *D. ranarum* was also recorded from *Chetia flaviventris* (native), *Micropterus salmoides* (alien) and *Schilbe intermedius* (native). *Chonopeltis inermis* was only recorded from *Clarias gariepinus* (native) and is a specialist for the Limpopo River System. Mean intensity levels were low for all branchiuran records but pathology was noted for *D. ranarum* on some fish species. This may lead to secondary infections and affect fish health. This study includes several new hosts and geographical records contributing to our understanding of the biodiversity of African branchiurans.

The Role of Self-Recruiting Species (Srs) in Rural Community Farmer Managed Fish Ponds. A Case Study of Selected Districts of Central Region Of Malawi

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There is an abundance of organisms that grow in a pond in addition to the stocked fish. These are known as self-recruiting species. The aquatic biodiversity of ponds that is useful to humans includes plants, fish, amphibians, reptiles, molluscs, crustaceans and insects. The role of these miscellaneous aquatic organisms harvested from fish ponds of small scale fish farmers has long been overlooked and neglected in rural based aquaculture communities where it is not often easy to resource inputs as aquaculture requires capital investments. Evidence suggests that self-recruiting species have considerable potential as cost-effective food-based strategies to enhance micronutrient intakes. The relative abundance of self-recruiting species has not been quantified due to lack of promotion or identification. In Malawi, the rural aquaculture practice is yet to tap on the potential of some of the self-recruiting species. Accurate information on the contribution of self-recruiting species is not available because what is produced by rural fish farmers is consumed by them or bartered locally. The contribution of the self-recruiting species to the nutrition and economy of the rural household has not been determined. There is limited information on nutrient composition of the self-recruiting species and their consumption. Not enough attention has been paid to these self-recruiting species and their potential in aquaculture development. This study will generate data so that the SRS are fully utilized by characterizing the role of self-recruiting species of farmer managed ponds in rural communities and to develop management approaches that enhance their production. The study will also help to generate advocacy, awareness and nutrition education on the role

of SRS thereby increasing diet diversity and strengthening micronutrient intake. The study will identify and quantify the diversity of SRS from fish ponds. It will also determine their role in the context of house nutrition and food security.

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