

**GLOW 9** *An international symposium*

# Emerging frontiers for African Great Lakes

Promoting blue economy, food security, and conservation

August 5–7, 2019 | Kisumu, Kenya

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• Fish landing site on Lake Victoria where dagaa/omena/mukene is dried, Uganda. © 2017 Martin Van der Knaap.

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## Welcome to GLOW9 in beautiful Kisumu, Kenya!

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GLOW9 is part of an ongoing series of symposia organized by the GLOW (Great Lakes of the World) Working Group of the Aquatic Ecosystem Health & Management Society (AEHMS). The AEHMS is a professional, scientific and non for profit organization established in Canada almost 30 years ago in 1989. The first GLOW symposium was organized more than 1996 in Victoria Falls, Zimbabwe. Since then the AEHMS has launched a continuing series of GLOW symposia regularly in order to promote interaction and communication amongst various Great Lakes/ Large lakes researchers across the world. The purpose of GLOW is to establish a global platform where ecosystem-based studies of the structure, function and performance of Great Lake ecosystems are promoted, organized and synthesized. In addition, GLOW propagates ecosystem science -based management from an integrated, multi-trophic and multi-disciplinary perspective.

GLOW9 is the seventh of the series organized in the African continent. The AEHMS always co-organizes GLOW conferences with local hosts with regional knowledge to improve participation of African scientists. This GLOW is being cohosted in collaboration with Kenya Marine and Fisheries Research Institute (KMFRI) which is a state corporate body, established in 1979 under the Science and Technology Act (Cap 250). KMFRI is under the Ministry of Agriculture, Livestock, Fisheries and Irrigation. The role of KMFRI is to contribute to the realization of national strategies of food and nutrition security, poverty alleviation, clean environment and employment. Its mandate is to undertake research in "marine and freshwater fisheries, aquaculture, environmental, ecological, and marine research including chemical and physical oceanography" to provide scientific data and information for sustainable development of the Blue Economy. During the GLOW9, KMFRI looks forward to providing quality and relevant aquatic and fisheries research data and information required to greatly contribute towards transforming the Blue Economy sector into an innovative and commercially-oriented sector in line with the aspirations of Vision 2030, and The Big Four Agenda initiative. The AEHMS is delighted to collaborate with KMFRI engaging African colleagues and researchers in an international exchange of ideas and peer reviewed high quality publications.

We are indeed pleased to report that GLOW9 had overwhelming response as evidenced by large number of accepted abstracts (over 180) from scientists, students and managers. Selected presentations will form the basis of an interesting GLOW program in Kisumu. Later it is planned to publish selected papers in special issues of the journal, *Aquatic Ecosystem Health and Management* (AEHM) published jointly with Taylor and Francis, USA and/or a book under the Ecovision World Monograph Series published by AEHMS- Canada and Michigan State University, USA.

We greatly appreciate the assistance of Organizing, Scientific and Local Arrangements Committees towards the organization of this meeting, especially committee members Dr. Martin van der Knaap, Dr. Christopher M. Aura, Dr. Victor Langenberg, Dr. Chrisphine Nyamweya, Dr. James Kairo, and Dr. Jacqueline Uku for their important contributions. Sincere thanks to the AEHMS secretariat (Jennifer Lorimer, Lisa Elder, Susan Blunt and Margaret Holmes) for their assistance in various aspects of the organization of GLOW9.

We are optimistic that the GLOW9 symposium in the beautiful surroundings of Lake Victoria's Winam Gulf, will be a productive, scientific and interesting African experience generating new ideas, energy and momentum for the continued success of the AEHMS-GLOW Working Group and its future activities.

### **Prof. James Njiru**

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### **Dr. Mohiuddin Munawar**

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## The AEHMS at a Glance

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The *Aquatic Ecosystem Health & Management Society (AEHMS)* was established in 1989 to promote ecosystem-based science for managing both marine and freshwater aquatic resources of the world. The Society has four broad objectives centering on health, management, the convening of conferences/symposia, and peer-reviewed publications through its international journal, monograph series, and website ([www.aehms.org](http://www.aehms.org)). The objectives of the Society are:

- To focus on the aquatic ecosystem structure, function, performance and management from an integrated multidisciplinary and multi-trophic and sustainable perspective.
- To enhance our knowledge about the ecology and integrity of the Great/Large Lakes of the world
- Advocate holistic approaches, novel concepts, techniques, tools, models and emerging technologies for remediation and restoration
- Elucidate food-web linkages from microbial loop to plankton, fish and fisheries
- To explore the impact of multiple stressors (climate change, invasive species, HABs etc.)
- To foster global interdisciplinary communication of ecosystem management science amongst researchers, managers, citizens, universities, governments, industry, and the public sector.
- To promote ecosystem-based science, practices, knowledge and publications in developing countries across the world

The Society is actively involved in primary and peer-reviewed publications. It publishes an international journal, *Aquatic Ecosystem Health and Management (AEHM)* on a quarterly basis (in collaboration with the publisher Taylor and Francis, Philadelphia). From 2007 onwards the AEHM was selected by Thomson Scientific for coverage in the Science Citation Index Expanded (SciSearch®); Journal Citation Reports; Current Contents®/Agriculture, Biology, and Environmental Sciences; Zoological Record; Biological Abstracts; and BIOSIS Previews. It has published over **45** special issues on diverse topics from across the world. Table 1 provides a general overview of lake publications (also see [www.aehms.org](http://www.aehms.org)).

Table 1. Special issues of the Aquatic Ecosystem Health and Management (AEHMS, 2000-2011), devoted to Great Lakes.

Special issues	Volume	Year
Large Lakes of the World: Comparative Ecology	3(1)	2000
Ecosystem Health of Lake Baikal, Russia	3(2)	2000
Great Lakes of the World: Food Web, Fisheries, and Management	5(3)	2002
Comparing Great Lakes of the World	6(3)	2003
Coastal Wetlands of the Laurentian Great Lakes: Health, Integrity and Management	7(2)	2004
Emerging Issues in Lake Superior Research	7(4)	2004
Great Lake Victoria Fisheries: Changes, Sustainability, and Building Blocks for Management	10(4)	2007
Changing Great Lakes of the World	11(1)	2008
State of Lake Huron: Ecosystem Change, Habitat, and Management, Part I	11(2)	2008
Checking the Pulse of Lake Ontario	11(4)	2008
The State of Lake Huron: Ecosystem Change, Habitat and Management, Part II	12(1)	2009
Changing Great Lakes of the World and Rift Valley Lakes: Sustainability, Integrity & Management	13(1)	2010
Assessing Large and Great Lakes of the World	13(2)	2010
Ecosystem Health and Recovery of the Bay of Quinte, Lake Ontario	14(1)	2011
Ecology of Lake Superior	14(4)	2011
Great Lakes of the World (GLOW VI): Linking Ecosystem-Based Science to Management	16(3)	2013
Protecting Great Lakes of the World: Managing Exploitation with Ecosystem-Based Science (GLOW VII)	17(1)	2014
State of Lake Vänern Ecosystem	17(4)	2014
Lake Ontario Ecosystem: Status and Future Directions	18(1)	2015
Application of ecosystem approach to fisheries and good governance in Lake Malawi and other Great Lakes	21(2)	2018
Restoring Great Lakes Areas of Concern: 32 Years of Remediation and Restoration	21(4)	2018

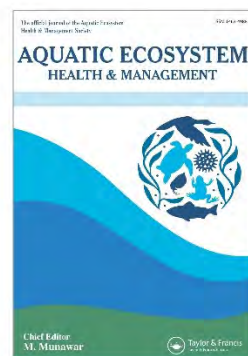
In addition, the AEHMS also publishes a peer reviewed book series under the banner of the *Ecovision World Monograph Series*. It has already published over 20 peer reviewed books on a large variety of subjects, including lakes, ecosystems and other topics of interest (see <http://aehms.org/publications/ecovision/published-books/>).

The Society welcomes individuals for membership belonging to a wide range of disciplines. AEHMS cordially invites you to join the Society to support global conservation and outreach. Membership includes 4 quarterly issues of the journal with on-line access as well as discounts on conference registration fees, purchases of books and back issues of our journal. A discounted membership is available for students, retired persons and members of developing countries. See <http://aehms.org/membership/> for the application. Welcome aboard.

**Mohiuddin Munawar, Ph.D**  
Research Scientist, Fisheries & Oceans Canada  
President and Chief editor  
Aquatic Ecosystem Health & Management Society, Canada



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## Publication Plans

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Selected manuscripts will be considered for publication subject to peer review in the ISI rated journal: Aquatic Ecosystem Health and Management (AEHM). AEHM is an ISI rated international primary journal published by Taylor & Francis, Philadelphia.

Presenters are encouraged to submit manuscripts to the AEHM for consideration for publication subject to the AEHMS instructions to authors, and guidelines (<http://aehms.org/publications/author-instructions/>). Due to the large number of manuscripts expected the AEHMS has set page limit guidelines as follows: Keynote: 10; Oral & Poster: 8 printed pages including tables and figures (Text: Times New Roman 11 pt, Margins: 2.5 cm (1”), Paper: letter size 21.6x28 cm (8.5x11”). For more information please contact Dr. M. Munawar, Chief Editor ([mohiuddin.munawar@dfo-mpo.gc.ca](mailto:mohiuddin.munawar@dfo-mpo.gc.ca)).

Presenters who are planning to publish in the special issues are requested to complete the publication questionnaire (<http://conferences.aehms.org/glow9/publication-plans/>).

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## General Information

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### **Copyright**

All presentations and posters are the property of the presenter. Audio recordings, copying, videotaping or photography of the presentations is prohibited. Media should obtain the permission of the AEHMS for use of any conference material.

### **Disclaimer**

Lake names may be given at the discretion of the contributors in their own presentations. The organizers are not responsible for the content of the presentations or abstracts.

### **Electronic devices**

We request participants to switch off mobile phones in the conference hall.

### **Badges**

You should consider your personal name badge as your entry ticket. Please wear your badge at all times during the conference.

### **Coffee and tea breaks**

Coffee/tea breaks are included with registration.

### **Liability**

Neither the conference organization, the Kenya Marine and Fisheries Research Institute, nor the Aquatic Ecosystem Health & Management Society can be held responsible for damage, loss or theft during the conference.

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## Abstracts

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The accepted abstracts are organized by presentation type (keynotes, orals, and lastly posters) and are then listed alphabetically by the presenting author's last name.

**Freshwater small pelagic fish and their fisheries in major African lakes and reservoirs in relation to food security and nutrition****Kolding, J.,<sup>1\*</sup> van Zwieten, P.,<sup>2</sup> Marttin, F.,<sup>3</sup> Funge-Smith, S.,<sup>3</sup> Poulain, F.<sup>3</sup>**<sup>1</sup>Department of Biology, University of Bergen, Norway<sup>2</sup>Aquaculture and Fisheries Group, Wageningen University, Netherlands<sup>3</sup>FAO Fisheries and Aquaculture Department, Italy

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The recorded catches of most of the larger commercial fish species in Africa, such as large breams (Cichlidae), carps (Cyprinidae) and perches (Perciformes), which have been the focus of fisheries management, have not changed greatly over the past three decades. In contrast, the landings of small species of herring (Clupeidae), carp, bream and characin species – mostly zooplankton feeders, predominantly living in open waters of African lakes and reservoirs – in short, “small pelagic fish” – have steadily increased. These fisheries have developed in addition to the fishing of, and sometimes as a reaction to, decreased catch rates of larger species, introductions, and the creation of large water bodies such as reservoirs. They now represent nearly three quarters of the total inland fish catch of the African continent, although a large proportion of the inland fishery catch statistics are acknowledged to be incomplete and unreliable. Stock assessments and estimates of exploitation levels are also largely absent. The expansion, technical development and marketing of these fisheries have nearly all been achieved by a multitude of local stakeholders with very limited scientific monitoring or management. Even though small pelagic fish species, and small fish in general, have always been part of the catch of subsistence fisheries in the large water bodies of Africa, they have conventionally been regarded by fisheries managers as resources with “low economic value” and consequently have been afforded low priority with respect to research and monitoring. As a result, there are still major gaps in our biological knowledge and understanding of the full potential of many species. Common to all, however, is their small size and corresponding high turnover rate, with most species being able to reproduce their own biomass around five times or more per year, which is at least twice the rate of the larger commercial species. This unparalleled level of production, together with the relatively simple technologies used for their capture, the reduced availability of bigger species because of heavy exploitation, and an increased demand for fish, are the main reasons for the considerable increase in fishing effort on smaller species that has been observed in African inland fisheries over the past three decades.

Nevertheless, due to the small size of these species and the corresponding necessity of using fishing gear with small mesh sizes, many of the fisheries are operating within the constraints of the current fisheries legislation, which is largely aimed at protecting juveniles of the larger species. Many of the capture techniques are therefore illegal and this can cause conflict between fishers and managers. The theoretical foundation for the conventional single species legislation is increasingly challenged and there is an urgent need to examine and evaluate the fishing patterns from an ecosystem perspective and revise the legislation where necessary. The fishing pressure on most of the small species is only a fraction of the pressure on large fish species, and there is huge potential for increased production and more balanced exploitation if the overall fishing pressure was directed away from the large fish towards the small. In fact, this is what is already happening in many African fisheries, as evidenced by the huge increase in their catches, but it is taking place without comprehensive scientific evaluation of pressures, ecosystem effects, or governance.

Small fish are processed, sold, and eaten whole. Most of the catch is simply sundried which is the most environmentally friendly and energy-efficient processing technology available, requiring limited investments to obtain potentially high quality products, although rainy seasons limit year-round preservation, and spoilage through overheating and rainfall remain serious issues. In addition, small whole fish are among the most vital suppliers of micronutrients, such as vitamins, iodine, iron, zinc and calcium, which all play a critical role in cerebral development, immune system support, and general health. Thus, the unique combination of high-quality protein and important micronutrients in small fish plays a significant role in combating the triple burden of hunger, micronutrient deficiency, and noncommunicable diseases. Malnutrition, or so-called “hidden hunger”, is responsible for about a third of premature deaths in sub-Saharan Africa, but national food policies virtually overlook the essential link between the production, distribution, and consumption of small sun-dried fish and human health. In fact, the qualities of fish are hardly recognized in the global food security discourse, and fish is strikingly missing from current strategies to combat nutrient deficiency among disadvantaged groups. The lack of recognition of the importance of small pelagic fish for nutrition, food security, livelihoods and public health has also prevented the necessary investments for improving the quality, shelf life and public awareness of this vitally important resource. Most of the processing and packaging is done under basic, open conditions on the landing beaches, with unhygienic facilities and little protection from contaminants, insect

infestations and moisture. Quality control in the whole value chain is virtually absent: there are significant post-harvest losses in the processing and trade of what are essentially low-quality, contaminated products, some of which are even infested with human pathogens. These factors all contribute to a vicious cycle that maintains the image of a “low-value” commodity, prevents the dissemination of knowledge and awareness of the huge potential that small pelagic fish have, and which could be greatly improved with proper policy attention as well as public and private investments.

In summary, catching small pelagic fish, which are simply sun-dried, affordably purchased in local, often remote markets and consumed whole, is the most high yielding, eco-friendly, low carbon dioxide (CO<sub>2</sub>)-emission and nourishing way of utilizing the high productive potential of African inland waters. However, a range of social, technical, economic, legal, and policy barriers inhibit the full potential of utilizing small fish to improve nutrition in low-income populations. These include lack of enabling fisheries management legislation and food safety challenges in processing and marketing. In addition, their local use as fishmeal in animal feeds, including for aquaculture, is increasingly competing for these resources.

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**LANGENBERG, VICTOR**

**KEYNOTE**

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**Innovative knowledge governance - How to achieve sustained change to restore the East African lake basins: Case Lake Victoria, from invasive water plants and waste to biofuels in Kisumu, Kenya**

**Langenberg, V.T.**

ACACIA-water experts, the Netherlands  
Netherlands-Africa Business Council (NABC), the Netherlands  
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Water represents the most challenging and complex risk faced by East Africa. Floods and droughts, pollution and water conflicts combined with a growing demand for food and energy, rapid urbanisation, demographic pressures, and climate change are potentially catastrophic for land and water resources use.

We report here on recent accumulation of anthropogenic pressures that have pushed the once productive waters of Winam Gulf further into a degraded system dominated by nuisance macrophytes (water hyacinths) and harmful algae blooms, affecting water intake, lake transport and logistics, fisheries, hydropower production and tourism.

Staggeringly, for over 50 yrs, we conclude that most introduced approaches, tools, knowledge and technology developed for improving or contributing to social development, economic stability, gender equality, and environmental sustainability have only been effective for a limited period of time. Yet, the connecting and interdependent strength of water in the EAGL region provides opportunities that cannot be ignored: water can be used as leverage for impactful and catalytic change.

A recent approach at Kisumu aims to make the large-scale harvesting of water hyacinths and use of other wastes attractive to local actors by processing them into biofuels – creating profit, jobs, clean fuel, and improved fisheries conditions. This work uses concepts of multilevel and multiactor fact-based inclusive governance to analyse the functioning of this approach.

The challenge in Kisumu was to match long-term comprehensive Integrate Lake Basin Resources Management planning with short-term visible and tangible transformations; ambitious climate adaptation plans based on bankable restorative businesses and projects. Other important factors found are the fact that returns are realized for all relevant partnership actors, and that actors, despite often conflicting interests, commit to long-term involvement for joint learning, and the coordination between the local governance structure and an overarching national governance structure for knowledge sharing, replication, and up-scaling in other lake counties (Siaya, Homabay and Busia), and elsewhere in the Lake Victoria basin.

This movement now aims to grow into a dedicated guild of engaged coalition partners from governments, investors, academics, corporate and community stakeholders committed to the aim of scaling-up demo-ed restorative African-proof entrepreneurship that deliver quality on economic, environmental, social and inspirational returns by coupling societal and corporate demand to applicable knowledge.

**Approaching Africa's future fresh water challenges through capacity building and collaboration****Lawrence, T.,<sup>1\*</sup> Ives, J.<sup>2</sup>**<sup>1</sup>African Center for Aquatic Research and Education, USA<sup>2</sup>University of Windsor, Canada

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During the past 30 years there have been efforts to positively affect policy and management on the various African Great Lakes (AGL), and numerous calls for enhancing research, collaboration, and centers of excellence. Though much good work has been accomplished, many efforts fall short, due, in part, to the underinvestment in universities and research institutions, the lack of harmonization in research approaches, and the drive of agendas by international agencies targeting short-term objectives. These issues can result in piecemeal or incomparable results, and drive research that may not necessarily be a priority 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 enhance the capacity of riparian nations to conduct and direct long-term, harmonized ecosystem research and monitoring to support sustainable basin development around the African Great Lakes. Creating a collaborative process driven by African freshwater experts has the potential for driving research, policy, and management processes historically co-opted by the global north. This talk invites discussion of 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.

**Understanding the impact of climate change: A case study from Lake Kariba****Marshall, B.**

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The 21st century will see far-reaching ecological changes driven in part by climate change and, like every ecosystem, African lakes will be impacted by these changes. There is presently some uncertainty about the consequences of climate change on these lakes because very few of them have long-term data sets that make it possible to evaluate the changes that have already taken place or predict what might happen in the future. This paper examines change in Lake Kariba, a 60-year old man-made lake that has undergone considerable change and has a relatively comprehensive set of historical data. The process of warming and the relationship between air and water temperatures is first discussed, and this is followed by a consideration of changes in the lake since the 1960s. This is followed by a discussion of thermal stratification in the lake and its significance for pelagic productivity. Previous workers have explored the impact of lake warming on the pelagic fisheries in the lake, and these findings are reviewed in light of new information. Finally, other rapid changes, some of which have been incorrectly attributed to climate change, are discussed to illustrate the rapidity in which an ecosystem can shift from one state to another. This paper concludes with some comments on data collection and interpretation.



### Diversity of algal blooms in the Great Lakes of the World: Long-term experience from the North American Great Lakes

Munawar, M.,<sup>1\*</sup> Belykh, O.I.,<sup>2</sup> Fitzpatrick, M.,<sup>1</sup> Niblock, H.,<sup>1</sup> Lorimer, J.<sup>1</sup>

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Cultural eutrophication of large lakes is an on-going global problem. Phosphorus enrichment of the nearshore regions is a leading culprit, resulting in blooms of both pelagic and benthic forms of algae. Occurrence of algal blooms has been reported from sub-polar Lake Baikal, temperate North American Great Lakes (NAGLs), to tropical African Great Lakes. Benthic (*Spirogyra* sp. and *Ulothrix* spp.) as well as toxic cyanobacterial (*Dolichospermum* and *Microcystis*) blooms have been reported in Lake Baikal. Similarly African Great Lakes such as Lake Victoria are not free of algal blooms dominated by cyanobacteria. Blooms with pelagic characteristics are common in the NAGLs such as western-central Lake Erie, and nearshore embayments in Lake Ontario (Bay of Quinte, Hamilton harbour), Huron (Saginaw Bay), and Michigan (Green Bay). Although the algal blooms have been attributed to nutrient enrichment (NP and SiO<sub>2</sub>), long-term robust data bases are needed to fine-tune the understanding of bloom dynamics. The best long-term database available in the NAGLs is on the Bay of Quinte, Lake Ontario. We will use it to assess the long-time trends, dynamics and the processes of remediation in changing climatic conditions. Regular taxonomic analysis of phytoplankton began in 1973 and continued until 2017. At one of the sites in the upper bay (Belleville) we tracked a total of 360 blooms during 44 years from 1973 to 2017. The taxonomic composition of the blooms exhibited great biodiversity, showing 267 of the blooms were dominated by filamentous diatoms (*Aulacoseira granulata*, *A. ambigua*), 57 were dominated by cyanobacteria (mainly *Dolichospermum Lemmermanni*, *D. crassa*, *D. circinalis*) and 36 were mixtures of various algal taxa. The frequency of blooms diminished from the 1970s to roughly half as many blooms in the 2000s. This was due to 30 years of remediation efforts including phosphorus abatement, which continues today.

This comprehensive study provides robust insight about algal bloom dynamics. The study was further expanded to assess the relative contributions of autotrophic carbon (phytoplankton, picoplankton) versus heterotrophic carbon (bacteria, heterotrophic nanoflagellates, ciliates) during the period of algal blooms versus non-bloom conditions. Our results indicated that heterotrophic microbes (primarily bacteria and heterotrophic nanoflagellates) contributed considerably to microbial biomass (an average of 18 to 64%) during bloom conditions. Consequently our data highlights the importance of including both autotrophic and heterotrophic assessments for a holistic understanding of food-web interactions prevalent during algal blooms conditions. The Bay of Quinte provides an excellent story of successful remediation and management of eutrophication based on a long-term robust data set. Establishment of long-term data bases is highly encouraged and recommended.

### Comparative analysis of factors affecting the management playing field for international lake basins: A case study of Lake Victoria in Eastern Africa

Odada, E.,<sup>1\*</sup> Ballatore, T.<sup>2</sup>

<sup>1</sup>University of Nairobi, Kenya

<sup>2</sup>Lake Basin Network (Lban), Japan

\*eodada@uonbi.ac.ke

Eastern Africa is well known for its large number of lakes. These lakes are locally important as sources of livelihoods and globally important as reservoirs of biodiversity. Unfortunately, climate and land-use change are negatively affecting water quantity, quality, and the various ecosystem services derived from many of these resources. And although there has been much discussion about the need for integrated management, little has been done so far to elucidate the baseline factors that differentiate one lake basin from another in terms of manageability. In short, each lake basin faces a different “playing field” which means that a one-size management approach cannot fit all. Here, we use geospatial tools and data to examine the key factors that influence the baseline difficulty in managing the Lake Victoria basin in the East Africa region. We examine nine key factors for Lake Victoria basin: the physical factors of (1) lake area, (2) drainage area and (3) drainage type; the climatic factors of (4) spatial distribution of precipitation and temperature (as reflected in an aridity index)

and (5) projected changes in the spatial precipitation and temperature (to 2050); and the human factors of (6) population density, (7) spatial distribution of population, (8) number of countries, and (9) number of linguistic groups. We present a typology of Lake Victoria basin that includes two main cases: the countries and the linguistic groups that are directly intersected by the Lake Victoria borders and those that lie downstream of the lake border, e.g. Sudan and Egypt. This typology and the output of the analysis of the nine geospatial factors can be used by the East African countries to identify opportunities for moving forward from conflict to cooperation over the sustainable development of Lake Victoria.

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**ODHENGO, PETER**

**KEYNOTE**

### **Blue-Economy-Food Security Nexus: An innovative sustainability model for the Great Lakes**

**Odhengo, P.,\* Muok, B., Ochuodho, S.**  
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The future sustainable-development paradigm shift of the great lakes in sub-Saharan Africa will greatly depend on the ecological integrity of lakes and rivers. It will also depend greatly on the integration of the blue-economy-food security nexus policy and fiscal models at the country and regional levels. The future development agenda for countries around the great lakes region, therefore, requires development and implementation of climate friendly policies and economic models aimed at building adaptive capacities of the fragile lakes ecosystems. This will be realized by establishing partnerships and linkages between public and the private sector operators' to enable realization of ecosystem sustainability in the next decade. The blue-economy-food security nexus in Sub Saharan Africa relates to the sustainable use and conservation of aquatic resources, such as lakes, rivers and groundwater. Many African countries such as Kenya have embraced the benefits and immense potential of these resources and are using them not only to further their social progress and economic growth, but also to safeguard the environment. When maintained, restored and protected, aquatic resources can contribute to sustainable and inclusive global development. Initiatives such as sustainable management of deltas, establishment of knowledge sharing hubs and platforms such as Africa Deltas Alliance Network (AfDAN), Green Climate Fund-Africa National Designated Authorities (GCF ADNANs), Greening Kenya Initiative Trust, sustainable financing mechanisms are examples of strategies and policy directives necessary for delivering great lakes innovative paradigm shifting.

The sustainable development goals adopted in September 2015 set up a new global development agenda. The most prominent feature of this agenda is its transformative nature and complex approach that combines social, economic and environmental issues. Improving human well-being and social equity in a way that does not harm the environment but reduces environmental risks scarcities requires a new economic paradigm- a green-blue economy whose importance is recognized by SDGs and Paris Agreement.

This discussion paper explores challenges and opportunities for advancing Blue-Green Economy-Food Security Nexus as an innovative sustainability model for the Great Lakes countries in Eastern Africa (Kenya, Tanzania, Rwanda, Uganda, Burundi, and South Sudan).

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**VAN DER KNAAP, MARTIN**

**KEYNOTE**

### **Evaluation of state-controlled monitoring, control & surveillance in relation to fisheries co-management on the Great Lakes of Africa**

**Van der Knaap, M.,<sup>1\*</sup> Njiru, J.<sup>2</sup>**

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In the late 1990s some form of formalized fisheries co-management was introduced on Lake Victoria, followed by Lakes Malawi/Nyasa/Niassa and Tanganyika in the next millennium. The introduction of co-management had some difficulties and faced many hurdles, but eventually the systems evolved naturally, until it appeared that despite community surveillance and landing-site linked management measures the commercial fisheries were not sustainable any longer. Illegal, Unregulated and Unrecorded (IUU) fishing found its way to all corners of the Great Lakes. Riparian states strengthened their Monitoring, Control and Surveillance (MCS) capacities and took harsh measures on the lake, affecting numerous fisheries professionals as well as fish value chains. The

phenomenon of co-management consists of a combination of state and community-based management measures. The question is whether the state interventions to conduct MCS activities have affected the willingness to implement co-management or to avoid all state-introduced means to control the lakes' exploitation, e.g. licensing, boat registration, compliance with gear regulations, and the like. The present paper discusses the delicate balance between state- and community-driven actions to exploit and conserve the fisheries' resources as well as the aquatic biodiversity on the three Great Lakes in Africa.

**ACHIENG', ALFRED**

**ORAL**

### **Development of a rapid bioassessment protocol for monitoring ecological health of riverine ecosystems in Kenya**

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The maintenance of good-quality, clean rivers that support high-quality biodiversity is universally recognized as a vital element of societal wellbeing. However, surface water quality is rapidly declining in Kenya, as a result of agricultural intensification, urbanization, domestic and industrial wastewater discharges. Biomonitoring approaches offer a practical and cost-effective way to assess the degree of environmental pollution and effectiveness of regulation for purposes of improving human and environmental welfare. Bioindicators, especially macroinvertebrates, have been found superior to chemical analyses because they integrate pollutant loads accumulated over long periods of time. Consequently, there has been an international trend to develop national or regional biological tools for monitoring water quality and overall ecological integrity of aquatic ecosystems. However, there is no biological criterion for assessing and monitoring the condition of water bodies in Kenya. This collaborative research brings together scientists from the University of Eldoret, Egerton University, and the National Museums of Kenya (NMK) who have wide experience in Kenyan aquatic communities, mainly macroinvertebrates and fish, as indicators of pollution and habitat degradation. Macroinvertebrates and fish were collected from four major ecoregions in the country, using standard sampling procedures. Water and habitat quality were also assessed using standard procedures. Distribution and occurrence of species in the ecoregions was evaluated in response to changes in water and habitat quality. The data collected on invertebrates was used to develop a national rapid bioassessment protocol, to be called the Kenya Invertebrates Scoring System (KISS), while fish data was used to validate the protocol. In addition, national and county water resources managers and other stakeholders are to be trained on the usefulness and application of the protocol. The findings will be disseminated as policy briefs to government agencies in order to guide sustainable management of water resources in the country.

**ALAL, GEORGE**

**ORAL**

### **Genetic diversity and population structure of selected lacustrine and riverine populations of African Sharp-tooth Catfish, *Clarias gariepinus* (Burchell, 1822) in Kenya**

**Alal, G.,<sup>1\*</sup> Kaunda-Arara, B.,<sup>1</sup> Barasa, J.,<sup>1</sup> Chemoiwa, E.,<sup>1</sup> Masembe, C.<sup>2</sup>**

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Profiling the genetic integrity of *Clarias gariepinus* populations in the wild would enhance their conservation capabilities. In this study, genetic diversity, demographic relationships, genetic differentiation, and structure analysis of lacustrine and riverine populations of *C. gariepinus* were determined. Pectoral fin clips from 128 individual *C. gariepinus* were collected as the source of mtDNA from three lakes (Victoria, Kamnarok, and Kenyatta), and three rivers (Nyando, Sosiani, and Tana) distributed across Kenya. They were sequenced for partial hypervariable site of mitochondrial DNA D-loop region. The 570 bp of mtDNA control region revealed 36 haplotypes in 462 polymorphic sites, seven distinct clusters (e.g. LKA/LK/NR, LK, TR, LKA/LK, LKA/TR, LV/NR/LKA/LK/TR and LV/NR/LKA/SR/LK/TR), and higher overall genetic diversity. Haplotype diversity was generally high in lakes, with Lake Victoria having the highest (LV, Hd=0.911) while rivers showed lower

diversities with lowest being River Sosiani (SR, Hd=0.518). *C. gariepinus* populations aggregated from lakes and rivers had clearly discernible multimodal shaped distributions, suggesting demographic equilibria in reference to demographic equilibrium theory, while there were negative Tajima's D values (Lakes -1.653, P>0.05 and Rivers -2.379, P<0.01), revealing stable populations undergoing purifying selection and effective population sizes undergoing genetic exchange. Fu's Fs exhibited lower values in lakes (10.575, P<0.001) than rivers (16.287, P<0.001). There were significant genetic differentiation in individual populations indicative of various catfish strains and high gene flow. ML tree analysis showed a continuous phylogenetic relationship. Minimum- spanning network showed a star-like radiation structure with one abundant central haplotype (H\_1) likely attributable to evolutionary ancestor of these populations. These results indicate genetically distinct populations that should be conserved and exploited sustainably for culture and capture fisheries. The lacustrine populations, more than riverine populations, were highly variable and exhibit great potential for conservation and production.

**AURA, CHRISTOPHER**

**ORAL**

### **Determining a major river catchment that pollutes a lake the most: a proof of concept for management implications**

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We present a Multi-metric Index of Biotic Integrity (MMIBI) methodological approach that allows for the ranking of major river catchments based on pollution status in the Kenyan portion of Lake Victoria, Africa. The study has a broader applicability to all of Lake Victoria, other African Great Lakes, and all lakes that have riverine discharge. The method presented utilizes water quality and environmental data, local knowledge, and pre-existing literature. The parameters considered were sampled in 2016 to 2018 during the dry season (July sampling) and the wet season (March sampling). Separation power of Mann-Whitney U test ( $p < 0.05$ ) qualified 11 discriminant metrics for both macroinvertebrate and fish samples into the scoring system of 1, 3, and 5 in the formulation of final MMIBI. Rivers in the northern section had lower MMIBI scores as compared to southern counterparts. The MMIBI ranking herein was validated by community perceptions on pollution levels. The River Nzoia catchment emerged as the most polluted, followed by River Yala, River Kuja, and Sondu-Miriu. Siltation, domestic washing, litter, and refuse emerged as the main agents of pollution. Management authorities should reinforce a balanced utilization of the vital water resources to minimize future impacts, and promote catchment-wide practices that ensure ecological health sustainability of the lake ecosystem.

**AWUOR, FONDA JANE**

**ORAL**

### **Women in aquaculture in Kenya**

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The declaration of the UN Decade of Women in 1975 saw the instigation of significant dynamism by various international organizations in recognizing women's contributions to rural development, in agriculture as well as fisheries. Aquaculture for many years has been viewed as a male-dominated sector, partly due to the high investment levels and or the technologies linked to the venture. Presently, about 20% of those engaging in aquaculture in Kenya are women. Further, 25% who engage in cage farming in Lake Victoria and 15% of pond fish farmers are women. Adverse regulatory mechanisms, laws, norms and beliefs lower women's ability to possess land, technology, and assets, hence putting them at the lower ends of the value chain. To that end, women fall victim and form a larger component of the poor, which limits their income-generating as well as asset-building potential. Uplifting women to engage in the aquaculture sector is pivotal as increasing their

proWess to make strategic life decisions will aid in alleviating the effects of poverty for individual households and communities alike. Similarly, eliminating gender barriers and motivating women to engage in aquaculture is crucial as is their registration in formal organization like fisheries association and/or aquaculture cooperatives. Endeavors to expedite the growth of aquaculture in Kenya should tackle 1) Breed improvement; 2) Sustainable feeds and environmental management alongside advocating for gender and collective impartial allocation of nutritional and economic well being. This paper attempts to define the present role of Kenyan women in different types and stages of aquaculture production, quantifying whenever possible the level of such engagements. Finally, it reviews sections where women's engagements can be strengthened with a view to increasing the importance of aquaculture production in Kenya.

**BALARIN, JOHN D.**

**ORAL**

**Application of an Environmental Performance Index, as a new tool for promoting inter-county, integrating water resources governance of Lake Victoria shared lacustrine and lake basin, Kenya. (A case study of Lake Victoria Basin, Kenya)**

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The 2010 Constitution of Kenya devolved responsibility for environment and natural resource management (E&NRM) to County governments and encourages inter-county cooperation in management of shared resources. The Environmental Management and Coordination Act (EMCA) has provision for Counties to plan for Integrated Water Resource Management (IWRM) through County State of the Environment Reports (CSOER) that guide mainstreaming of sustainable development into County Environmental Action Plans (CEAP). These in turn, guide priority setting in County Integrated Development Plans (CIDP) and budgeting frameworks. In 2018 the National Environmental Management Authority (NEMA) included in the SOER an Environmental Performance Index (EPI), based the Global EPI approach but domesticated to an analysis of 13 indicators, important to all 47 Counties. This paper demonstrates how the EPI can be used as a tool for better Lake Basin governance.

The Lake Victoria Basin Counties average EPI stands at 51%, with low performance in sustainable management of waste water treatment (14%), sanitation (40%) and solid waste disposal (25%). This, coupled with high use of wood fuel 78% leads to deforestation and downstream river and lake pollution. The EPI suggests that the Lake Basin Counties lack adequate environmental expertise (15%) and that investment in County budgets, at 41%, is below the economic value of the shared resource.

This paper demonstrates how the EPI can be used as a new tool to guide decision makers in prioritizing actions for sustainable lacustrine and lake basin development. It opens a new pathway for inter-County cooperation and integrated planning in Lake Basin management, identifying the priority actions required of the various County stakeholders. It elaborates the use of fact based County EPI info-graphics as a visual guide to better inform County governments where to prioritize focal sectors and areas for interventions in their Green and Blue Economy.

**BARASA, JAMES**

**ORAL**

**How many clariid catfish species inhabit Lake Victoria basin, Kenya, today? Insights from molecular and morphological analyses**

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Following ecological changes to Lake Victoria basin, which reduced Lake Victoria from a multi-species fishery of the 1960s to one dominated by only three species currently, ascertaining the actual number of Clariid catfish

species inhabiting the Lake today is crucial both for biodiversity conservation and for food and nutrition security. Clariid catfishes are exploited for human food and as live bait for Nile perch using long line and hooks in the Lake. Clarias aquaculture for bait fish is a sustainable strategy to conserve indigenous fish species of the basin. DNA barcoding using mitochondrial Cytochrome oxidase I (COI) region and key morphological characters of catfish were used to identify the species inhabiting 10 sites of Lake Victoria basin, Kenya. A total of 75 DNA sequences recovered clustered into four different groups, identified as *Clarias alluaudi*, *Xenoclaris eupogon*, *C. liocephalus* and *C. gariepinus*. Similar clustering was found using several morphological characters, which were significantly different ( $p < 0.05$ ) among identified fish species. Similarly, length of the two pairs of barbels was significantly different ( $p < 0.05$ ) among identified species. *Xenoclaris* was distributed only in Lake Victoria at Asembo Bay, and Lake Kanyaboli, while *C. alluaudi* was distributed only in Lake Victoria at Kendu Bay, suggesting a recovery of these small-sized *Clarias* species, having disappeared from Lake Victoria due to predation by Nile perch. *Clarias liocephalus* inhabited all rivers sampled, reservoirs and Lake Kanyaboli, while *C. gariepinus* occurred in all 10 sites. A total of four *Clarias/Xenoclaris* species inhabit the Lake Victoria basin of Kenya, which should be conserved, and evaluated as candidates for aquaculture, and used in artificial propagation at hatcheries.

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**BASWETI, GEORGE**

**ORAL**

**Does cage fish culture operation influence key physical chemical parameters of the waterbody? A case study of the ecological impact of cages in Lake Victoria, Kenya**

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Growing of fish in cages is currently practiced in Kenya and was first introduced as a trial in 1998 at Dunga beach, where it was successful. This encouraged investors to venture into the fish cage culture in Lake Victoria, where more resources were put into this farming activity. Earlier fish farming in Kenya was based on pond production to supplement the wild fisheries, but the high demand of fish due to population increase has led to diversification of fish farming methods. Cage fish farming is a method gaining in popularity, since fish culturing depends on the use of natural water and natural food chains. This pushed for environmental monitoring study of the ecological status of the water quality at the selected fish cages from June 2018 to Dec 2018. In-situ measurements of key variables (temperature, dissolved oxygen, pH, ORP, total dissolved solids, and conductivity) were made at the six sampling sites, each having four points using a HANNA HI9829 multi-parameter meter. Nutrients and chlorophyll-a samples were collected and analyzed following standard methods of analysis. Dissolved oxygen as an indicator of pollution ranged from 2.04 to 8.64 mg L<sup>-1</sup>. Total nitrogen and total phosphorous had a range of 109.64–996.91 N-μg L<sup>-1</sup> and 43.43–197.71 P-μg L<sup>-1</sup> respectively. Chlorophyll-a exhibited a range of 8.7–555.05 mg m<sup>-3</sup> due to high nutrient concentrations during the survey in the waterbody. As the aim of the fish cage culture is to improve food security, the risks involved should be solved by a clear understanding of the ecological impact brought about by unregulated and illegal installation of fish cages in the waterbody and lack of using the laid-down rules and regulations of this farming activity.

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**BUNYANGHA, JACKSON**

**ORAL**

**Historical land cover changes in Mpologoma River catchment, Eastern Uganda**

**Bunyangha, J.,<sup>1\*</sup> Muthumbi, A.,<sup>2</sup> Gichuki, N.,<sup>2</sup> Majaliwa, M.,<sup>1</sup> Egeru, A.<sup>1</sup>**

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Over the last decades, freshwater river basins in Africa have become centers of human population growth and focal points of economic development. However, the magnitude of encroachment to guide strategic interventions remains blurred. Thus, to quantify and thus gain an understanding of the land use and land cover changes and drivers in Mpologoma River Catchment system over a 32-year period (1986-2018), we used remote sensing and GIS technologies. Ground truthing was conducted between August and November 2018. Results indicated that Mpologoma River catchment had undergone significant LULCCs during the last three decades. A total area of 4276 km<sup>2</sup> (or 62.4%) of terrestrial habitats including wetlands had been lost through clearing for

agriculture, settlements and infrastructure. The principal driver of land use and land cover change in Mpologoma River Catchment was farming, dominated by smallholder farmers (73.13%) on private land trying to meet local food demand and improve household income from rice sales to the local markets. Nonetheless, Doho Rice Scheme and corporate commercial farmers have also been steadily expanding their productive land. Additionally, the area under settlements quadrupled over the same period. A combination of factors may have encouraged local residents to encroach on natural forests and woodlands, and reclaim natural wetlands for farming. These include climate variability, population pressure, reliance on traditional farming methods, declining crop yields on existing farmlands and inadequate control of land use. We recommend that a participatory integrated development planning process be initiated in Mpologoma River Catchment with a clear objective of protecting and rehabilitating degraded ecosystems, promoting climate smart agriculture and agroforestry, and community involvement in environmental conservation, such as tree planting to meet domestic wood requirements and for carbon sequestration. Furthermore, as with the rest of Uganda, it is prudent to re-introduce family planning initiatives to check population growth.

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**DABI, SHAMBEL BOKI**

**ORAL**

### **Physiological and ion-regulatory responses in Common Carp (*Cyprinus carpio*) exposed to short term copper and ammonia exposure**

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This study aimed to investigate the interactive effects of copper and ammonia as to whether they have synergetic or antagonistic effects on the physiological performance and ion regulation of common carp (*Cyprinus carpio*) exposed acutely to two sub-lethal combinations of copper and ammonia concentrations (i.e. 5.2 µM Cu with 1.3 mM ammonia, and 2.6 µM Cu with 0.65 mM ammonia) and copper equilibrium in different tissue. Juvenile common carp (*Cyprinus carpio*) of 15±3.35 g body weight were exposed for one day to different copper and ammonia concentration and also to mixture of copper and ammonia. The experiment was done in two rounds; in the first round 50% 96 h LC50 of copper (5.2 µM), 50% 96 h LC50 of ammonia (1.3 mM) and their combination (5.2 µM + 1.3 mM) was exposed to juvenile common carp. In the second round 25% 96 h LC50 of copper (2.6 µM), 25% 96 h LC50 of ammonia (0.65 mM) and their combination (2.6 µM + 0.65 mM) was exposed to juvenile common carp. The result showed that ammonia excretion was inhibited both in high and low combination (copper and ammonia) and renovate after 24 h exposure. Plasma copper was elevated after 12 h to 1.80±0.15 µg ml<sup>-1</sup> and also after 24 h to 1.84±0.15 µg ml<sup>-1</sup> in copper and 1.30±0.17 µg ml<sup>-1</sup> and 1.55±0.12 µg ml<sup>-1</sup> in combination after 12 h and 24 h respectively. In the present study, high copper accumulation was observed in liver and the least accumulation in muscle tissue. There were no significant MWC found in any of our experiments. In general, the interaction effects of copper and ammonia in both high and low combination are lower than their additive effects (antagonistic), except the accumulation of copper in gill tissue.

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**DEGAGA, ABERA HAILU**

**ORAL**

### **Water hyacinth (*Eichhornia crassipes*) biology and its impacts on ecosystem, biodiversity, economy, and human well-being**

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The aim of this review was to show water hyacinth biology, chemical composition, and its negative impacts on aquatic ecosystem, biodiversity, economy, and human wellbeing. Water hyacinth is challenging the ecological stability of freshwater bodies. It is native to the Amazon Basin in Brazil and other nearby South American countries. In Africa, the first introduction of water hyacinth was in Egypt in 1880. In Ethiopia, water hyacinth was officially reported in 1956 in Koka Lake and the Awash River. Nutrients and temperature are considered the strongest determinants for water hyacinth growth and reproduction. Under favorable conditions, water hyacinth can double its mass every 5 days; it also grows from seed, which can remain viable for 20 years. Due

to its extremely rapid growth, the weed has become the major floating water weed of tropical and subtropical regions. In the absence of natural enemies, the weed quickly becomes invasive, colonizing slow-moving waters and resulting in thick, extensive mats that degrade aquatic ecosystems and limit their utilization. These mats affect fisheries and related commercial activities, the functioning of irrigation canals, navigation, hydroelectric programmes, and tourism. Its 95% mass weight is water from 5% dry matter 50% is silica and 30% is K, 15% N and 5% protein. The spread of this invasive plant is difficult to manage and not easy to reverse. Its impact is not only loss of biodiversity in aquatic ecosystems but also economic development and human wellbeing. The best method to control water hyacinth is to prevent it from entering a water body. The Ethiopian Government should declare water hyacinth and other invasive species a national pest and then put legislation in place to control them.

**GICHURU, NICHOLAS**

**ORAL**

### **Poor management of Lake Victoria fisheries (Kenya): A threat to sustainable fish supplies**

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The Kenyan portion (6% of surface area) of Lake Victoria provides 80% of the nation's annual fish landings from both marine and freshwater bodies. The fishery provides employment, food, and income to lake-edge communities. Fish is highly perishable and needs to be consumed as soon as it is caught or preserved for later use. Currently in Lake Victoria, post-harvest losses are estimated between 20% and 40%. In addition, the fishery is facing unnecessary human-induced pressures like overfishing, pollution, illegal fishing, lack of policy to guide and coordinate cage farming, and conflicting roles of three institutions managing the same resource: the beach management units (BMUs), county government and national government, causing confusion and vested interests in fisheries management. The prior factors have contributed to a decline in fish stocks, aggravating poverty and reducing nutritional food security. The most recent fisheries resource evaluation using the Schaefer model revealed that Nile Perch (*Lates niloticus*) fishery has declined by 31% from 2014 to 2016, Dagaa (*Rastrineobola argentea*) and Haplochromines/other species have declined by 40% and 72% respectively. Nile tilapia (*Oreochromis niloticus*) declined by 38.2% in the same period. The number of fishing crews slightly increased from 41,912 in 2010 to 43,799 in 2016. Based on these findings, the maximum sustainable yield (MSY) for Nile perch and tilapia is estimated at 86,096 tons and 27,892 tons respectively. This calls for a reduction of 40% fishing effort for Nile perch and tilapia and an annual review and update of the appropriate fishing capacity. Equally important is to increase the overall fish available to consumers through use of cost effective post-harvest technology to minimize post-harvest losses.

**GITHIORA, YVONNE**

**ORAL**

### **Assessment of local perceptions of climate change impacts in Yala Wetland**

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Wetlands provide a broad range of ecosystem services including supply of fish and fibre, water supply, water purification, and recreational services. Further, wetlands play a key role in supporting climate change adaptation and resilience, by acting as a buffer against climate change. However, they are profoundly impacted by climate change, which alters their hydrological regime. Participatory local level assessments, which include assessing the perceptions of local communities, are needed to support proper implementation of policy to address climate change impacts. This study examines the local communities' perception of climate change, its impact, and the role of the Yala Swamp in helping the community adapt to climate change. In addition, the study sought to analyse the long-term mitigation measures both at the national and county level by looking at the policies and



regulations put in place. The study employed open-ended interviews with key informants and community members who are direct users of the wetland. Our study presents a case for the understanding of community perceptions and knowledge of climate change impacts, as well as the perceived role of the wetland in climate change adaptation, in order to develop appropriate policy responses to climate change.

**GITHUKIA, CECILIA**

**ORAL**

### **Transforming aquaculture in Kenya through gender equality and empowerment for development**

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As the fastest-growing food producing sector in the world, aquaculture is increasingly acknowledged for its role in improving income and providing protein-rich food, especially in developing countries. In Kenya, fish-demand is constantly growing due to an increase in population and changing behaviours towards a healthier diet. Fish supply, however, lags behind owing to declining natural fish stocks, which have increased the volume of fish imports in Kenya, especially Nile tilapia. Aquaculture will therefore serve to fill the fish demand-supply gap due to its intensification. However, the benefits from aquaculture are not evenly distributed by gender. Women have lagged behind in terms of aquaculture development and benefits because of lack of gender sensitivity in aquaculture projects and initiatives. Gender incorporation in aquaculture is important in promoting the realization of sustainable development goals: 1) ending poverty; 2) ending hunger; 3) promoting good health and the well-being of people, and 4) gender equality. This paper reviews gender contribution, challenges, and possible solutions towards transforming aquaculture in Kenya for increased productivity. The results of the review showed that women are involved in all value chain nodes of aquaculture but receive minimal benefits from the same. Despite government's efforts in promoting aquaculture, access to capital, to quality feed, and to seed remains a major constraint in aquaculture growth. A more gender-sensitive approach in aquaculture initiatives is proposed.

**GÓMEZ-CARDONA, SANTIAGO**

**ORAL**

### **Tale of two fisheries: Economics effects of ecological interactions under open access - towards an integrated understanding of market and ecological interactions for Lake Victoria fisheries**

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We develop a bioeconomic model of two fisheries that allows interaction at the ecological as well as at the market level. This model allows understanding of the channels through which changes in the market for one particular fish affects interrelated fisheries. For the case of a predator-prey relationship, which conforms to the relationship of Nile perch with other species in the Lake Victoria, changes in price for one species affects the other one asymmetrically. Particularly, increases in the price of a predator could increase the level of catches for its prey, increasing the income that people derive from this alternative. In the other direction, increases on the prices for prey could negatively affect the income derived from predator fishing. These, among other results, speak to the changes in these fisheries over the last years. We need a better understanding of the underlying forces that govern the relationship of fisheries and markets, among them, the self-correcting or reinforcing dynamics between the ecological and market interactions. This understanding will allow for better regulation designs to the management of Lake Victoria resources. This model advances in such direction.

### Biogeochemical characterization, phosphorus sources and intrinsic drivers to its speciation within Nyanza Gulf – Lake Victoria

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Lake Victoria, like many African great lakes, was formed through tectonic activity that formed the East African Rift Valley. The lake's ecology has undergone dramatic reorganization dating back to the 1920s, before agricultural mechanization and high urban populations. Its trophic status has changed from mesotrophic to eutrophic/hypertrophic; TN:TP exhibits one of the lowest ratios; algal composition has shifted from diatom to cyanobacteria predominance; and primary productivity has increased more than tenfold. This study was to understand Nyanza Gulf's biogeochemical characteristics, phosphorus sources, and driving forces to their speciation. Five littoral-limnetic-littoral transects were sampled for water associated phosphorus (SRP; TPW); sediment associated phosphorus (NAIP; AP; IP; OP; TPS); elemental compositions (Ca; Fe; Al; Mn); Organic Matter (OM); and Organic Carbon (OC) contents in the sediment. Soluble Reactive Phosphorus (SRP) and Total Phosphorus (TPW) observations ranged from 22.9 to 142.9  $\mu\text{g-P L}^{-1}$ , and 57.1 to 277.1  $\mu\text{g-P L}^{-1}$ , respectively. Littoral stations exemplified higher TPW concentrations than limnetic stations. Sheltered bays and stations off sewerage discharge points had higher Non Apatite Inorganic Phosphorus (NAIP) concentrations exceeding 400  $\text{mg.kg}^{-1}$  compared to strong current areas. Apatite Phosphorus (AP) and Total Phosphorus (TPS) concentrations ranged from 136.7 to 1511.3  $\text{mg.kg}^{-1}$ , and 512.5 to 2254.4  $\text{mg.kg}^{-1}$  respectively. AP and TPS concentrations were higher within littoral compared to limnetic zones, with littoral stations close to documented carbonatite rock substrates manifesting exceptionally high concentrations. Nyanza Gulf's eutrophic/hypertrophic status is derived highly from shoreline erosions of phosphorus-enriched carbonatite rocks associated with rift valleys and from municipal sewerage discharges. Re-afforestation, fringing wetland restorations, and tertiary treatment of municipal wastewaters are vital for ecological restoration.

### Value chain analysis of Lake Turkana tilapia fish as food to the local market to identify investment gaps

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Lake Turkana fish production currently averages 8,000 metric tonnes, valued at 600 million Kenyan shillings, and accounts for a paltry 4% of the total fish production from Kenyan waters. Approximately 16 fish species support commercial fishery from Lake Turkana. Tilapia dominates the catches, accounting for 38%–42% of the volume of fish landed and may reach 80% during “tilapia boom” seasons. Once landed, tilapia undergoes various methods of processing, ranging from chilling, descaling, and frying or splitting and sun-drying in the salted and non-salted form. The processed products are readily sold at both local and external markets, depending on market preference. Unknown quantities are also consumed along the lakeshore. There are many opportunities along the value chain that can be exploited. This study was therefore meant to assess the value chain of tilapia fish as food to the local markets within Turkana County to identify investment gaps. Data was collected through interviews and secondary sources from both market actors and managers using the snowball sampling technique. Provisional results indicated that that Lake Turkana tilapia fish value chain flows through a number of channels from the input supplies, through processing nodes to the consumers. From local market demands, supply did not keep pace with production due to bottlenecks such as use of antiquated rudimentary fishing practices, a poorly developed road network, lack of cold chain storage facilities and unavailability of good marketing organization. An interim recommendation is to embrace the new fish value chain dynamics and re-orient policy towards resource sustainability with equitable benefits for all, while balancing the needs of each actor group.

### **Influence of large mammalian herbivores on nutrients and carbon loading, and benthic algal development in the Mara River, Kenya**

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This study focused on how large mammalian herbivores (cattle and hippos) influence water quality, and on their contribution to nutrients and organic matter input in the Mara River through their in-stream behaviour and its impact on benthic algal development. A total of 12 sites were selected based on the changing distribution and abundance of livestock and hippo populations along the Talek, Molibany, and Olare Orok tributaries of the Mara River. The results showed a spatial significant variation ( $p < 0.05$ ) in water quality variables, organic matter and nutrient concentration among the livestock and hippo sites due to variation in livestock and hippo input amounts and their numbers among the sites. This was reflected by the strong significant positive correlation between the total livestock numbers and the levels of TN and DOC ( $r > 0.70$ ,  $p < 0.05$ ). The input of C, N and P by one cow from direct defecation into the river was estimated to be 5.41 g C, 0.17 g N and 0.04 g P per day. Based on the population estimates of cattle and hippos that egest directly in the Talek sub-catchment, the total input to the river by cattle was 856 Kg C, 26.7 Kg N and 6.7 Kg P per day and by hippos was 547 Kg C, 56.9 Kg N and 7.5 Kg P per day. The spatial variation in the development of benthic algae noted in the study was majorly affected by the turbidity levels at the livestock and hippo sites. Diatoms, which are indicators of nutrient enrichment, were the most dominant and abundant class of algae among the sites.

### **Community based natural resource management in the Mara River Basin, challenges and opportunities**

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The Mara-Serengeti Ecosystem (MSE) is a trans-boundary resource that provides important ecosystem services to wildlife and communities. It is classified as the eighth wonder of the world due to its annual migration of game, especially wildebeest. Apart from the protected areas, communal lands within the ecosystem form part of the migratory routes. In the core areas of Masai Mara National Reserve (MMNR) and Serengeti National Park (SNP) only wildlife tourism is permitted. The entire area comprising the MMNR is within the Mara River Basin (MRB= area 13,750 km<sup>2</sup>) but only 35 % of the SNP is found in the basin.

This study aimed at conducting inventory and determining the basis for strengthening Community Based Natural Resource Management (CBNRM) groups in the MSE. A SWOT analysis was used to prepare guidelines for engagement of CBNRM groups (WMAs and Conservancies) and document best practices. Natural resources considered were water, wildlife, and forestry. Others were fisheries, agriculture, beekeeping, eco-tourism, and mining. A structured questionnaire, rapid field surveys and a predetermined Focus Group Discussion (FGD) question guide were used to obtain primary data.

Most CBNRM officials had primary school education (45.8%) or no formal education (8.3%). In forest management the main challenges were limited knowledge (66.7%) and ownership (33.3%). Low water quality and quantity and inadequate knowledge on catchment area management were the main challenges. Human-wildlife conflict (54.5%) was the main challenge while fire outbreaks (25%) posed the least threat. Acceptance of natural resource management policies by CBNRM was at 41.7%; lack of policy implementation at 21.4%; lack of 'biting' power enforcement 21.4%, and conflicting policy intentions (46.7%). A trans-boundary NRM committee and network is proposed for tackling wildlife trans-boundary issues.

**Nyanja is not Lake Victoria: Ontological problems and possibilities around an inland African sea****Johnson, J.**Purdue University, United States of America  
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The fascinating complexities of Lake Victoria's contemporary fisheries situation and assumed fisheries crisis have motivated a recent florescence of social science scholarship. These studies have identified a central paradox: despite living next to and making their living from Africa's largest freshwater fishery, residents of Lake Victoria's fishing communities are surprisingly food insecure and eat surprisingly few fish. In this talk, I argue that this paradox is a result of four interrelated ontological problems (that is, problems around the nature of existence) that implicitly frame studies of and attempts to address Lake Victoria's contemporary fisheries crisis. These problems are: what constitutes a body of water, a complete meal, fish, and fisheries themselves. Attention to these problems configures a paradox otherwise: it is still possible to eat and live well with fish in a place where some social scientists have already determined almost no one can.

**Implications of 1.5 degrees warming to Kenya's aquatic ecosystems****Kairo, J.**Kenya Marine and Fisheries Research Institute (KMFRI), Mombasa, Kenya  
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Kenya's economy is highly dependent on climate-sensitive sectors, including agriculture, tourism and energy production. This sensitivity stems in large measure from the dependence of these economic sectors on a sufficient supply of freshwater. Already, Kenya is grouped amongst water-scarce countries with water availability recorded below 1000 cubic meter per capita. Based on current population growth and climate change effects, water availability is projected to fall to 350 cubic meters per capita by 2020. Climate change could further reduce the availability of this resource through higher evaporation, altered rainfall patterns, accelerated loss of glaciers, and sea-level rise. Already, severe drought has dried up water resources in half of Kenya's 47 counties and an estimated 3 million people lack access to clean water. Recurrent droughts have destroyed livelihoods, triggered local conflicts over scarce resources and eroded the ability of communities to cope. Degradation of water catchment is an additional challenge that is expected to cost the country 0.5% of GDP per year. With demand for water projected to exceed supply, achieving Kenya's 'blue growth' and sustainable development goals (SDGs) could become difficult. This paper will relook at climate change impacts on freshwater resources in Kenya and actions needed to ensure that the country does not experience worsening climate related devastations and retains some capacity to meet its development aspirations

**The seasonality of the spatial distribution of dissolved selected metals in Lake Naivasha, Kenya****Kamau, J.,<sup>1\*</sup> Gachanja, A.,<sup>2</sup> Ngila, C.,<sup>3</sup> Kazungu, J.,<sup>1</sup> Zhai, M.<sup>4</sup>**<sup>1</sup>Kenya Marine Fisheries Research Institute, Kenya<sup>2</sup>Jomo Kenyatta University of Agriculture and Technology, Faculty of Science, Kenya<sup>3</sup>Kenya Pipeline Company, Kenya<sup>4</sup>Geology Department, University of Botswana, Gaborone, Botswana

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Lake Naivasha is the only freshwater Rift Valley Lake, in Kenya. It lies in a fertile semi-arid basin. The lake has no surface water outlet and is presumed to be under stress. Dissolved metals are directly taken up by bacteria, algae, plants, and planktonic and benthic organisms. Dissolved metals can also adsorb to particulate matter in water column and enter aquatic organisms through various routes. Cadmium, copper, lead, and zinc may bioaccumulate within lower organisms, yet they do not biomagnify up the food chain as do mercury and

selenium. This study reports on the levels and distribution of dissolved heavy metals and investigates the influence of physicochemical parameters on metal mobilization. The bioavailability of selected metals was investigated by relating the levels of dissolved metals to those in fish. Water abstraction for irrigation and domestic use, compounded with organic matter inflow will affect physicochemical parameters and hence influences the mobilization of heavy metals. Dissolved Zn correlated highly with sediment pH ( $r = 0.67$ ) indicating that dissolution increases with increase in Eh. In addition, the fact that the pH also correlated positively with organic matter  $r = 0.50$ , Eh  $r = 0.63$ , temperature  $r = 0.56$  and dissolved oxygen  $r = 0.56$ , would suggest that organic bound Zn contributed significantly to the concentration of dissolved Zn. In situ flux experiments indicated that the fringing papyrus reeds located along the shores of Lake Naivasha provided sites for metal immobilization due to their coprecipitation on redox-sensitive metals.

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**KAMTAMBE, KINGSLEY**

**ORAL**

### **Finding common ground: The complexity of marketing small fish of Lake Malawi**

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Lake Malawi, a multi-species fishery, has gone through a series of changes in fish catch composition where larger, more profitable fish species have been replaced by small cichlids. These small cichlids now contribute more than 80% of the annual total catch, and are often sold sun-dried or smoked. Unlike the larger fish species, which are sold per piece or kilogram, the smaller fish are sold by volume. This has brought a complication and inefficiencies in that there are different containers and the filling measurements are different from market to market and trader to trader. This also has promoted unsafe and unconventional fish drying methods which promote fish bloating during drying to manipulate the volume of the dried fish.

This study aimed to identify commonly used fish marketing containers and standardize their volume by weight for differently processed small cichlids of Lake Malawi. A total of 26 sites in Salima, Mangochi, and Blantyre districts were assessed. Four types of containers were identified, comprising 40, 20, 9, and 5 liters. The first three containers were common at fish landing and processing sites and used when processors or fish traders buy fish directly from fishermen. Five-liter containers were used at retail local markets. Fresh *E. sardella*, *Diploaxodon*, *capadichromis* species, 40 liter containers weigh  $45 \pm 1.5$  kg,  $43 \pm 1$ kg and  $41 \pm 0.93$ kg, respectively.

The study showed that for fresh products, there was an overestimation of weight while for dried products there was underestimation, hence fish traders lose revenue when they used volume of container instead of weight.

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**KIRIMI, JAMES**

**ORAL**

### **Evaluation of protein quality of rations for Nile tilapia (*Oreochromis niloticus*) containing soybean meal, canola meal and sunflower meal as replacements of fishmeal**

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This study aimed to evaluate the amino acid profile of the diets for Nile tilapia containing soybean meal, canola meal, and sunflower meal as replacements of fishmeal. Four isonitrogenous diets (30% crude protein) and isocaloric (2900 Kcal/kg) were formulated using fishmeal (FM), soybean meal (SBM), canola meal (CM), and sunflower meal (SFM), such that each contributed 10% of the 30% crude protein (CP) in diet 1, 2, 3, and 4 respectively. The amino acid profiles of ingredients and diets were determined by MPA FT-NIR spectrometer (Bruker, Germany) which is a non-destructive method of analysis. Fishmeal recorded higher levels ( $P < 0.05$ ) for amino acid lysine (7.81), methionine (2.89), arginine (5.87), threonine (4.28), and isoleucine (4.55). Substituting 10% CP of FM with either SBM, CM and SFM, reduced the levels of isoleucine, leucine, arginine, lysine, phenylalanine, histidine, and threonine ( $P < 0.05$ ), and increased levels of methionine in diets with SBM substitute. The chemical scores for all essential amino acids in fishmeal were higher than 100. In all the diets,

methionine was the first limiting amino acid and isoleucine second limiting. Although the diet containing FM exhibited higher ( $P<0.05$ ) essential amino acid index (EAAI) (0.97), it was not satisfactory because it was limiting in methionine. EAAI reduced ( $P<0.05$ ) with replacement of fishmeal by SBM (0.78), CM (0.77), and SFM (0.76). The study showed that substitution of 10% CP of FM with SBM, CM, and SFM provided a useful protein diet.

**MALALA, JOHN**

**ORAL**

### **Invasive alien species: Impact of the introduced *Prosopis juliflora* on the fishery and biodiversity of Lake Turkana, Kenya**

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Invasive species have been blamed for causing losses in biodiversity, changes in ecosystems, and impacts to economic enterprises such as agriculture, forestry, fisheries, power production, and international trade amongst others. The shores of Lake Turkana, normally devoid of vegetation, have witnessed the prolific growth of *Prosopis juliflora* (Sw) DC, in many cases blocking access to the lake. This study assessed the impact of the weed on the livelihoods of the fisher communities and on the fishery. The study was informed by many emerging issues affecting the environmental health of Lake Turkana, such as continuous drop in lake water level, drying up of macrophytes along the lakeshore, and ongoing construction of a series of cascading dams along the river Omo, amongst others. Information was gathered through field observations, use of questionnaires, and an analysis of present and historical data. The results indicated that *Prosopis* was widely distributed along the shoreline and Northwestern areas close to the River Omo wetlands, Turkwel River mouth, and Kerio. The Kerio-Napasinyang river deltas had the highest vegetation cover. Various roles of the alien species included sustaining the fishery through increased aquatic production, protection of fish breeding zones, enhancement of fish growth, natural limitation of overfishing through gear restriction and access by fishers and fishing vessels. Perceived negative effects were many. We propose management measures such as mapping and identification of hotspots and valuation along the fish value chain for mainstreaming into the blue economic growth of the lake.

**MANYALA, JULIUS**

**ORAL**

### **Sustainable aquaculture development in Eastern Africa: Current knowledge, research priorities and policy implications**

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Aquaculture has been identified as one of the best-bet innovations for adaptation in agriculture, which can help achieve food security under a changing climate while also delivering co-benefits for environmental sustainability, nutrition and livelihoods. Given the increasing scarcity of water, land, and other aquaculture resources, a growing body of literature calls for the sustainable intensification of food production, broadly defined as “producing more using less.” Despite decades of research and development, hundreds of millions of dollars of investment, and high biophysical potential, aquaculture has not yet significantly contributed to sustainable food supplies or economic development in sub-Saharan Africa. Notably, aquaculture in East Africa has not developed its potential and accounts for only 7–8% of regional fish consumption. In recent years, there is evidence of increasing investments into the intensification of aquaculture systems and commercialization of the value chain on the continent. In this paper, we synthesize current understanding on the status and potential for sustainable intensification of aquaculture in Eastern Africa. We adopted a scoping and systematic review methodology of innovations in aquaculture to address three overarching questions: (1) Why is the significant potential for development of a commercial aquaculture not yet realised despite increasing investments in the

intensification of production systems? (2) What are the technological, socioeconomic, and institutional changes needed to achieve sustainable aquaculture production and livelihoods in Eastern Africa? (3) What data are available to inform research and policy development to support the contributions of aquaculture to wider societal development? The paper addresses these questions with the aim of situating dialogue squarely within the science-policy interface. The overall goal is to provide a foundation of knowledge to inform the trajectory of research, policy, and practice that supports the role of aquaculture in achieving sustainable development goals (SDGs) to end poverty (SDG1) and hunger (SDG2).

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**MASESE, FRANK O.**

**ORAL**

**Baseline determination in stable-isotope studies of Afrotropical lotic systems and implications for tracing energy flow in food webs and calculated trophic positions**

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Stable isotope ratios are commonly used to reconstruct consumers' diets and determine trophic structure in ecological communities, but the accuracy of diet estimates from this approach is influenced by our understanding of the isotopic baseline or value of producers at the base of food webs and diet-tissue discrimination. Because  $\delta^{15}\text{N}$  values vary in freshwater systems in response to changes in land use, suitable baseline indicators must be specified. Since suitable baseline organisms vary among regions, there is a need to identify region-specific taxa. We screened individual taxa and bulked groups representing different feeding modes as baselines. The baseline organism or group has to meet some criteria, which include it being abundant and easy to collect, and aligned with the isotopic value of its dominant energy source. We then used data on  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  of consumers (mainly invertebrates and fish) and their food resources (mainly algae and periphyton) from aquatic ecosystems in East Africa to determine fractionation values between trophic groups and trophic positions. The trophic positions (TPs) for fish ranged between 4 and 6 without a clear distinction among most species. TPs for macroinvertebrate separated clearly between predators (values between 3.5 and 4.5) and herbivores (values between 1.5 and 3), while those for predatory invertebrates were within ranges for insectivorous fishes. In agreement with other tropical studies, our findings show that trophic fractionation of nitrogen ( $\Delta\delta^{15}\text{N}$ ) is generally much less and trophic fractionation of carbon ( $\Delta\delta^{13}\text{C}$ ) is much greater than in temperate aquatic food webs. These findings show that different values for isotopic fractionations need to be considered for tropical vs. temperate regions. Use of appropriate baseline and fractionation values for consumers will lead to more constrained and satisfactory results when tracing energy flow in food webs using isotope mixing models.

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**MAY, LINDA**

**ORAL**

**The sustainable development of the Winam Gulf, Kenya: An ecosystem services approach**

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The Winam Gulf of Lake Victoria, Kenya, is an important Natural Capital Asset that improves the health and livelihoods of over two million people. It is also a complex and intricately linked socio-economic system that provides a range of ecosystem services, including provisioning, supporting, and cultural services. In recent years, the value of this asset has been falling, mainly due to over-fishing and increasing levels of pollution. In this study, we have combined published information on fish breeding areas, cage fish farm locations and water hyacinth hotspots, with unpublished data on spatial variations in water quality, to improve the scientific evidence available to inform the management of this system. These water quality data include secchi depth

transparency, chlorophyll levels, and concentrations of nutrients and heavy metals. Our results will contribute to securing a sustainable future for the Winam Gulf by helping to reduce the risk that the quality of the water, and of the fragile ecosystems that it supports, are not degraded further by any management decisions aimed at promoting socio-economic development. A particular problem that has been considered is that, recently, there has been a proliferation of cage fish farms around the shorelines of the Gulf and of the Kenyan part of Lake Victoria. More than 70% of these are located in sheltered bays, shallow waters, and within 200 m of the shoreline. Here, they can damage the natural ecosystem of the lake, for example by interfering with the natural habitat and breeding areas used by wild fish populations and by discharging waste products into the water. We conclude that unintended ecological damage can be avoided through better control of polluting discharges to the Gulf and by the improved regulation of conflicting uses. This is key to achieving sustainable development.

**MIRERA, DAVID**

**ORAL**

### **Rethinking blue economy through aquaculture development: Linking the Great Lakes and the Indian Ocean, a Nile tilapia approach**

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According to the global environment outlook of 2019, meat production currently uses 77% of agricultural land and consequently, agricultural production consumes 70% of global freshwater resources. Therefore, to feed a population of 8.55 billion people globally by 2030, new strategies are required to ensure that food is sustainably produced while the integrity of key ecosystems like the Global Great Lakes is maintained. In this regard, aquaculture development provides the way to sustainably use the limited global water resources for food production. In the spirit of blue economy, water resources in the Global Oceans are quite underutilized in food production. In an effort to establish the link between freshwater and marine water resources and make use of the unutilized space through aquaculture, KMFRI scientist innovatively developed a tilapia strain for farming in the ocean from the currently established freshwater Nile tilapia. The marine tilapia strain is successfully bred in the ocean waters and is farmed in intertidal earthen mangrove ponds and fish cages. Marine tilapia has been observed to have a growth rate of 0.5–1.2 g/day, which is equivalent to growth rates recorded in freshwater extensive culture systems. The marine tilapia strain is now providing food and income to coastal communities who could otherwise have their culture facilities without fish due to the limited marine hatchery in Kenya and the region. This innovation will go a long way to support utilization of marine waters for aquaculture development, thus saving the Global Great Lakes which are already constrained by the different agricultural activities globally and rethinking Blue Economy.

**MIRUKA, BABU**

**ORAL**

### **Riverine inputs on phytoplankton diversity and cyanobacterial abundance in Nyanza Gulf, Lake Victoria, with implications on human health**

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Phytoplankton forms the basis of aquatic food chain and can be used as indicators of water quality and ecosystem health. Although phytoplankton abundance, diversity, and the distribution of cyanotoxins have been studied in Nyanza Gulf, little is known about occurrences and spread of toxic algae strains. An investigation was carried out between June and September 2018. Both ELISA kit and counting using Utermöhl sedimentation chamber methods were used to determine algal concentrations, which were among the highest levels so far recorded from the lake. An elevated level of cyanobacteria was observed, raising concerns over possible toxin effects on the health of water users. The high levels were influenced by input of nutrients: the TN:TP ratio (<22) indicated that phytoplankton growth in the lake may be nitrogen-deficient, a situation favoring dominance of nitrogen-fixing cyanobacteria. The proportion of cyanobacteria was > 70% of the samples obtained, with *Microcystis* spp. emerging as the dominant species. Microcystin was found to be higher in algal cells found both



in wet and dry season, with toxin concentrations ranging from 0.8 - 17.0  $\mu\text{g L}^{-1}$  with a mean value of 15.06  $\mu\text{g L}^{-1}$ . An attempt was made to classify the water quality and relate the same to general phytoplankton and cyanobacteria abundance and diversity in order to assist decision makers in defining restoration conservation strategies, and provide an important tool for assessing water quality status as regards the Lake Victoria aquatic ecosystem for harnessing the growth of the blue economy.

**MLAPONI, ENOCK**

**ORAL**

### **Is the current fisheries management intervention in Lake Victoria efficient?**

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The ecosystems of Lake Victoria have undergone dramatic changes, which began around 1980 and coincided with the rapid expansion and decline of the Nile perch (*Lates niloticus*) population due to fluctuation in environmental processes and unsustainable illegal fishing practices. The fisheries of Lake Victoria are of crucial economic importance to the region as they support around 250,000 fishermen. The earnings of these fishermen are a major contribution to economic growth and the exports of Nile perch are worth around USD 350 million per annum. In a few years the stock of Nile perch was observed to decline from the 1999 stock size to 2018 stock size. Various management interventions by East African countries in different periods in curbing illegal fishing practices were implemented several times, without success. The EAC fisheries sector ministers conducted an operation with the belief that this would increase the fish stock and boost the economic growth of the riparian states. Following the one-year operation, the current regional stock assessment survey through Standard Operating Procedures (SOPs) of Lake Victoria Fisheries Organization revealed that Nile stock measured along the slot size of 50–85 cm TL increases to 5.3% from 0.4% within a year, more ever stock of fish has increased to 32% optimal fish volume from 3.3%. It has been evident that the mean length of Nile perch shows increases by 58.3% from 15.95 cm TL (2017) to 25.17 cm TL (2018). However the current slot-size regulation needs urgent reconsideration since it is impractical to target the only 5% of biomass that lies within this limit. This harvesting strategy exerts pressure on the spawning stock which constitutes a small proportion of the total biomass, thus compromising the recruitment potential of the species.

**MORARA N., GEORGE**

**ORAL**

### **Spatial variations in assemblage and size structure of *Oreochromis niloticus* (Cichlidae) in Lake Naivasha, Kenya**

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Studies of fish species population abundance and size structure provide useful information for their sustainable exploitation and conservation. Nile tilapia, *Oreochromis niloticus*, is a recent introduction in the fishery of Lake Naivasha. Thus, this paper investigated the spatial variations in its relative abundance and size structure in relation to habitat conditions. Fish samples were collected at 9 spatially distinct points between October 2017 and December 2018. A total of 2700 specimen of *O. niloticus* were sampled using replicate fleets of gillnets ranging from stretched mesh sizes of 2 to 8 inches and standardized by soak duration of about 12 hours at each sampling points. Physicochemical parameters were determined in situ using a multi-parameter meter. Sorted samples were enumerated and their individual weight-length data recorded. Relative abundance, means sizes, length-weight relationship, and the Fulton's condition factor (K) of the species were determined and spatial comparisons performed using F-test (One-way ANOVA). Correlation analysis, testing the association of

physicochemical parameters with the observed relative abundance, mean sizes and condition factor was done. Levels of significance were at  $p < 0.05$ . Results show that spatial variations in relative abundance, mean sizes and condition factor variables of the *O. niloticus* were significant. Water temperature, dissolved oxygen, and conductivity had insignificant variations ( $p > 0.05$ ), while depth and pH levels significantly varied among the site ( $p < 0.05$ ). Abundance had weak positive correlation with depth levels ( $r^2 = 0.149$ ) and dissolved oxygen ( $r^2 = 0.194$ ). Depth also had strong positive correlation with mean sizes ( $r^2 = 0.619$ ), but weak negative ( $r^2 = -0.228$ ) with condition factor. Variations of pH had moderately weak negative correlation ( $r^2 = -0.310$ ) with condition factor values. Management implications of these findings for the fishery of Lake Naivasha are discussed and recommendations provided.

**MUNGAI, DANIEL**

**ORAL**

### **Modelling the impacts of fishing on trophic interactions in Lake Victoria using ecotroph and ecospace**

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Ecotroph(ET) is a model articulated around the idea that ecosystems can be structured as flows of biomass from low to higher trophic levels. It views ecosystems as systems of energy transfer from one phase to the next. Through ET, energy flows from lower to higher trophic levels through ontogenic and predatory processes. This idea that species disappear behind the trophic levels is seen as the ultimate stage in trophic structuring of aquatic ecosystems. Lake Victoria is an important inland aquatic resource and has in the recent past faced overexploitation and degradation of its resources. Overfishing, the main factor for the decline, should be examined with keen interest. It is therefore the objective of this proposed study to determine impacts of fishing on the Lake Victoria ecosystem. The ET in this study will derive its data from an Ecopath model created for Lake Victoria and use it to create a trophic spectrum that will be used to simulate different fishing scenarios and their impacts on trophic interactions. The model will be used to simulate changes in fishing pressure, providing estimates of trophic spectra for the virgin state of the ecosystem, as well as assess the current state of this ecosystem. In particular, the model will identify which trophic classes are currently under-, fully- or over-exploited. It will quantify the effect of fishing on biomass or catch mean trophic level. Data will be collected over April and May, courtesy of Kenya Marine and Fisheries Research Institute fishing expeditions in Lake Victoria to validate the model. Model output will be compared with corresponding data sets to check whether simulations are able to preserve both trends and magnitude using Pearson's correlation and modelling efficiency (E). By August the model will be fully functional and thus appropriate for this conference.

**MUNGUTI, JONATHAN**

**ORAL**

### **Fish feeds and cage farming in Lake Victoria: feed management practices, challenges and opportunities**

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Fish feeds contribute to over 50% of the total operational costs of any fish farming venture. Since feed quality and management practices significantly impact the economic performance of production systems, adopting appropriate feed management strategies is instrumental in maximizing returns from aquaculture. For fish farmers to actualize high profit margins, they must have access to well-balanced and cost-effective feeds, coupled with optimal on-farm feed management practices. Unlike feed management in inland culture systems such as ponds and tanks, feeding fish in cages in a lake set-up directly or indirectly leads to nutrients loading in the natural ecosystem, which negatively affects the water quality. To sustain the fast growth of cage culture in Lake Victoria, they must be suitably sited and farmers must have access to quality fingerlings, high quality floating feeds with good bioavailability. The Kenyan fish feed industry has been boosted with the development of fish feed standards for tilapia, catfish, and trout by the Kenya Marine and Fisheries Research Institute (KMFRI) in collaboration with the Kenya Bureau of Standards (KEBS), in order to ensure quality fish feeds for all farmers. Previously, small-scale semi-commercial feed manufacturers produced much of the aqua feeds used

in Kenya but there has recently been an establishment of three specialized commercial fish feed producers markets in Kenya and the Eastern Africa region.

Challenges facing the feed sector include inadequate access to finance; limited knowledge on feed formulation and processing; and poor feed handling and storage techniques. The government should frequently carry out spot checks on feeds supplied to agrovet sales outlets to ascertain its quality through a regular and routine surveillance by KEBS. Fish farmers require training on feed formulation, transportation, and storage to maintain a constant supply, quality, and good management practices, and to save on feed costs.

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**MUSA, SAFINA**

**ORAL**

### **Evidence of organic enrichment of bottom sediment quality from cage culture in a eutrophic lake**

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Organic loading on watersheds and sediments is one of the primary environmental impacts of aquaculture. Environmentally sustainable aquaculture requires a sound understanding of the impact of organic matter from aquaculture on the sediments and its impact on the ecology of the waterbody. We assessed the impact of organic matter from cage culture on the sediment of Lake Victoria, Kenya using cages near Anyanga beach in Siaya County from October 2018 to March 2019. Four locations were surveyed for sediment physicochemical characteristics and macrobenthos: 0 m, 50 m, 150 m and 1000 m (as control site) away from cages. The average total organic carbon (TOC), total nitrogen (TN) and total phosphorus (TP) levels at the fish cage stations were 5.8, 3.1, and 11.3 times higher than those at control site, respectively. The N:P molar ratio reduced from 2.3 at the control site to 0.6 at the fish cage stations, indicative of increased load of TP from fish feeds. High biological oxygen demand (BOD, > 10 mg g<sup>-1</sup>) was found in close vicinity to the cages at the end of the culture period — a very sensitive indicator of ecological footprint. Shannon diversity indices exhibited a declining tendency at the cages in relation to the control site, indicating a negative impact of aquaculture on natural biodiversity. Faunal diversity was negatively correlated ( $r = 0.054$ ;  $p = 0.84$ ) with nutrient levels at the cage stations, reflecting the adverse impacts of nutrient enrichment derived from fish farming activities on the benthic assemblages in the lake. With the mushrooming of cages in the lake and with potential in other lakes, there is a need for development of regulations to guide fish feed usage and a need for capacity building of cage farmers on organic enrichment.

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**MUSINGUZI, LABAN**

**ORAL**

### **Open data sharing opportunities for conservation of freshwater biodiversity in Africa: lessons from biodiversity informatics projects in Uganda**

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Freshwater biodiversity is more threatened in Africa than anywhere else apart from Asia. Apparently, the threats are intensifying because freshwater biodiversity and dependent ecosystem services are overlooked in policies due to limited awareness by the public and decision makers. The limited awareness is associated with inaccessibility to user-friendly freshwater biodiversity data and information. Elsewhere, increased access to freshwater biodiversity information has been shown to facilitate conservation planning thereby mitigating threats to aquatic biodiversity and ecosystem services. Here, we seek to share (1) experiences of biodiversity informatics projects in Uganda that are mobilizing existing freshwater biodiversity data and making it publicly available through online data repositories, including how to change perceptions of data holders to embrace open data sharing, and (2) opportunities that the mobilized user-friendly data could offer for freshwater biodiversity conservation. Mobilized freshwater biodiversity data has facilitated wider access to data in user friendly formats, provided baseline data and trends in aquatic ecosystems previously thought to have no baseline information, and is applicable in ways that enhance conservation. These applications that were previously

limited by inadequate data include knowledge of localities of threatened species, designating key biodiversity areas, and assessing conservation status of previously data deficient and un-evaluated fish species. More importantly, the data is useful for raising awareness among the public and decision makers to support decision making.

**MUTIE, ALICE**

**ORAL**

**Comparative study of *Oreochromis niloticus* (Linnaeus, 1758) and water quality conditions of adjoined freshwater and alkaline lakes: Lakes Naivasha and Oloidien**

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There are concerns on the sustainable management of the Lakes Naivasha and Oloidien ecosystems and the need for best practices in efforts towards development of decision tools for better ecosystem management. Nile tilapia (*Oreochromis niloticus*) is a recent re-introduction in Lake Naivasha and is one of the fish species that has crossed into Lake Oloidien. This research aimed at assessing and comparing the population characteristic of *Oreochromis niloticus* under different physicochemical conditions. Selected water quality parameters were sampled in the years 2017 and 2018. Fisheries data was from catch survey, conducted in 2017 and 2018. From the selected physicochemical parameters determined, conductivity had the highest variation from the two lakes. Oloidien's highest value was  $2916 \pm 11.30 \mu\text{S cm}^{-1}$  in the year 2017 and a high of  $282.33 \pm 4.33 \mu\text{S cm}^{-1}$  in the year 2018 for Naivasha. Size ranges of the fish sampled varied widely between the two study areas. Mean values for total length (TL) were  $19.1 \pm 1.8 \text{ cm}$  and  $23.6 \pm 2.9 \text{ cm}$  for Lake Oloidien and Main Lake respectively. Similarly, mean weight of *O. niloticus* was  $129.3 \pm 37.8 \text{ g}$  for Lake Oloidien and  $260.9 \pm 81.0 \text{ g}$  from the main lake. Length-weight relationship analysis showed a negative allometric growth ( $b = 2.526$ ) for *O. niloticus* population in Oloidien compared to the insignificant negative allometric growth ( $b = 2.983$ ;  $p > 0.05$ ), observed in Lake Naivasha. Condition factor (Kn) values were slightly lower in samples of *O. niloticus* samples taken from L. Oloidien compared to those from the main Lake; Kn values were  $1.89 \pm 0.23$  and  $1.90 \pm 0.31$  for Oloidien and main Lake respectively. Differences between the two lakes in length-weight relationship and condition factor may be attributed to difference in habitat conditions.

**MWALUMA, JAMES**

**ORAL**

**Growth and survival of mud crab, *Scylla serrata*, reared in two culture systems within Mida Creek mangroves, coastal Kenya**

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The growth and survival rates for mixed-sex mud crabs was investigated for a period of 230 days using bottom and floating cages, and two feed types in a crab fattening experiment. Crabs attained harvestable weight by the third month for both floating ( $542.2 \pm 109.3 \text{ g}$ ) and bottom cages ( $466.2 \pm 137 \text{ g}$ ). There was no significant difference in mean total weight of mixed-sex crabs in the two culture systems ( $t = 1.75$ ,  $p > 0.05$ ), however males showed significantly higher total weight gain compared to females. A higher overall survival rate was found for crabs cultured in floating cages (63.8%), compared to bottom cages (44.9%). There was no significant difference in growth performance between crabs fed gastropod tissues and those fed fish offal. The long-term specific growth rate for floating cages (0.92 g/d) was not significantly different from that of bottom cages (0.69 g/d). An analysis of potential return on investment showed the floating cages to be more profitable per production cycle compared to the bottom ones. The floating cage system and mono-sex male crab culture are recommended to farmers within mangrove tidal flats in Kenya.

**Spatial trends of cadmium and zinc concentrations in water and enrichments in surficial sediments within Nyanza gulf of Lake Victoria (Kenya)****Mwamburi, J.**

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Metal pollution is still a significant environmental problem in lake ecosystems. The study evaluated the spatial trends in cadmium and zinc concentrations in surface water, un-fractionated and the <63  $\mu\text{m}$  grain size fraction (silt and clay) of surficial sediments within Nyanza gulf, from lake monitoring stations in 2010 and 2012 surveys. Significantly higher Zn total concentrations were found in surface lake water compared to earlier surveys, but cadmium levels were low and not detectable as in previous studies. Variable contents of Zn and Cd were found in un-fractionated and finer sediment fractions. Much higher sediment Cd contents were found in 2010 compared to other surveys. Major areas under river and urban influences recorded much higher sediment Cd contents than offshore sediments. However, there were no significant differences between Cd and Zn contents between gulf and main lake zones. Cd sediment enrichment factors were highly variable compared to Zn, which showed a more uniform trend in most of the gulf areas, but Cd sediment enrichment factors appear to increase when compared to previous data. The spatial distribution of Cd and Zn in the surficial sediments show unpolluted to moderate pollution levels, according to geo-accumulation index. Only 4% of Zn samples exceeded the sediment quality threshold effect concentration (TEC) values, but all were below the mid range effect values. Cadmium is a recognized toxicant and there are potential ecological concerns regarding the variable sediment Cd contents since it has been found previously in bioavailable forms in surficial sediments and 2% of the samples contained Cd (un-fractionated sediment) above the threshold effect concentration during the 2012 survey compared to 51% in 2010, but none exceeded the severe effect levels. Continuous monitoring of priority heavy metals is of relevance to the understanding of potential longterm ecological impacts to the lake ecosystem.

**Barriers to genetic connectivity of the smooth flat sedge (*Cyperus laevigatus*) among alkaline saline lakes of the Eastern Rift Valley, Kenya****Mwaniki, P.,<sup>1\*</sup> Terer, T.,<sup>1</sup> Sierens, T.,<sup>2</sup> Ludwig, T.<sup>2</sup>**<sup>1</sup>National Museums of Kenya, Kenya<sup>2</sup>Vrije Universiteit Brussel, Belgium

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The saline-alkaline Rift Valley lakes of Kenya are isolated habitats supporting emergent halophytes on the shorelines. *Cyperus laevigatus* L. (Smooth flatsedge) is common to these endorheic lakes, suggesting connectivity over long distances. The main objective of this study was to assess the amount and pattern of genetic diversity in *C. laevigatus* populations in wetlands and along shorelines of lakes of the Eastern Rift Valley in Kenya. The clonal, allelic and gene diversity, population genetic structure and fine-scaled spatial genetic structure were assessed on 204 *C. laevigatus* individuals from nine populations, using 13 newly-developed microsatellites. *Cyperus laevigatus* populations maintained high levels of clonal and allelic diversity, though with significant within-population inbreeding. No or only restricted local clonal growth over a few metres could be found along shorelines of most lakes. A fine-scaled spatial genetic structure was revealed on sheltered populations, indicating contemporary local dispersal from repeated seedling recruitment. Significant differentiation and isolation-by-distance were observed, supporting a stepping-stone model. A north-to-south gradient, as revealed from pairwise FST, PCoA, Structure and a Barrier analysis, included barriers between some lakes, with Lake Magadi fully separated. Bayesian clustering of individuals revealed a gene pool corresponding to the Great Nakuru-Elementaita basin. Historical hydrological connectivity during the Holocene as well as geographical distances between Rift Valley lakes were proposed as major driving forces explaining the contemporary genetic structure.

**Eutrophication: Sources and drivers of nutrient loading on estuarine and coastal waters of Kenya****Mwaura, J.,\* Kamau, J., Karisa, J., Kilonzo, J.**

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Globally, increased anthropogenic nutrients generally enter into nearshore marine environments unnoticed and infrequently measured, especially in locations close to growing urban and tourism centers. The cumulative effects of global change, including climate change, increased population, and more intense industrialization and agribusiness, will likely continue and intensify the course of eutrophication in estuarine and coastal waters. As result, the symptoms of eutrophication, such as reduced water quality and loss of habitat, and its extent in coastal waters will increase. Kenya's fringing coral reefs can be affected locally by wastewater and land runoff, and regionally by polluted river flows, but the knowledge of the precise source(s) and extent of its influence on coastal ecosystems remains poor. Seasonal effects of these inputs on water column nutrients, benthic community and on chemical composition of algal bioassay were investigated on nearshore reefs adjacent to a variety of potential, land-based nutrient sources along Kenyan coast. Although dissolved nutrient (DIN) in water column showed inconsistent patterns across and among the reefs, concentrations of stable nitrogen isotope ratio ( $\delta^{15}\text{N}$ ) and N contents in macrophytes were detected greatest in locations close to urbanized center, with higher population density, followed by sites adjacent to a seasonal river and least in locations with low population density. Further, the study revealed a clear and consistent spatial gradient of  $\delta^{15}\text{N}$  and N content values from natural macroalgae and uptake-experiment using *Ulva* spp., and declined with distance from the shores; essentially detecting the source of sewage-derived N. These findings illustrate the usefulness of employing stable isotope approaches than standard water column nutrient analysis alone in detecting nutrient pollution sources and spatial impact, and can assist managers to warrant investment in land-sea/or lakes planning and management of interventions.

**Ecosystem models of Lake Victoria (East Africa): Can Ecopath with Ecosim and Atlantis predict similar policy outcomes?****Natugonza, V.**

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Ecosystem simulation models are valuable quantitative decision tools for supporting ecosystem-based fisheries management. However, use of ecosystem models in fisheries management is still undermined by lack of simple procedures to test effect of model uncertainty on policy outcomes. The use of multiple, complementary ecosystem models is presently being promoted as "insurance" against increased uncertainty emanating from modelling complex systems. This calls for investigations to ascertain whether models with different structure can give consistent policy evaluations. We compared two structurally-distinct ecosystem models, Ecopath with Ecosim (EwE) and Atlantis, for Lake Victoria (East Africa) using fishing scenarios and ecosystem-based indicators. We compared model behaviour at ecosystem level, and at the level of functional groups. At functional group level, we posed two questions: 1) what is the change in biomass of targeted groups ("single-species effects")?; and 2) what are the consequent effects of changes in target groups on non-target groups ("multi-species effects")? Results showed qualitative similarities (direction of change) for both single- and multi-species effects, but the sensitivity of indicators to fishing pressure varied substantially across models. We conclude that EwE and Atlantis have the capacity to provide consistent qualitative advice, which can support strategic management decisions, even when quantitative results differ. Consistency in model setup (especially representation of functional groups and feeding interactions) can minimise variations in predictions due to model structure. The importance of this work is in identifying areas where model considerations and assumptions lead to varying predictions, which subsequently can be used in standardizing models to maximize equivalence of outcomes.

**Use of Kenyan produced Artemia for improved feed quality and increased fish production from aquaculture****Ngarari, M.,\* Opiyo, M., Nyonje, B., Mirera, D.**

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The Kenya Economic Survey report of 2018 shows that fish production from both freshwater and marine sources declined by 9.5 and 3.7% respectively in the year 2017. Fish farming is thus the best option to bridge the gap created by the decline. For aquaculture to thrive, survival of fish fry has to improve. This is dependent on the choice or lack of live feeds used. The culture of fish fry is highly dependent on live feeds (Faruque et al., 2010) in their early life stages. Live feeds suitable for fish fry include Artemia and rotifers, among other small organisms. Artemia has proven to be the most convenient of the live feeds since its cysts can be stored for many years in airtight cans and hatched 24 hours prior to the feeding time of the hatched fry. Aquaculture is being targeted to contribute effectively to the “big four” agenda on food security, hence the increased demand for a good amount of healthy fish larvae. Subsequently the demand for Artemia cysts has increased. In Kenya, hatchery managers import shell-free artemia (SFA) outside the African continent at a high cost despite the fact that Artemia exists in Kenyan salt farms. Reports from many fish hatchery managers indicate that despite SFA being a good source of animal protein it is quite costly and uneconomical for the aquaculture industry, which is in its infancy. In this study, growth and survival rates of *Clarias gariepinus* fry that have been fed on SFA, Great Salt Lake (GSL) Artemia and Kenyan-produced Artemia spearheaded by KMFRI were assessed. The results of the study indicate that the Kenyan-produced Artemia, which are much cheaper, constitute an alternative to the imported Artemia. The ability to increase farmed fish in Kenya is thus guaranteed.

**Kenya marine fisheries: Is it the next frontier for economic growth?****Njiru, J.,<sup>1\*</sup> Kimani, E.,<sup>1</sup> Omukoto, J.,<sup>1</sup> Aura, C.,<sup>1</sup> Van der Knaap, M.<sup>2</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Kenya<sup>2</sup>FAO regional office, Accra, Ghana; Netherlands

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Kenya's total fisheries production peaked in 2006 with a total production of 1 million mt attributed mainly to boom of introduced Nile perch. This production has since reduced to 160 000 mt in 2017 with inland capture fisheries contributing about 83%, aquaculture 12%, and marine artisanal fisheries 5%. The fishery provides employment to about 2 million people, and accounts for 0.8 % of National GDP. Lake Victoria that contributes up to 90% of capture fish production has shown catches decline in the recent past, and the trend indicates that the fishery may not be sustainable.

Aquaculture production barely exceeds 20 000 mt.

The Kenya Exclusive Economic Zone (EEZ) of 142,000 km<sup>2</sup> and an extended EEZ of 103 000 km<sup>2</sup> constitutes about 42% of the country's landmass and has several commercially important species that are barely exploited. Marine fisheries currently produce a paltry 26,000 mt annually that is estimated at about Ksh 5 billion (500 million USD). However, recent estimates have found that Kenya EEZ contains up to 2 million mt tons of fish that was valued at about Ksh 130 billion (USD 1.3 billion). Full exploitation would see further, additional worth along the value chain and a substantial trickle down effects with positive impact on the blue growth in Kenya. This makes marine fishery potentially the most valuable fishery in Kenya with the potential of contributing up to 10% of the GDP if sustainably exploited. The paper traces the history of fisheries production in fresh waters, aquaculture and marine systems in Kenya and emphasises the potential of marine fisheries.

### Emerging frontiers for blue growth in African Great Lakes: The potential for recreational fishing industry in Lake Victoria

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The fishing industry in Lake Victoria provides employment opportunities to over 220,000 people directly involved in fishing, with approximately 43,799 fishers in Kenya representing the largest fishery in the country (about 90%). Declining stocks call for diversification of the fishing industry from commercial and subsistence fishing to recreational fishing in order to promote sport fishing in the region and environmental conservation. The lake's biodiversity is well documented and forms the basis for this shift whose potential remains under exploited in the region. Recreational fishing offers economic opportunities in the designing, manufacture and selling of fishing gears and boats providing the local communities as an alternative source of income while opening up opportunities in exploration of marine life beyond consumption and trade. Economic benefits accrued from recreational fishing include income generated at local, regional, and national levels in fishing expenditure-dependent commercial activities. Blue opportunities associated with recreational fishing include the fish bait industry, regional business trade fairs, ornamental fish industry, angling tourism, spur in hospitality industry, boat hire services/ charter boat trips, and investment in passenger transport services across Lake Victoria. Whilst recreational fishing offers a new frontier in Blue growth, there is a need for a balance in policy, people, and science in order to harness the sector's resources and guide its development in inland waters.

### The genesis of Lake Victoria degradation: Will cage culture redeem its image?

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Lake Victoria, the second largest freshwater body globally is rich in biodiversity but one of the world's hot spots in biodiversity loss. The current state of the lake has been attributed to overfishing, invasive species, pollution, and climate change. The fishery, which is the main economic activity supporting over 40 million people, is at the crossroads. In order to boost fish production, cage culture has been embraced and this raises serious concerns as to whether it will offer a sustainable solution to the lake's fishery. The current study aimed at assessing the genesis of Lake Victoria's degradation and determines whether cage culture can offer a solution to the current situation. Literature, (i.e. both primary and secondary data) was reviewed. The degradation of the lake can be traced back from the 1930s to the 1950s, when the fishery declined and changes in zooplankton communities were experienced. The Nile perch, *Lates niloticus* was as a result introduced in early 1950s to replenish the fishery but its ecological impacts were felt in the 1980s when the haplochromines started to disappear. However, the ecological effects became complex with eutrophication when in the early 1990s water hyacinth was spotted in the lake. Since then, the situation has been dire. The introduction of cage culture aimed at increasing fish production has complicated the situation even further, through an excess of nutrients. The number of cages has increased tremendously (over 4000), with 10% of introduced feeds being utilized. Whereas fish production may increase in the short run, sustainability is not guaranteed especially with the wild fishery due to eutrophication, thus compromising the livelihoods of the majority. This study highlights the need for the



adoption of a clear policy framework on the adoption of cage culture but recommends that for the meantime it should be stopped.

**NYAMORA, JANE**

**ORAL**

### **An analysis of institutional, legal and policy frameworks on the management of aquatic resources in Kenya: Challenges**

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The major concerns related to the environmental integrity of aquatic resources worldwide are associated with three types of threats; habitat destruction, pollution, and weak governance structures. This paper analyzes institutional, legal, and policy frameworks in Kenya by reviewing relevant literature for the purpose of providing a way forward on the management of aquatic resources. Major governance weaknesses impinging on the aquatic resources of Kenya have been identified and include policy and legislative inadequacies, limited institutional capacities, inadequate awareness, inadequate financial resources and mechanisms, and poor knowledge management. There is also insufficient updating, implementation, enforcement, and monitoring of existing legislations. Despite Kenya being a signatory to many international and regional instruments, there is inadequate domestication of relevant international commitment and obligations into national laws. With regard to limited institutional capacities, there is apparent lack of mechanisms for effective coordination and inter-sectorial governance among the institutions involved in the governance of the aquatic environment in the country. Also there is inadequacy of human and technical resources and capacity in institutions charged with responsibilities over the management of aquatic resources in Kenya. Finally, it is apparent that there is poor knowledge management concerning aquatic resource issues in the country, including inadequate scientific and socio-economic data to support policy making, monitoring, and enforcement. We therefore recommend that institutions involved in the management of aquatic resources seek and develop a cooperative and synergistic mechanisms in the management of aquatic resources in the country. Second, there is a need to update, implement, enforce, and monitor the existing legislations for effective management of aquatic resources. Third, the government must ensure that all international commitment and obligations are ratified into national laws. Finally, there is a need for institutional capacity building.

**NYAMWEYA, CHRISPINE**

**ORAL**

### **Bounties of Lake Victoria: A case for blue economic investment**

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Located in East Africa, Lake Victoria is iconic in both its size and function. With a surface area of approximately 68,000 km<sup>2</sup>, it is the largest freshwater lake in the tropics and second in the world. The lake is of immense ecological and socio-economic significance for the riparian communities. Whether it is for food, transportation, water for domestic and industrial uses, recreation or regulation of climate, aquatic ecosystems, it has always been an integral part of the survival and wellbeing of lake-edge communities. To underscore its importance, the lake's fisheries annual catch of close to 1 million tons accounts for about 1% and 8% of the world's total and inland capture landings respectively. Herein, we decouple and quantify the various ecosystem services offered by the lake. We bring to the fore the true contribution of the lake to the wellbeing of the region that has largely been taken for granted. This is especially worth attention in the backdrop of human-induced pressures such as overfishing, introduction of alien species, increased eutrophication, and climate change impacts that threaten the sustainability of the lake's ecosystem services. Diversification of investments to unexploited niches of the resource and value-addition opportunities for potential blue economic growth are highlighted.

**Bio-economic modeling of fishing of a Ramsar lake: The case of Lake Naivasha, Kenya****Obegi, B.,\* Boera, P., Waithaka, E., Mutie, A., Morara, G.**

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Lake Naivasha fishery has long been one of the best-known sources of protein for the community. Approximately 2,000 people directly depend on fishing in Naivasha. The lake has been managed using a number of policies put in place since 2001. The ultimate aim of this study was to explore Lake Naivasha's fishing cost of production, revenues, and role of management. The study was conducted by collecting data on fish landings and prices commencing from 1980–2017 from four beaches from the fisheries department which keeps records on daily basis. Consequently to the main aim, the study sought to determine the total costs of fishing along with generated total revenues. Findings derived from the study spell out that total costs of production were higher than the total revenues. With the number of boats and vessels increasing from 26 in 1980 to 50 in 2013, fishing boats and vessels increased drastically to 176 in 2016. The increasing number of boats was found to affect fish stock as it adversely impacted on brooders. Data analysis was done using Excel spreadsheets and the Gordon-Schaefer's model. A regression model was run to develop graphs that explain the relationship between total costs, total revenues, harvests, and number of boats. Information gathered will inform decision on resource economics and management of Lake Naivasha.

**Advancing Africa's Great Lakes research and academic potential: A call for harmonized, long-term, collaborative networks and partnerships****Obiero, K.,<sup>1\*</sup> Lawrence, T.,<sup>2</sup> Ives, J.,<sup>2</sup> Njaya, F.,<sup>3</sup> Kayanda, R.,<sup>4</sup> Hecky, R.<sup>5</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Kenya<sup>2</sup>African Center for Aquatic Research and Education, USA<sup>3</sup>Department of Fisheries, Malawi<sup>4</sup>Lake Victoria Fisheries Organization, Uganda<sup>5</sup>Large Lakes Observatory, University of Minnesota, Duluth, USA

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The African Great Lakes (AGL) are known for their rich fisheries and as "biodiversity hotspots" with spectacular endemic fish faunas. The biodiversity and natural resources of the AGL, together with the ecosystem services they provide, underpin the welfare and livelihoods of over 50 million people in 11 countries. Despite the recognized importance of the AGL, these vital ecosystems and their livelihood support systems are threatened by numerous anthropogenic stressors at local, regional and global scales. Despite well-meaning attempts, research on the AGL has been plagued by parochial, short-term research leading to inconsistent and incomparable datasets that hinder evidence-based policy formulation and implementation. Over the past two decades, several international workshops, conferences and publications have identified the need for collaboration, knowledge sharing, and harmonization of research and management as key elements to enhance AGL conservation efforts. In this commentary, we introduce the African Center for Aquatic Research and Education (ACARE) that aims to build on ongoing calls to bring together multidisciplinary researchers in the AGL to collaborate on research, inform policy, train and support undergraduates and postgraduates and create a platform for research dissemination. We propose three major strategies to be coordinated by ACARE: (1) Strengthen global, regional partnership, and collaborative networks to bring together the vast existing knowledge on freshwater resources; (2) Establish long-term transboundary and inter-jurisdictional lake advisory groups to harmonize and promote joint multi-lakes research monitoring projects; and, (3) Expand and develop comprehensive education and training programs to produce the next generation of freshwater researchers, policymakers, and practitioners.

**The effect of situation analysis practices on implementation of poverty alleviation mariculture projects in the coast of Kenya****Ochiewo, J.,<sup>1\*</sup> Sakwa, M.,<sup>2</sup> Wakibia, J.,<sup>2</sup> Munyi, F.,<sup>1</sup> Owiti, H.,<sup>1</sup> Waiyaki, E.<sup>1</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Kenya<sup>2</sup>Jomo Kenyatta University of Agriculture and Technology, Kenya

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This research was carried out in Kwale, Mombasa, and Kilifi counties in the coast of Kenya. The general objective of the research was to assess the effects of adherence to situation analysis practices on implementation of mariculture projects in Kenya. The specific objectives were to examine the effect of stakeholder analysis on implementation of poverty alleviation mariculture projects, establish the effect of problem analysis on implementation of mariculture projects, and determine the effect of needs assessment on implementation of poverty alleviation mariculture projects. The research was based on quantitative research approach involving the application of survey method with a cross sectional design. Factor analysis, Pearson correlation analysis and regression analysis were conducted. Results showed that the mariculture projects in Kenya are dominated by female actors compared to male actors. Those involved in mariculture had a mean age of 40 years and had attained primary level of education. Factor analysis revealed that degree of success and degree to which the mariculture projects have addressed their objective of poverty alleviation were the most important measures of project implementation. Stakeholder analysis emerged to have the strongest influence on implementation of mariculture projects. Being the single most significant factor influencing mariculture project implementation, stakeholder analysis should be undertaken at the situation analysis stage so that it informs project design. It was concluded that improvements in situation analysis practices brought about by improvements in stakeholder analysis would address poverty among coastal fisher communities by improving implementation of poverty alleviation mariculture projects.

**Enhancing the value of small fish species for food and nutrition security through improved drying and packaging****Odoli, C.,\* Aura, C., Nyamweya, C., Njiru, J.**

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Small pelagic fish species significantly contribute to nutrition and food security, especially for poor populations in Kenya. The silver cyprinid, *Rastrineobola argentea* (Omena) is one of the most important commercial fisheries of Lake Victoria accounting for more than 50% of fish landed in Kenya. The fishery is however, characterized by high post-harvest losses, and products are often of low quality, restricting the sales to low-income groups and impeding the sector's contribution to the national gross domestic product (GDP). This study aimed at improving the quality of dried small fish and determines the marketing potential of improved dried and packaged small fish as new products where habitually dried small fish are commonly found. The influence of drying, fat level, and packaging methods on lipid degradation, sensory properties and microbial quality of dried small fish products during storage was assessed, as well as the marketing potential of small fish species dried under more hygienic conditions. Drying under controlled conditions improved the fish quality, and when atmospheric oxygen was excluded by vacuum packaging, dried fish became more stable during storage with less lipid degradation, less rancid odor and lower counts of microbes. High fat content in fish slowed down drying thereby increasing the drying time, but at the same time it offered protection against conformational changes in proteins during drying. The new dried small fish products obtained high acceptability ratings, indicating there is market potential for improved dried Omena among consumers of traditional dried small fish as well as middle income groups who demand high quality products. The results from this study show that well processed and packaged dried small fish can be highly nutritious and could contribute to food and nutrition security as well as advance the blue economy's contribution to GDP.

### How to beat a bully: New biocontrol agents and novel remote sensing applications in the fight to suppress water hyacinth

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Floating weeds are a navigational hazard, they reduce water quality and water quantity, and with a wet weight of 450 tonnes per hectare they can and do damage infrastructure, harbour disease, and carry negative implications for a wide variety of ecosystem services. The worst floating weed is water hyacinth (*Eichornia crassipes*), whose impact on Lake Victoria has been devastating. Existing weed control measures are hugely expensive. While the plants are virtually impossible to eradicate, suppression and containment make sense economically; in Louisiana USA, between 1975 and 2013 \$124 million was spent on control, with a benefit estimated at \$4.2 billion, giving a cost:benefit ratio of 1:34. Biocontrol agents are relatively inexpensive and at Lake Victoria have a significant effect in suppressing water hyacinth. However, the weed remains at nuisance levels and further suppression is required. A broad-ranging strategy is likely to be required, involving reducing eutrophication and suppressing the weed population.

Here we consider the future options for control of water hyacinth at Lake Victoria. We concentrate on the use of additional biocontrol agents at Lake Victoria. There have been a number of additional insects identified with high host specificity and here we review their suitability for deployment at Lake Victoria. *Ecritotarsus catarinensis* (Carvalho) (Hemiptera: Miridae), *Niphograpta albiguttalis* (Warren) (Lepidoptera: Pyralidae) and *Megamelus scutellaris* Berg (Hemiptera: Delphacidae).

Identifying and testing candidate control agents on their own is insufficient. A careful strategy is required if the weed is to be suppressed as effectively as possible. In addition to the widespread suppression of the plant it is critical that refugia and source populations around the lake's margins be heavily targeted. We review the potential of Sentinel-1 SAR and Sentinel-2 MSI data to help identify these key locations.

### The ornamental fish trade: Enhancing opportunities towards blue economy growth in Africa

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The global trade in ornamental fish provides employment opportunities for employment and revenue generation in developing countries across the globe. Due to the high value to volume ratio, the industry ranks among the frontiers in renewable resources that can enhance Blue Economy growth. According to FAO statistics, the trade has grown immensely into a multi-million dollar industry over the last two decades, valued at an estimated USD 372 million. This has been fuelled by technological advancements which have enabled improved handling practices and targeting on new species. Over 2 500 species of fish are currently traded with over 60% originating from freshwaters. The freshwater species constitute about 85% of the global market by value. About 90% of the freshwater species are bred in captivity, in contrast to about 98% of marine species which are collected from the wild.

The value of Africa's ornamental trade indicate is estimated at about 2.2% of the global market value (USD 7.6 million), varying at different levels of intensity and development among countries. African countries exporting both freshwater and marine fish include Kenya, Nigeria, and South Africa. This study provides a general overview of the industry and highlights the national and regional efforts to explore avenues for stimulating growth across the continent. The study further highlights the major impacts and constraints limiting expansion and long-term sustainability. Recommendations focus on the important role of research in increasing knowledge and steering industry in addition to capacity building, strengthening policy and governance structures as well as encouraging public-private partnerships to enhance competitiveness and access new markets towards enhancing opportunities for Blue Economy growth.

### Gains from implementation of a fishery observer programme: Lessons from coastal and marine fisheries in Kenya

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The marine fishery sector is important to the economy of Kenya and the coastal region by contributing to employment, food security, and income generation through local and export markets. The Observer programme is responsible for providing training and technical support necessary for deploying observers on fishing vessels to collect independent fishery information essential to achieving set fishery management objectives. This study was carried out to review the gains made in implementing a fishery observer programme in coastal Kenya. The requirement to have fishery observers on board commercial fishing vessels is enshrined in the Fisheries Management and Development Act, 2016, Article 147. Results indicate that since its inception in 2016, the scientific observer programme achieved 39 deployments summarized as 26, 9 and 4 for shallow water-trawl fishery, deep-water trawl trials and longline fishery respectively. Gains from the programme included various learning by the observers on designated protocols to collect basic fisheries data, catch composition and biological data using developed observer data collection forms, data field guide and manual; generation of useful spatial, fisheries catch, effort and biological data that was collated, analyzed and used to produce technical reports, publications and other information materials such as information sheets and policy briefs to inform government, stakeholders and the fishing industry on the status of the fishery; and providing recommendations for management. Data and information collected under the programme provides basis for the review of fishery management strategies and plans through identifying effects of fishing on the target and non-target resources as well as the ecosystem. We recommend the establishment of the Observer Board and the full operationalization of Article 147 of the Act among other related articles on observers and continued training of observers and observer programme managers, and incorporation of the National Observer Programme within Great Lakes Fishery towards enhanced blue economy monitoring.

### Drivers-Pressure-State-Impact-Response (DPSIR) Model as an alternative management tool for Lake Baringo

**Nyakeya, K.,<sup>1</sup> Nyamora, J.,<sup>2</sup> Ogendi, G.,<sup>3</sup> Getabu, A.,<sup>3</sup> Omondi, R.,<sup>3</sup> Onchieku, J.,<sup>3\*</sup> Ondiba, R.<sup>4</sup>**

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Lake Baringo is a Ramsar site but because of the myriad challenges (socioeconopolitical and environmental) it faces, it can be described as an ecosystem under perturbation and likely to collapse. Based on literature reviewed, we discuss the suitability and the application of the drivers-pressure-state-impact-response (DPSIR) model in the assessment and monitoring of Lake Baringo Basin (LBB). Past management interventions have focused on co-management of the lake fishery alone, ignoring major drivers of environmental degradation. Whereas co-management has been successful in regulating the fishery (i.e. use of recommended gears, and demarcation and protection of breeding/nursery grounds), little has been achieved in terms of improved catches, recruitment, and growth of for example *Oreochromis niloticus baringoensis* whose existence is threatened to extinction. We report here that other variables are at play that are beyond the control of co-management (Beach Management Units (BMUs)) whose efforts have been rendered dysfunctional. Currently, out of six gazetted BMUs none seems to be active, which calls for management intervention. The DPSIR model has been widely adopted and used in the assessment and monitoring of environmental degradation. It is a conceptual framework characterized by a feedback system of drivers, pressures, states, impacts and responses. We demonstrate how various environmental and socioeconomic factors can be linked to one another by illustrating a causal relationship. Further, we show that in combination with appropriate indicators, the particular components and

their developments can be assessed and managed holistically. It is in view of the above that the DPSIR model can be used to illustrate the effects of anthropogenic activities in LBB in a simplified manner that can be understood, interpreted, and applied by all stakeholders. Hence if incorporated into co-management, it can be a robust tool in the management of LBB, and we recommend DPSIR for management of LBB.

**ONDIBA, ROBERT**

**ORAL**

### **Limnological changes and its implications on the fisheries of Lake Victoria**

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Lake Victoria is the second largest lake in the world, with unique biological diversity both in numbers and endemism. The lake has undergone significant changes since the beginning of the 20th century and is experiencing varied pressures. This review endeavours to provide an update of limnological changes that have occurred in Lake Victoria since the beginning of the 20th century and their impact on the lake's fishery. Studies have shown that deteriorating water quality, destruction and extinction of endemic species and reduced fish catches are some of the notable changes that have emerged as a result of pollution and invasion of alien species. Within a span of the last four decades there has been a notable increase of water temperature, significant reduction of DO levels and increased levels of nitrogen and phosphorous in various parts of the lake. Consequently, the lake is now dominated by cyanobacteria, which were rare in the 60s, as opposed to diatom communities such as *Nitzschia*, *Aulacoseira*, and *Cyclostephanos* spp which comprised between 70% and 99% of algal species. Between 1930 and 1950, calanoids and cladocerans dominated the lake but in the current decade, cyclopoids are dominant. Due to establishment of the water hyacinth, some endemic macrophyte species have declined and some are near extinction, such as *Pistia* spp. and *Azolla* spp. Before the introduction of Nile perch in the 60s, haplochromine fishes were the dominant species of socioeconomic importance. Currently, Nile perch and Nile tilapia are dominant after eliminating endemic fish species such as *Oreochromis variabilis*, *O. esculentus*, and *O. leucostictus* due to algal changes as a result of tropical cascading. In order to save Lake Victoria, there is a need to control pollution and related anthropogenic activities through sustainable management and exploitation.

**ONGORE, COLLINS**

**ORAL**

### **Effectiveness of biocontrol agents (*Neochetina* sp.) on water hyacinth (*Eichhornia crassipes* [Mart.] and implications for ecosystem health restoration in Lake Victoria, Kenya**

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Water hyacinth (*Eichhornia crassipes*), the major invasive weed currently afflicting Lake Victoria, exhibits sporadic invasion episodes with concomitant ecological and economic impacts. Controlled weed populations in the lake have been attributed to resilient biological agents and macrophyte succession. The use of biological agents, *Neochetina bruchii* and *N. eichhorniae*, has been explored albeit with weaknesses in sustaining the weevil rearing and release programs, leaving only the resilient residual seed in the wake of the massive mats. This study aimed at establishing the relationships between the water hyacinth coverage trends and the weevil's biological vigour on the water hyacinth mats, hence the reliability of the bioagent as a control mechanism in the lake. The multi-annual spatial and temporal water hyacinth coverage data generated from spectral satellite imagery, and observations made on assessment of biological vigour of the weed populations at the sheltered hotspots, were used to establish the relationship between the weed and weevil populations. Results of the satellite estimation show that the weed coverage rose since February 2018 peaking at 17,372.62 ha in December 2018 before declining to 7,300 ha in March 2019. The gradual changes in the coverage correspond to the trends in the multiplication of the weevils with significant negative correlations occurring after the nascent phases of the weevil population growth, at all hotspots. The data indicates that the weevils had greatest impact on the

water hyacinth mats within Homa Bay, possibly due to existence of larger populations of remnant weevils within fringe weeds after previous invasions. These observations are indicative of the weevils' effectiveness in controlling the water hyacinth in Lake Victoria, but are constrained by their delayed multiplication following every fresh invasion. We recommend a revamped and sustained weevil rearing and release program alongside other measures targeting reduction of nutrient levels in the lake.

**ONYANGO, DAVID**

**ORAL**

### **Review of the current state of knowledge and the impact of microcystin in fish in Lake Victoria**

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A family of hepatotoxic cyclic peptides from various species of blue-green algae, blue-green algae are widespread in many equatorial eutrophicated lakes including Lake Victoria with microcystin mainly from cyanobacterial blooms released in water causing different effects along the aquatic ecosystem trophic levels. Depending on the length of exposure and the exposure route, microcystin effects may include perturbations to embryonic hatching, decrease in survival and growth rate, change in behavior, osmoregulation, increase in liver activities and heart rate, as well as histopathological effects. However, little is known on the microcystin effect on the fishery and ultimately on the human population, thus forming the basis for the review. The results of the first round of microcystins survey in the Nyanza Gulf of Lake Victoria demonstrated no significant variations ( $p > 0.05$ ;  $F = 0.34$ ) in the sampled sites with varied comparisons of environmental parameters recording significant relationships ( $p < 0.05$ ,  $R^2 > 0.5$ ). Chlorophyll-a ( $R^2 = -10.21$ ): chlorophyll-a measurements had significant correlations at  $p < 0.01$  with TN ( $R^2 = 0.741$ ) and TN/TP ( $R^2 = 0.557$ ). There was a moderate mix of different phytoplankton taxa in the sampled sites in which cyanophytes were the most dominant group, contributing an average of 40 % to the total phytoplankton biovolume. Mbita west open waters had the highest cyanophyte percentage (80%) while Utajo had the lowest (1.23%). Microcystin concentrations measured in Homabay sewage discharge and Mbita East were above the WHO levels (1  $\mu\text{g/L}$ ), with the highest measurement of 21.4  $\mu\text{g/L}$  at Homabay sewage discharge and Mbita East at 13.1  $\mu\text{g/L}$ . Preliminary data from ongoing monitoring indicate cyanobacterial toxin levels at the riparian community shores are above the WHO guidelines for daily intake.

**ONYANGO, HORACE OWITI**

**ORAL**

### **From how many to how much? Economic and financial valuation of Lake Victoria fisheries, Kenya**

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Owing to the challenge of under-estimation of catch and value in official fisheries metrics, this study provided a methodological option to compare, contrast and validate official fisheries statistics in Kenya. We applied a standardized Fishing Business Model (FBM) to reconstruct estimates of economic returns from Lake Victoria fisheries, taking into account fish auto-consumption, post-harvest losses, and landings from illegal gears, which are often missing in the official estimates. Primary data was collected using questionnaires in various fish landing sites in February and March 2018, while secondary data was sourced from latest surveys on fish stocks, catches and fishing effort in the lake. Results indicate that Total annual Fishing Revenue (TFR) per boat was Ksh 7,108,509.01 (USD 71,085.10), with beach seine fishers using Sesse pointed boats supplying the greatest revenue (Ksh 42,255,130.65  $\approx$  USD 422,551.30). Fish auto-consumption and spoilage amounted to Ksh 1,274,244.20 (USD 12,742.44) annually whereas Total Costs (TC) were Ksh 1,056,326 (USD 10,563.26). Sesse flat boats using long lines have the highest operational costs annually (Ksh 3,612,633.70  $\approx$  USD 36,126.34), while Sesse boats using small seines have the highest annual wage for fishermen (Ksh 13,942,098  $\approx$  USD 139,420.98). The annual Gross Operating Income (GOI) was Ksh 6,152,435 (USD 61,524.35) and the Net Profit Margin was 0.2012. Overall, our reconstructed data shows that average annual landings were 3.9 times more,

while value to fishermen was 7 times more than the official estimates. We recommend a review of official fisheries statistics in order to correct undervaluation of Lake Victoria fisheries; adoption of regular economic and financial impact assessments of the Lake; and use of the information supplied in this survey to adjust the management cost recovery and revenue allocation framework by national and county governments in regard to the fisheries subsector.

**ONYANGO, JOEL**

**ORAL**

### **Assessment of grey water footprint for L. Naivasha, Kenya**

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The Grey Water Footprint (GWF) can be used as a tool to allow scientists and managers to address the needs of stakeholders through informed water management decisions despite the critiques. Thus this study aimed to assess and quantify the GWF of L. Naivasha with an attempt of examining pollution loading from the catchment. The GWF and water pollution level (WPL) were calculated for all fractions of nitrogen according to the Kenyan water quality guidelines and standards. The findings indicate that Malewa subcatchment had a higher GWF than the Gilgil subcatchment, but the Gilgil subcatchment had a higher WPL. The highest WPL in either the Gilgil or Malewa catchment was 0.04, indicating that the pollution assimilation capacity was not exceeded in either catchment. In both subcatchments, the area-weighted GWF was generally higher in the lower catchment areas than the upper catchment areas. In previous studies, the GWF of the upper part of the catchment was 5.1 Mm<sup>3</sup> yr<sup>-1</sup> (39%), and the GWF from the commercial farms around the lake was 7.9 Mm<sup>3</sup> yr<sup>-1</sup> (61%). The current study, however, estimated that the combined GWF for the Gilgil and Malewa catchments (1940 km<sup>2</sup>) was significantly smaller at 3.2 Mm<sup>3</sup> yr<sup>-1</sup>. Previous estimator studies have recorded a WPL of 0.06, whereas the highest WPL in this study was 0.04. Although the previous analysis used a different definition of the upper catchment based on spatial data rather than defining the catchment through a hydrological definition, the calculation does provide a baseline. This study concluded that the pollution load was within the pollution assimilation capacity and the environmental flow requirements and determined that nitrate was the critical pollutant. This study recommends that the GWF needs to be applied to a broad range of pollutants within the Lake Naivasha catchment.

**OPIYO, MARY**

**ORAL**

### **Dietary probiotics modulates non-specific immunity and gut microbiota of Nile tilapia (*Oreochromis niloticus*) cultured in low input ponds**

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The use of antimicrobials has become rampant to control diseases and infections in farmed fish worldwide. However, cases of antimicrobial resistance have been reported in aquaculture as a result of uncontrolled usage. To reduce these negative effects, probiotics have been widely used as immunostimulants in fish because of their multiple benefits. However, no studies have been conducted on fish cultured in low-input ponds despite high susceptibility to infectious pathogens in these environments. We studied the effects of commercial probiotics, *Saccharomyces cerevisiae* and *Bacillus subtilis* supplementation on non-specific immunity, gut microbiota and microbiological quality of Nile tilapia (*Oreochromis niloticus*) cultured in low input ponds. *O. niloticus* fingerlings of an average size of 40 g were stocked at 50 fish m<sup>3</sup> in cages in low-input ponds and were fed diets supplemented with *S. cerevisiae*, at 2 g kg<sup>-1</sup> (Diet 1); 4g kg<sup>-1</sup> (Diet 2) and 6g kg<sup>-1</sup> (Diet 3); and *B. subtilis*, at 5g kg<sup>-1</sup> (Diet 4); 10g kg<sup>-1</sup> (Diet 5) and 15g kg<sup>-1</sup> (Diet 6) and Control (Diet 0) for a period of 180 days. Results



indicated that haemato-immunological parameters (haemoglobin (Hb), red blood cells (RBC), white blood cells (WBC) serum protein, albumin, globulin and lysozyme activity) were significantly ( $P < 0.05$ ) higher in probiotic-treated groups than in the control group. However, fish fed on Diet 6 presented significantly similar values to the control ( $P > 0.05$ ) for Hb and globulin. Additionally, fish fed on probiotic-treated diets retained the probiotics in their gut and lower microbial load not important in food safety was realized in their muscle ( $P < 0.05$ ). Therefore, *S. cerevisiae* at dietary levels of  $4\text{g kg}^{-1}$  and *B. subtilis* at  $10\text{g kg}^{-1}$  use in low-input ponds is important in improving immunity, manipulation gut microbiota, and flesh quality for Nile tilapia.

**ORINA, PAUL**

**ORAL**

### **State of cage culture in Lake Victoria, East Africa: A focus on the sustainability, rural economic empowerment and food security**

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Capture fisheries and aquaculture have remained important sources of food, nutrition, income, and livelihoods to millions globally, with annual per capita consumption of fish in developing countries having increased from 5.2 kg in 1961 to 18.8 kg in 2013. In the contrary, low income food-deficit countries annual fish per capita consumption rose from 3.5 to 7.6 kg against 26.8 kg among industrialized countries. Increased demand for animal protein and declining capture fisheries has seen aquaculture grow rapidly than any other food production sector over the past three decades. Rapid global aquaculture growth is directly related to levels of technological advancement, adoption and adaption prompting aquaculture transition from semi-intensive to intensive and super intensive production systems among developing and developed countries. In light of the Blue Economy potential, cage culture in Lake Victoria is fast gaining prominence in aquaculture production contribution. This began with trials by KMFRI and NAFIRRI and later by private investors at Dunga and Obenge beaches of Kenya, SON in Uganda and Bulamba BMUs in Bunda District of Tanzania. However, only Kenya has so far documented cage culture development recording 3,696 cages across the five riparian counties with an estimated production capacity of 3,180 MT valued at Kshs 955.4 Million (9.6 million USD), created over 500 jobs directly and indirectly created income opportunities for over 4,000 people. The sub-sector's value chain, its supportive value chains and associated enterprises are rapidly expanding thus creating jobs, enhancing incomes and ensuring food security in rural and urban areas. As cage culture commercialization takes root, there is an urgent need to address issues such as introduction of alien species, diseases, marine parks, and maximum carrying capacity, among other aspects. This will require trans-boundary policy to ensure sustainable utilization of the lake as a common resource.

**OTIENO, DENNIS**

**ORAL**

### **Impact of industrial wet processing stages on the quantity and quality of Nile perch (*Lates niloticus*) oil extracted from the visceral organs**

**Otieno, D.,\* Nyabokeye, H., Odoli, C., Nyamweya, C., Aura, C.**

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Global fish oil production is between 1 to 1.25 million tonnes, primarily exploiting fatty fish such as menhaden, herring, pilchards, anchovy, and sardines, among others. The main producing countries include Japan, USA, Chile, and Peru. Yet, fish oil from developing countries ends up as biowaste since only the flesh is consumed. This paper discusses a simple approach for utilizing the oil for consumption and as supplements. The visceral organs were collected from the fish filleting factory and markets in Kisumu town and oil was extracted through a modified wet pressing adopted from Blight and Dyer 1959. The effects of temperature and serial washing on the quality and quantity were assessed, with extraction temperature set at  $800^{\circ}\text{C}$ ,  $900^{\circ}\text{C}$ ,  $950^{\circ}\text{C}$ , and  $970^{\circ}\text{C}$ ,

and three serial washings using distilled water. The quality of the oil produced was then determined for omega - 3, vitamin A and E, peroxide value, iodine value and free fatty acids. Results indicate that maximum extraction efficiency was achieved at 80° C for 30 minutes where 156.05 g extracted at 80° C, 155.32 g at 90° C, 155.24 g at 95° C, and 155.23 g at 97° C from tissues of 171.25 g. The data was then analyzed using ANOVA at P<0.05 and post hoc to determine significance. It was concluded that the temperature manipulation procedures as per this project was reliable to produce maximum yield and should be adopted by oil-producing plants.

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**OTIENO, ERICK N.**

**ORAL**

### **Challenges facing small-scale aquaculture farmers in the lake basin: Estimated economic losses owing to predatory birds**

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This study assessed the economic value of pond-fish damage by piscivorous bird and other vertebrate predators across small-scale aquaculture systems in western Kenya and how this impacts local food security. Using a combination of questionnaires and actual field sampling, non-bird predators were characterized for species identity and encounter rates while for piscivorous birds, further detailed surveys were conducted through daily focal scan sampling to record abundance and species richness. Along with farmer questionnaire responses, overall fish damage by piscivorous birds was quantified from daily feeding rates, and projection made of annual estimates economic fish loss from all farms. Also evaluated were influences of farm habitat features such as hedgerow characteristics, fallow sizes, woodlot presence, tree densities and pond proximity to human dwellings, on frequency and assemblage of predator groups. Thirteen bird and eight non-bird vertebrate predators were identified, and all respondents cited birds as the most serious fish predators. Piscivorous bird abundances and frequency increased with tree densities and pond distance from houses except when exotic hedgerows were present. Conversely, non-bird predator frequency increased with distance from houses, when ponds were near fallow areas and where tilapia was stocked together with catfish. Total annual fish damage by piscivorous birds was estimated at 4.281 tonnes, valued at USD 17,124, representing 24 % of projected county production. These results demonstrate that this level of damage constitutes a substantial and challenging setback to rural aquaculture. Addressing such setbacks requires urgent control action through habitat management and capital support as the necessary steps to reduce investment losses and sustain local food security.

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**OWINO, ARGWINGS**

**ORAL**

### **Changes in phytoplankton community structures in Lake Naivasha, Kenya**

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Phytoplankton community structure plays a vital role in freshwater ecosystems. Besides provision of dissolved oxygen through photosynthesis, phytoplankton also form an important diet for several fish species. Plankton are also used as biological indicators of water quality. The objective of this paper is to determine the changes in phytoplankton community structure and their functional roles. The diversity, distribution, and abundance of phytoplankton are influenced by both abiotic and biotic factors. Lake Naivasha has undergone drastic ecological changes due to growth in human population, industrial development, and changes in its fisheries. The lake is surrounded by horticulture farms that greatly influence its ecosystem health, and the major fish species in the lake are all introduced species. These anthropogenic activities, together with hydrological changes, are expected to play a role in the changes in phytoplankton community structure. Previous investigations indicate that there are more than 143 species of phytoplankton and there is seasonal shift in phytoplankton dominance over time between Chlorophyta, Bacillariophyta, and Cyanophyta. Due to various limnological, hydrological, and ecological changes being witnessed in the lake, there is a need for monitoring of phytoplankton community structure. Such information would be useful in the lake's management and conservation.

**Functional organization of benthic macroinvertebrates assemblages as surrogates of ecosystem attributes in the Nzoia River, Kenya****Sitati, A.,\* Wanderi, E., Raburu, P., Achieng', A., Masese, F.O.**

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Despite the potential of using functional feeding groups (FFGs) of benthic macroinvertebrates as indicators of ecological health of streams and rivers, studies in Afrotropical systems are limited. This study investigated changes in the relative abundance of macroinvertebrate FFGs along the Nzoia River and used ratios of the various FFGs as indicators of ecosystem attributes and to assess the ecological health of the river. A total of 25 sites were sampled during the dry and wet seasons along a land use gradient from the forested upper-reaches, through the agricultural and urban middle reaches to the lower reaches receiving effluents from towns and food processing factories. Five FFG'S were identified: collector-gatherers, collector-filterers, scrapers/grazers, predators, and shredders. FFG ratios were employed as surrogates of the balance between autotrophy and heterotrophy (production/ respiration {P/R} ratio), linkage between riparian inputs of coarse particulate organic matter (CPOM) and fine particulate organic matter (FPOM), top-down predator control, geomorphic channel stability and relative dominance of fine particulate organic matter in transport compared to that deposited in the sediments. Collectors dominated agricultural and urban sites while shredders dominated in the forested upper reaches. Scrapers were dominant in mid-order streams (4th–5th order) indicating a shift from heterotrophy to autotrophy. The metrics used were able to detect shifts in the predominating source of energy at the sites and the conditions of water and habitat quality. Although preliminary, the findings show a potential for use of FFGs as indicators of the ecological health of Afrotropical streams. This is a cost-effective approach to monitoring changes in ecological condition of streams and rivers arising from human influence. More studies are needed to establish thresholds for the various attributes of ecosystem functioning given the divergence of our findings from values in the literature.

**Investigating stakeholders' perceptions of the Nile perch stock dynamics at Lake Victoria****van den Broek, K.**

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The Nile perch fishery supports the livelihoods and protein availability for 4 million people and represents a vital economic contribution to the Lake Victoria Basin. Experts advise that the flourishing of the Nile perch hinges on a delicate balance of the ecosystem of Lake Victoria. The Nile perch is part of a complex system that consists of a web of social-ecological factors. With such complex systems, divergence in mental models (or perceptions of the system) are inevitable. When stakeholders hold vastly different views of the processes that influence the Nile perch stock, collaborations to manage the fishery will be challenging. Here we present an interdisciplinary research project, developed with Lake Victoria stakeholders, that will focus on these mental models and the differences in these perceptions. We present the results of this process, including a problem analysis that has been conducted with stakeholders, as well as the development of a novel tool to measure the perceptions of the Nile perch stock dynamics. The first findings on Tanzanian fishers' mental models of the Nile perch stock will be presented. We conclude with preliminary policy recommendations and outline what lies ahead in this 3-year research project.

**Effects of a probiotic *Bacillus* sp. on *Artemia* nauplii challenged with pathogenic *Vibrio parahaemolyticus*****Wainaina, M.**Kenya Marine & Fisheries Research Institute, Mombasa, Kenya  
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This study investigated the protective effect of a probiotic, *Bacillus* sp., on *Artemia* nauplii challenged with an aquaculture pathogen, *Vibrio parahaemolyticus*. Gnotobiotic *Artemia* nauplii were distributed into sterile glass tubes with filter autoclaved sea water. The nauplii were fed with *Aeromonas hydrophila*, then challenged with an equivalent of 107 cells/mL of cell free supernatant (CFS) of either virulent strain (positive control) or non-virulent strain of *V. parahaemolyticus* (negative control). The results displayed that probiotic *Bacillus* sp. was able to protect challenged *Artemia* nauplii. There was a significant higher survival and swimming activity of *Artemia* nauplii treated with the probiotic than those not treated when challenged with the virulent strain of *V. parahaemolyticus* ( $p < 0.05$ ). Highest survival and swimming activity was recorded in the probiotic-treated groups both compared to the group lacking the probiotic ( $p < 0.05$ ). In conclusion the results of this study showed that probiotics can be used as biocontrol against the pathogenic *V. parahaemolyticus*. This has implications in creating alternatives to the use of antibiotics and chemotherapeutics that are used to boost survival against this bacterial disease.

**Trends in fishing on Lake Naivasha and their implications for management****Waithaka, E.,<sup>1\*</sup> Boera, P.,<sup>1</sup> Morara, G.,<sup>1</sup> Mutie, A.,<sup>1</sup> Nzioka, A.,<sup>1</sup> Keyombe, J.<sup>2</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Naivasha, Kenya<sup>2</sup>Kenya Marine and Fisheries Research Institute, Turkana, Kenya

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This study assessed trends in fishing and determined their implications for the management of Lake Naivasha fisheries. Data on fish catches and fishing effort from 1999 to 2016 were compiled from daily records at four landing beaches (Central, Kamere, Karagita, and Tarambete). A catch assessment survey (CAS) and a socio-economic survey were conducted at the beaches in 2018. Results showed that Lake Naivasha fishery is a male youth-dominated occupation with males owning 69% of the boats. On average, 2.87 tons of fish were landed daily in all the beaches, with Karagita recording 1.07 tons followed by Kamere (0.8 tons), Central (0.6 tons), and Tarambete (0.4 tons). Karagita recorded the highest Catch Per Unit Effort (CPUE) at (35.8), followed by Kamere (22.7), Central (17.3) and Tarambete (13.68). *Oreochromis niloticus* and *Cyprinus carpio* accounted for approximately 69% and 29% respectively of the total daily catches. At least 33 boats were recorded per beach on any given day, making an average total of 133 boats for the whole lake. The increase in catch was attributed to increased fishing effort. The previously set out management guidelines for Lake Naivasha fishery should therefore be implemented and enforced.

**The potential of seaweed farming to contribute to food security in Kenya: Reflections from Kwale County****Waiyaki, E.,\* Kimanga, F., Ochiewo, J., Munyi, F., Karani, N., Ngoa, H., Angwenyi, R.**

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Over the years, the open access nature of Kenya's inshore marine fisheries has led to a severe decline in these resources, resulting in diminished incomes for numerous artisanal fishing communities, coupled with the associated food insecurity. Achieving food and nutritional security for all is one of the four objectives contained in Kenya's "Big 4" agenda – the country's development strategy over the next five years. Seaweed resources can contribute to food security, either directly as a nutritious food source (acceptance of seaweeds as food may take a while in Kenya!), or indirectly as a source of income to purchase food. The purpose of this survey was to

establish the impact of seaweed cultivation on the incomes of seaweed farmers in Kwale County in Kenya's south coast region. A descriptive, cross-sectional survey design was employed in the study. In June 2018, seaweed-related socio-economic data was collected from 78 active seaweed farmers in three villages, viz: Kibuyuni, Funzi, and Nyumba Sita, by means of a semi-structured questionnaire. Two focus group discussions were conducted in Kibuyuni and Funzi. Data was entered, cleaned, and analysed using Excel software. The survey revealed that for almost 50% of the respondents, seaweed farming had produced a positive impact on their incomes. Most farmers received their last earnings from seaweed sales in 2015, when the average selling price for a kilo of seaweed was Ksh 21. Average earnings for the farmer at this time were Ksh 6,768. These earnings enabled the farmers to construct their own houses, pay for their children's education, provide food for their families, and meet medical expenses. The absence of a steady and reliable market for the seaweed has meant that incomes from seaweed have been irregular. Immediate and concerted efforts must be made by relevant government agencies to identify and secure a stable market.

**ABWAO, JACOB**

**POSTER**

### **Socio-economic dynamics and sustainability aspects of land based aquaculture in Western Kenya**

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With the global decrease from capture fisheries, aquaculture remains the focus in bridging the gap and meeting the demand for fisheries products. Currently, aquaculture contributes approximately 50% of world total fishery production, hence becoming an important intervention in promoting food security, nutrition and employment creation. Western Kenya is suitable for aquaculture production due to favorable climate and good soil; but still there is high demand for fish. The present survey proposed to find out the socio-demographic characteristics of fish farmers, fish feed and seed producers in nine counties within western Kenya. The information obtained included age, gender, marital status, level of education, ownership of aquaculture enterprise, and income level as well as challenges hindering fish farming. Fish farming mainly occurs in rural areas in western Kenya, where the most dominant system is earthen ponds measuring 300 m<sup>2</sup>. Aquaculture in the region is male-dominated, and majority players practice individual enterprises. The majority of the hatcheries are authenticated, and the lack of credit facilities was mentioned as the most important challenge. However, for feed producers a lack of adequate raw materials was the most important bottleneck. From this study, both environmental and social factors in the region must be synergized to achieve aquaculture sustainability. There is a need for empowerment of farmers through capacity building and availability of credit facilities, while hatcheries and feed producers must be empowered with adequate skills and infrastructure in order to adhere to good standards.

**ALHASSAN, ELLIOT**

**POSTER**

### **Fish fauna and potential fish yield of the Bui reservoir in Ghana during the first 18 months after impoundment**

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The study was conducted from June 2011, when the Black Volta River was impounded near the Bui gorge. A total number of 19 families, 35 genera, and 57 fish species were recorded during the first 18 months after impoundment. The numbers of fish species recorded per fish family were: Alestidae (7 species); Anabantidae (1 sp.); Bagridae (2 spp.); Centropomidae (1 sp.); Cichlidae (6 spp); Citharinidae (1 sp.); Claridae (4 spp.); Clarotidae (3 spp.); Clupeidae (1 sp.); Cyprinidae (3 spp.); Distichodontidae (3 spp.); Hepsetidae (1 sp.); Malapteruridae (1 sp.); Mastacembelidae (1 sp.); Mochokidae (8 spp.); Mormyridae (9 spp.); Osteoglossidae (1 sp.); Scilbidae (3 sp.); and Tetraodontidae (1 sp.). The family Cyprinidae dominated the catches by number (25.71 %) and weight (33.81 %) during the study period. The Morpho-edaphic index was used to estimate the potential fish yield of 16.13 kg ha<sup>-1</sup> yr<sup>-1</sup> of the Bui reservoir in its formative years. This implies that the fish yield of the Bui reservoir is relatively low and may be due to the fact that the study was undertaken in its formative

years. It is however anticipated that there will be a quick turnover that will increase primary productivity of the reservoir as a result of breakdown of organic load from submerged vegetation as a result of the impoundment.

ATUGA, GILBERT

POSTER

### Natural attenuation in chlorobenzenes degradation: Case study of Zeebrugge River harbour sediments Belgium

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Chlorobenzenes (CBs) are compounds that are persistent in the environment, found in organic chemicals such as pesticides. The accumulation of these compounds in the environment may lead to their biomagnification in the food chain. CBs have been found to be toxic to human and aquatic organisms. Here we evaluate evaluate anaerobic reductive dechlorination of enrichment cultures from the Zeebrugge River harbour, Belgium, and its application in bioremediation. Anaerobic enrichment cultures that were initially amended with one of specific chlorinated benzene, i.e. HCB, 1,2,4,5-TeCB, and 1,2,3,4-TeCB were spiked with 50 µM of the respective CBs serving as electron donor, and lactate as electron acceptor. Two serial transfers were conducted. The reductive dechlorination of enrichment cultures was studied using Gas Chromatography Flame-Ionization Detector (GC-FID) for 44 days, after which a second transfer was done. Quantitative real-time PCR (qPCR) was performed on the samples at day zero of first transfer and day 26 of the second transfer targeting putative *Dehalococcoides* spp. CBs degraders. Based on the achieved results, reductive dechlorination was observed in all samples. HCB was dechlorinated via two major degrading pathways i.e. HCB via PCB, 1,2,4,5-TeCB, 1,2,4-TCB, 1,4-DCB to MCB, or HCB via 1,2,3,5-TeCB to 1,3,5-TCB. The 1,2,4,5-TeCB enrichment samples also showed two degrading pathways i.e. 1,2,4,5-TeCB via 1,2,4-TCB to 1,3-DCB, or 1,2,4,5-TeCB via 1,2,4-TCB to 1,4-DCB to MCB. The dechlorination pathway of 1,2,3,4-TeCB dechlorination process of 1, 2, 3, 4-TeCB was observed but at a very slow pace. qPCR analysis of the enrichment cultures showed total quantities of bacteria for the first and second transfer of 105 to 107 copies/ml respectively for HCB. *Dehalococcoides* spp. were also detected in all other samples. These organisms have been found to be involved in reductive dechlorination of CBs, and its study unwinds its application in bio-remediation of polluted aquatic environments.

AURA, CHRISTOPHER

POSTER

### A delineation approach of lakescape for cage culture suitability to minimize lake-use conflicts

Aura, C.,<sup>1\*</sup> Musa, S.,<sup>2</sup> Nyamweya, C.,<sup>1</sup> Ogari, Z.,<sup>1</sup> Njiru, J.,<sup>3</sup> Hamilton, S.<sup>4</sup>

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We present a GIS-based methodological approach that allows for the delineation of suitable and unsuitable locations for tilapia cage culture sites in the Kenyan portion of Lake Victoria, Africa. The study has broader applicability to all of Lake Victoria, other African Great Lakes, and all lakes in which tilapia cage culture already occurs or may occur in the future. The method presented utilizes high-resolution bathymetric data, field-collected water quality data, delineation of current cage areas, local knowledge, and pre-existing literature. The parameters considered are water depth, water temperature, levels of dissolved oxygen, levels of chlorophyll-a, and the distance to the lake shoreline and to the constraint. The entire study area is 4,100 km<sup>2</sup>. Results indicate that the study area has a maximum suitable area for cages of 362 km<sup>2</sup> or approximately 9% of the Kenyan portion of Lake Victoria. The majority of the lakescape, 3,737 km<sup>2</sup> or 91% of the study area, is either unsuitable or highly unsuitable for tilapia cage culture. We identify a need for stakeholders to be involved in validating and approving potential sites, for the adoption of suitable and unsuitable zones, and for entrenching the lakescape delineation into regulations and management frameworks.

### Ecosystem integrity of the Upper Victoria Nile (UVN), East Africa based on habitat and fish species biotic indices

Bassa, S.,<sup>1\*</sup> Owiti, D.,<sup>2</sup> Getabu, A.,<sup>3</sup> Orina, E.,<sup>3</sup> Muhumuza, E.,<sup>4</sup> Olwa, R.,<sup>4</sup> Taabu, A.<sup>1</sup>

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Rivers and streams drain large amount of surface water into seas and lakes, and are important sources of fisheries and hydro power resources. However, riverine ecosystems have continuously been compromised by human activities that threaten their integrity. There has been an effort to assess the integrity of these ecosystems for conservation and better management purposes using expensive methods of physico-chemical parameters that constrain developing countries. This study was carried out on the Nile based on the habitat and fish biotic indices method. Experimental gillnet was done bi-annually in 9 stations along the river from 2008 to 2018. Nine habitat metrics were used to estimate the habitat quality index at every sampling station. The fish were sampled, sorted, identified to species level, then weighed. Counts of exotic/indigenous and tolerant/intolerant species were recorded to generate species richness. This data was used to develop 12 metrics of fish-based index of biotic integrity by summing up scores. A total of 1,642 fish were recorded, belonging to 7 families and 73 species. The most dominant were *Lates niloticus* 23.51% followed by *Mormyrus kannume* 13.64%; other species were least with  $\leq 0.06\%$ . Insectivores were more abundant with 41.5%, omnivores (21.5%), carnivores (20.0%), and detritivores (16.9%). The mean habitat quality index for total fish catch and fish-based index of biotic integrity were highest at Makwanzi:  $26.6 \pm 6.9$ ,  $289.19 \pm 51.80$ , and  $30.6 \pm 7.9$ , respectively. They were lowest at Kisadha:  $19.4 \pm 7.3$ ,  $93.06 \pm 13.16$ , and  $26.7 \pm 6.8$ , respectively. On a spatial basis, the indices recorded significant difference values ( $p < 0.05$ ). It was observed that the fish-based index correlated positively with the habitat quality index, species richness, and fish population size. Thus, the fish-based index of biotic integrity can be used to predict habitat quality index, fish population, and richness of the Nile systems.

### Longitudinal trends in macroinvertebrate communities, functional feeding groups and performance of regional biotic indices for bioassessment of the Gura River, Kenya

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Benthic macroinvertebrates have been used widely in biomonitoring and aquatic restoration due to their great value in conservation. Land use change, especially loss of riparian vegetation, has led to loss of diversity and major shifts in the structural and functional organization of macroinvertebrates in streams. At a local level, the Gura River is coupled with challenges of land use change, hydropower, erosion, sedimentation, and water abstraction. The present study aimed at determining the longitudinal trends in macroinvertebrates communities, functional feeding groups, and performance of regional biotic indices for bioassessment of the Gura River from an altitude of 2977–1179 m a.s.l. A three-month study was carried out on a monthly basis between October and December 2018. Ten Hydropsychidae types were identified from upstream to downstream sites in the Gura River. Sites; G2, G3, G4 and G5 in the Gura River had phoretic association of Simuliidae and *Afronurus* sp. (Heptageniidae). The Ephemeroptera and Trichoptera were the dominant taxa in all sampled sites and their abundance decreased from upstream to downstream sites. The cluster analysis revealed two main macroinvertebrates clusters in the Gura River (upstream and downstream macroinvertebrate clusters). Macroinvertebrates representative taxa of the upstream cluster included Scirtidae, Potamonautidae, Philopotamidae, Hydropsychidae type ACE, and Lepidostomatidae. For the downstream macroinvertebrates cluster, the representative taxa included Hydropsychidae type G and type J. The South Africa Scoring System (SASS), Tanzania River Scoring System (TARISS), and ETHbios biotic indices were applicable in determining the ecological condition in the Gura River. Functional feeding groups (FFGs) in the Gura River did not correspond to the River Continuum Concept (RCC); scrapers were the dominant FFGs followed by collector-

filters. Shredders and predators had the least relative abundance of FFGs in all sites. However, there was no correlation between shredders and landcover classes along the Gura River.

**BOERA, PRISCILLA**

**POSTER**

### **The impact of demarcation and protection of critical fish breeding and nursery sites, the case of Lake Naivasha, Kenya**

**Boera, P.,\* Morara, G., Waithaka, E., Mutie, A., Obegi, B., Nzioka, A., Loki, p.**

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This study evaluates the impact of demarcated fish breeding areas of Lake Naivasha. Experimental gill net survey and commercial catch data from 2013 to 2017 was pooled and analyzed for indicators that included species diversity, size structure, abundance, spawning biomass, and production. Water quality parameters were assessed to characterize the fishery environment. The study reveals that there were no significant spatial differences in physicochemical parameters. Fisheries data showed significant difference in the abundance of *C. carpio*, *O. niloticus*, and *O. leucostictus* between the breeding and fishing areas. The mean sizes of these species were significantly higher ( $P < 0.05$ ) in breeding areas compared to fishing areas. Sex ratio analysis reveals male dominance in all the species populations. Spawning biomass composition of the three major species was higher in the breeding areas. Fish production trends revealed an increase from 2.3 to 341.5 tonnes for *O. leucostictus* and 222 to 320.3 tonnes for *C. carpio* from 2013 to 2014. Increase in mean sizes of *C. carpio* in the breeding areas had strong correlation ( $r^2 = 0.791$ ). Overall results show that fish breeding grounds still remain important for stock replenishment in Lake Naivasha. Monitoring, control and surveillance need to be strengthened in a spirit of shared responsibility and co-management coupled with regular monitoring of the resource performance.

**BOERA, PRISCILLA**

**POSTER**

### **Using geoinformatics to assess macrophyte populations in Lake Naivasha, Kenya**

**Boera, P.,<sup>1\*</sup> Waithaka, E.,<sup>1</sup> Mutie, A.,<sup>1</sup> Morara, G.,<sup>1</sup> Nzioka, A.,<sup>1</sup> Obegi, B.,<sup>1</sup> Loki, P.,<sup>1</sup> Khamala, E.<sup>2</sup>**

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The encroachment of the exotic aliens *Salvinia molesta* and *Eichhornia crassipes* in Lake Naivasha is associated with deteriorating water conditions. This paper presents the findings of a study designed to assess the distribution and quantify the extent of the macrophyte population in Lake Naivasha between February and March 2017. High-resolution optical Earth Observation (EO) and in-situ data were used. Mapping of the distribution and extent of macrophytes was done using remotely sensed imagery Sentinel-2 acquired on 28th February 2017, 20th and 30th March 2017. The images were geo-referenced and geographically rectified. The datum was set to WGS 84 and referenced to Universal Transverse Mercator (UTM) zone 36 North. Image compositing using both false colour and natural colour band combinations was conducted including image enhancement, and clipping the images based on the extent of the study area. The image interpretation was done at a scale of 1:50000, while ground truthing was undertaken to provide supplemental details of actual information in the field. Maps were produced and the macrophytes quantified in terms of distribution and coverage using different spectral signatures. Kappa Index of agreement was used to assess the accuracy of the maps of 28th February 2017 and 30th March 2017. Multi temporal analysis of the satellite images (28th February 2017, 20th and 30th March 2017) showed there were two major types of macrophytes that could be identified and quantified. It also showed that the area covered by water hyacinth had increased significantly from 940 Ha to 1480 Ha between the study dates, while the area under papyrus had also increased, from 570 Ha to 590 Ha. The overall findings indicate that the coverage of papyrus remained relatively stable both in terms of distribution and area covered, whereas the coverage of water hyacinth was dynamic both in terms of distribution and coverage.



### Elucidating influence of interstitial seawater physical and chemical attributes on polychaete (*Marphysa mossambica*) occurrence at Mtwapa Creek, Kenya

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Polychaetes are one of the major sources of bait in fishing. Artisanal fishers excavate the large-sized *Marphysa mossambica* from the muddy/sandy intertidal substrate. The harvested polychaetes are used by artisanal hooks and lines fishers as fish baits. The number of *M. mossambica* exploited by individual fishers varies depending on the number of fish targeted, but a fisher may take up to 20 *M. mossambica* per day. However, limited information is documented on this species along the coast of Kenya in relation to usage as baits, morphometrics, and breeding in addition to physical and chemical characteristics that affect occurrence. Taking cognizance that physical and chemical parameters may guide farming of *M. mossambica* to provide adequate bait for artisanal fishers and marine aquaculture feeds which will by extension reduce the impact on the ocean shoreline due to its current exploitation, the current study was carried out to determine the effects of physical and chemical parameters on the occurrence and distribution of polychaetes in mangrove sediments along the coast in Mtwapa creek. Using transects of 300 m<sup>2</sup> and 1 m<sup>2</sup> quadrants, polychaetes were counted, measured, and recorded. Different water quality parameters, including dissolved oxygen, salinity, temperature, and pH in interstitial seawater were measured using HANNA HI9142 model meters. Pearson correlation was used to determine the relationship between the polychaetes population density against physical and chemical variables. The average density of *Maryphsa mossambica* was 23.33±1.462 ind.m<sup>2</sup>, salinity was 32.28±.34777 ppt, temperature 28.4674±0.14978° C, pH 7.4017±0.02053, and dissolved oxygen 0.457±.0375 mg/l. The average length of the polychaete during study was established as 18.0788±0.74867 cm and weight 3.5620±0.24124 g. Further research could be done to farm and breed the polychaetes, providing the interstitial water parameters as in the natural environment.

### Effects of digenean trematode and monogenean infections on cage cultured Nile Tilapia *Oreochromis niloticus* in Lake Victoria

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Tilapia aquaculture is a major source of nutritional security to Kenyans. It is, however, constrained by anthropogenic factors arising from environmental degradation, and by natural attributes such as prolific breeding and fish diseases. Monogenean and trematode attacks are directly linked to environmental degradation and can cause massive fish kills by physical injury, inducing respiratory problems and making fish susceptible to secondary bacterial and fungal infections. The study investigated the effects of trematode and monogenean infections in Nile tilapia (*Oreochromis niloticus*) in Lake Victoria, with specific objectives: to identify trematodes and monogeneans affecting cage cultured Nile tilapia, determine trematode and monogenean infection at different stocking densities in cage culture, determine water quality and seasonality as drivers of trematode and monogenean infections, and determine the relationship between infection and fish size. The study adopted an experimental research design: 600 fish of different sizes and sexes were randomly selected to form the study sample. Standard parasitological techniques were used to identify the trematodes and monogeneans, to determine the prevalence, mean intensity, mean abundance, and fish condition factor. Factor analysis was used to determine water quality and seasonality as drivers of trematode and monogenean infections, and nominal logistic regression was used to determine the relationship between infection and fish size. The dactylogyrus species of monogenea and the digenean trematodes; tyloodelphys, neascus and the Clinostomum parasites were abundant. High stocking density induced stress to the fish, leading to physical injuries causing blindness, eroded fins, and tissue injuries, predisposing the fish to secondary infections. The dactylogyrus displayed seasonal fluctuation in prevalence and mean intensity with increase in water temperature. Parasite intensity increased with length but had no effect the condition factor of fish.

**Community engagement in seagrass restoration: A case study of Wasini, Kwale County, Kenya****Daudi, L.,\* Uku, J., Alati, V., Muthama, C.**

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Seagrass restoration is the process of re-establishing a self-sustaining habitat that closely resembles a natural condition in terms of structure and function. In Kenya, massive areas of seagrass beds have been degraded, mainly as a result of sea urchin herbivory. The Kenyan artisanal fishery is mainly dependent on healthy seagrass and coral reef ecosystems. In recognition of the value of these ecosystems to the local coastal communities and their continued degradation, the Kenya Coastal Development Project (KCDP) supported a pilot seagrass restoration programme in Wasini, Kwale County. The pilot programme involved community participation with members of the local Beach Management Unit being trained on various aspects of restoration including monitoring. At the onset of the programme, a degraded site in Wasini with no seagrass cover was selected. In over four years, the area has been transformed into a healthy meadow comprising mixed seagrass species and with a total cover of approximately 80%. This success was a result of sediment stabilization through settlement, creating an enabling environment for colonization by seagrass species leading to the restoration of natural healthier conditions. The restoration work involved site selection, extraction of material from a donor site, transplantation, and monitoring. The lessons learned during the community restoration effort will be shared.

**Efficacy of macrophyte dominated pond inclusion as post-treatment polishing of domestic wastewater effluents for pollution control within urban lakes****Donde, O.,<sup>1\*</sup> Makindi, S.,<sup>2</sup> Xiao, B.<sup>1</sup>**<sup>1</sup>Institute of Hydrobiology, Chinese Academy of Sciences, China<sup>2</sup>Machakos University, Kenya

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Variability in microbial strains, virulence and pathogenicity within wetland ecosystems is a topic that needs considerable attention due to increasing climate change and human population. Although many studies currently focus on wetlands ecology, there is still inadequate documentation particular to the relationship between bacterial abundance, diversity, and pathogenicity, as well as the mechanisms and roles of aquatic macrophytes in wastewater treatment. To shed more light on the fate and virulence of members of Enterobacteriaceae and Enterococcaceae in a winter-tolerant, macrophyte-dominated artificial wetland system, this chapter presents a study that evaluated the efficacy of macrophyte-dominated Wastewater Polishing Pond Inclusions (WPPIs) in influencing the abundance, survival, and pathogenicity of faecal bacteria pathogens. The study showed that WPPIs offers more than 95% reduction of pathogenic forms of *Escherichia coli*. WPPIs is an additional effort that provides a good sustainable and environment-friendly method of wastewater polishing and its efficiency is a factor of macrophytes percentage cover. Therefore, the application of WPPIs in domestic wastewater polishing is recommended for better pollution control on aquatic ecosystems that receive more effluents from a highly populated urban setup with huge domestic wastewater generation.

**Species composition, abundance and diversity in Nyegezi Bay, Lake Victoria, Tanzania****Elison, M.,\* Mlaponi, E., Musiba, M., Kashindye, B.**

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Nyegezi Bay is among the numerous small bays in Lake Victoria. The bay has potential for an aquatic laboratory as it is in the vicinity of fisheries research and training institutions. The bay is subject to increasing

residential, recreational, and agricultural activities that may pose threats to its well-being. However, little has been done to understand the nature and dynamics of the bay. This study investigated composition, abundance, and diversity of fish species in Nyegezi Bay. Samples were collected from five stations; of which one site was in the river entering the bay, while the other five sites were in the bay. The sites in the riverine ecosystem were FETA Bridge, and the sites in the lake ecosystem were TAFIRI Pier, FETA Pier, Corner Point, Entrance Point, and Centre Point. The study was conducted during October and November 2014 and February and June 2015. Fish data within the bay were collected using experimental gillnets from five stations in the bay and beach seine was used in one station from the River entering the bay. From each gillnet panel, fish samples were collected and identified to species level. Fish that could not be identified on the field were preserved in 10% formalin for identification at later stage. A total of 18 fish species from nine families were encountered and identified, apart from the haplochromine group. TAFIRI pier had more species richness and also demonstrated a more species evenness and diversity. The catch of Nile perch and Nile tilapia was dominated by immature juveniles. This signifies the importance of Nyegezi Bay as a breeding and nursery ground for the species. Proper management should be enforced to regulate and control the fishing activities in the bay.

FONDO, ESTHER

POSTER

### Sustainable crab fishery for the blue economy in Kenya

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Kenya's fisheries and aquaculture sector contributes approximately 0.8% to the country's GDP. With an EEZ of 142 400 km<sup>2</sup>, Kenya's marine capture fisheries produce about 9,000 tonnes per year. Marine finfish are highly exploited and form the bulk of the marine production, while shellfish (e.g. prawns, lobsters, and crabs) and molluscs (e.g. octopus and squids) are underexploited. The fishery sector has the potential of about Ksh 500 billion for the blue economy in Kenya. Crab fishery in Kenya is active in some areas of the south and north coast. The crab resources along the Kenyan waters are diverse, and a variety of species are edible including those of the families Lithodidae, Macridae, Caneridae, Portunidae, Xanthidae, Potamidae, and others. However, very few of these species constitute an important food source. The commonly fished crab is the mangrove mud crab *Scylla serrata*, which is fished by artisanal fishers. Semi-commercial and industrial fishers usually have portunid and other deep-sea crabs as bycatch in the prawn and longline fisheries; which in many cases are unutilized. Apart from being an important food source, crabs have medicinal value. Sustainable development of crab fishery provides a potential area for blue economy development in Kenya. Research into the abundance, biology, ecology, and distribution of crab species is essential to crab fishery development.

GITHIORA, YVONNE

POSTER

### Assessment of ecosystem services of the Yala Swamp using the Matrix Approach Tool: An initial step to integrated natural resources management

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Freshwater ecosystems of the world provide important ecosystem services that sustain human wellbeing. However, these socio-ecological systems in Africa continue to face serious challenges resulting mainly from changing climatic conditions and increasing human population. These two drivers are likely to lead to a reduction in the services provided by freshwater wetlands, a major source of ecosystem services that support livelihoods in Africa. Major policy decisions based on scientific data therefore need to address trade-offs among current uses of wetlands. This study employs the matrix approach, a quantitative and qualitative tool to characterize land use / land cover classes (LU/LC) and identify and rank ecosystem Services (ES) in the Yala swamp wetland, Kenya's largest freshwater ecosystem, which is facing ecological and economic pressures emanating from changing land use patterns, human population pressures, climatic conditions, and local political

dynamics. Selection of ecosystem services was done using a combination of literature review, expert and local knowledge, after which the matrix model was used to analyse flow of ecosystem services by land cover type. Finally, mapping of flow of ecosystem services by land cover type was done using GIS, providing a spatially explicit way of linking land use with ecosystem service provision. Our findings present a case for an ecosystem services management approach as a more inclusive, demand-driven, and environmentally sustainable approach to achieve the apparently conflicting needs for biodiversity conservation, food security, and socio-economic transformation within the Yala swamp wetland.

**GUYA, FREDRICK**

**POSTER**

### **Intrinsic and extrinsic sources of phosphorus loading into River Nyando, Kenya**

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The River Nyando supports a large population and an enriched biodiversity. The basin has undergone extreme modification through changes in hydrological and Land-use activities over the last century. The impact of the changes have severely shifted the ecology of the river from desirable to less desirable. Of all the major rivers draining into Lake Victoria-Kenya, the River Nyando is consistently the most turbid and with the highest phosphorus load. Between 2015 and 2016, this study investigated the present status and sources of phosphorus loads through water and sediment sampling for variations in physico-chemical observations during high and low flow regimes. Water and sediment samples were analyzed for associated phosphorus of Soluble Reactive Phosphorus (SRP), Total Phosphorus in water (TPw), Non Apatite Inorganic Phosphorus (NAIP), Apatite Phosphorus (AP), Inorganic Phosphorus (IP) Organic Phosphorus (OP) and Total Phosphorus in sediments (TPs). The observed Soluble Reactive Phosphorus (SRP) and Total Phosphorus (TPw) concentrations showed hypertrophic conditions with means for both high and low flows ranging from 79.3 to 165.7  $\mu\text{g L}^{-1}$ ; and 200.0 to 243.9  $\mu\text{g L}^{-1}$ , respectively. Apatite Phosphorus (AP) concentrations were high, with mean measurements between high and low flows ranging between 766.9 and 790.5  $\text{mg kg}^{-1}$ , respectively. The sources of high phosphorus loads were established to be both natural and anthropogenic; with major drivers being the industrial establishments along the river basin. Runoff discharges from erosion of catchment phosphorus-enriched carbonatite rocks and river banks also contributed significant phosphorus loads. Enhanced effluent treatment, quarry dust containment, improved forest cover, and regeneration of riverine buffer strips are recommended in order to restore the river's ecosystem.

**HENRY, CHADWICK**

**POSTER**

### **Ovarian development of the Penaeid shrimp *Penaeus Indicus* (Decapoda): A case for the Indian Ocean coastal waters of Kilifi Creek, Kenya**

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The Indian prawn *Penaeus indicus* is widely distributed in the Indo-West Pacific. The species grows to 22 cm, inhabiting depths of 100 m. *P. indicus* is widely studied, although the majority of the studies have focused on developmental stages between shallow waters and the deep seas. Studies on the maturity of this species in shallow waters are lacking for the Kenyan coastline. This study was conducted in the Kilifi Creek. Samples were collected from six landing sites. Morphometric and biological data including total length (TL, cm), carapace length (CL, cm), body weight (BW, g) and sex were recorded, and the specimens dissected to check for ovarian development and maturity. Ovarian development stages were determined from size, shape and colour of the ovaries, and through frequency analysis of the cortical granules. A total of 1,149 specimens were sampled. The catch mostly comprised the 1.5 cm to 2.5 cm CL size class. Some individuals in the >4.0 cm CL size class were recorded, suggesting that some individuals still matured in the creeks although the majority are known to migrate to the deep sea. Regression analysis showed a strong positive correlation between CL, and TL ( $r^2=0.7548$ ) and BW ( $r^2=0.7497$ ). The condition factor ranged from 0.19–0.94, indicating the presence of both immature/spent (4.7%) and ripe individuals (95.3%) in good condition. Size frequency analysis of the ovary cortical granules displayed a polymodal pattern with two peaks of immaturity and three peaks for developing

and near-ripe, respectively. The presence of spent stages as well as mature specimens in the creek waters indicated that apart from using these habitats as nursery and feeding grounds, some of the individuals might also be growing, maturing, and spawning in the creek.

**JAIME, GRACA**

**POSTER**

### **Socio-economic assessment of artisanal fisheries on Lake Niassa**

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In Mozambique, fishing occupies a significant place in the country's economy, helping to improve the population's diet as well as GDP. Fishing is the main activity in the Metângula village on Lake Niassa. Captured fish are an important source of protein for the community and make a significant contribution to the local economy. The lack of information on artisanal fisheries in Lake Niassa and the weak economic development in this region of the country is the main problem for the sustainable management of fishery resources. The objective of this work was to assess the socio-economic impact of artisanal fishing on Lake Niassa. Semi-structured interviews were conducted with 87 fishermen from the fishing centers of Chuanga 1, Chuanga 2, Seli, Mecuio, and Thungo during the month of October 2018, in order to describe the profile of the fishermen, to characterize the gears used by them for fishing and the incomes that comes from the exploitation of fisheries resources. Data were processed and analyzed in SPSS 17.0. The fishermen of the lake are male, aged between 18 and 65 years of age, married, and with primary and secondary education levels. The gillnet was the main gear used by fishermen for fishing, and the fishermen use boats for fishing. On average, the fishermen's income varies from 2500 to 5000 Meticaís per day. In general, fishing activity in Niassa Lake has a positive socio-economic impact on the lives of fishermen in Metangula Village as it provides employment opportunities for the fishermen to meet basic daily needs such as feeding and schooling of children, buying household appliances, and maintaining fishing equipment.

**JEMBE, TSUMA**

**POSTER**

### **Partitioning of Lake Victoria Catchment (Kenya) *Oreochromis Niloticus* (Linne) stocks using randomly amplified polymorphic DNA**

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The tilapia, *Oreochromis niloticus* (Nile tilapia) is currently the third most important commercial fish in Lake Victoria after *Lates niloticus* and *Rastreneobola argentea* (Omena). Its occurrence in the lake catchment (Kenya) has been noted since the last 50 years after several direct introductions into the Kavirondo Gulf (Nyanza gGlf) in the early 1950s. Currently, populations of *O. niloticus* exist in three satellite lakes and numerous dams within the catchment, making it the most widely distributed species. Nile tilapia continues to dominate and replace endemic tilapiine species such as *Oreochromis esculentus* and *Oreochromis variabilis*. While information on demographics, reproduction, and feeding exists, little is known on the effects of its wide distribution and possible genetic fragmentation of populations isolated in various satellite lakes and dams that are subjected to varying physical and chemical regimes. This study aimed at determining retrogression within the tilapiine fraternity and resultant changes in genetic levels to inform fishery and conservation efforts. Four populations were genetically evaluated on the basis of the Hardy-Weinberg equilibrium and tested to determine differences between the various populations. Randomly Amplified Polymorphic DNA (RAPD) was used to assay several loci to determine changes in twenty loci distributed amongst the populations. The average gene diversity of *O. niloticus* ranged from 0.148 to 0.342 in the four populations sampled. Loci sampled by OPM-07 and OPM-14 had much lower values than those by OPM-11 and OPM-02. The four populations however showed no statistically significant differences in the average gene diversity at the 95% significance level ( $Df = 3$ ,  $F\text{-ratio} = 0.14$ ,  $p\text{-value} = 0.936$ ). No significant genetic variation exists within natural populations of *O. niloticus*. Geographic isolation and exposure to varied physical and chemical conditions may have promoted only non-genetic variation in *O. niloticus* populations within the sampled habitats.

**Variation in the distribution and abundance of fishes caught with a bottom trawl in the Nyanza gulf and open waters of Lake Victoria, Kenya****Jembe, T.,\* Nyamweya, C., Mbaru, E.**

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Fish collections were made by quarterly trawls at 28 stations in the littoral and deeper areas of Lake Victoria, Kenya, from the periods 1998 to 2000, and later from 2003 to 2005. In 124 trawl hauls made from 1998 to 2000, 26,248 fishes were caught, and 29 species (nine families) were identified from the collections. The 98 2003–2005 trawl hauls caught 21,879 fishes, consisting of 31 identified species (nine families). In the period 1998–2000, the gulf environment was characterized by large mobile mats of hyacinth and low turbidity and temperatures. This permitted the occurrence of many littoral species in the gulf to breed under cover of the hyacinth.

The period 2003 to 2005 was relatively free of hyacinth, had higher turbidity and temperature, and witnessed greatly increased faunal diversity. In the period 2003 to 2005, shoreline and shallow littoral areas, although not trawled, typically exemplified breeding and nursery areas due to the occurrence of significantly greater numbers of fingerlings and juveniles of species such as *Oreochromis niloticus*, *Protopterus aethiopicus*, *Haplochromines*, and *Clarias gariepinus*. These areas formed the bulk of faunal input for Lake Victoria. Differences between the gulf and open waters were more pronounced during the 2003–2005 period, with the gulf recording higher faunal diversity, while the open waters recorded marginal gains. An unusual abundance of *Lates niloticus* occurred during the latter half of the 1998–2000 sampling period. This abundance also observed after this period was generally widespread in the gulf. An abundance of fish and increased diversity in the gulf as a response to changing hyacinth changes is inferred. Other parameters that affect abundance and diversity are discussed. Length frequency distribution for abundant species shows that smaller individuals were found in the inner gulf area, and the larger were more frequently observed in the outer gulf and open-water areas.

**Salinity tolerance of fresh water prawn *Macrobrachium rude* (Heller, 1862) larvae and the potential for aquaculture in Kenya****Karanja, H.,<sup>1\*</sup> Kochev, J.,<sup>2</sup> Kairo, J.<sup>3</sup>**<sup>1</sup>Karatina University, Kenya<sup>2</sup>Geoth University, Germany<sup>3</sup>Kenya Marine and Fisheries Research Institute, Kenya

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Seafood consumption has rapidly increased over the last two decades due to its high level of proteins. However, wild stocks have declined due to overfishing and climate change. Mariculture has the potential to offset this deficit and reduce overfishing. Most of the cultured marine species have been on fin-fish and crustaceans. The present study aimed to investigate survival of fresh water prawn *Macrobrachium rude* larvae to salinity gradient. Eggs were hatched in room temperature under salinity range of 0–14 ppt. The nauplii were then collected and grown in three replicates under salinity ranges of 0–35 ppt. Survival of the larvae was monitored for 7 days from nauplii to zoea stages. Results of this study indicate that berried females of *M. rude* prefer a medium salinity of 14‰ for spawning and hatching their eggs. The best salinity range for survival of *M. rude* larvae was recorded to be between 7 and 14 ppt. These results have applications in the establishment of a hatchery for freshwater prawns.

**Life history of threatened African carp *Labeo victorianus* from Migori River basin, Kenya****Kembenya, E.,<sup>1\*</sup> Getabu, A.,<sup>2</sup> Njiru, J.<sup>1</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Kenya<sup>2</sup>Kisii University, Kenya

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The threatened African carp *Labeo victorianus* is a freshwater fish species endemic to Lake Victoria basin. The objective of this study was to give a description of the life history of *L. victorianus* in the Migori river system. The life-history traits described include gonadosomatic index (GSI), fecundity, egg size, sex ratio, relative condition factor, and diet composition. Sampling was done from March 2018 to February 2019. Fish length and weight were measured to the nearest 0.1 cm and 0.01 g, respectively. The relative condition factor (KR) for each individual fish was calculated as  $KR = W / (aL^b)$ , where W is the BW, L is the TL and a and b are the length–weight relationship parameters. The GSI for each fish specimen was calculated using the formula:  $GSI = GW / W * 100$ ; where GW is gonad weight and W is the fish weight in grams, respectively. Fecundity ranged from 47,842 to 101,902 eggs (mean 83,663±2605) and correlated highly with body size ( $R^2 = 0.92$ ). The relationship between fecundity and total length was  $F = 782.4TL^{1.381}$ . Mean GSI for females was  $10 \pm 2.6$ , while that of males was  $3 \pm 0.45$ . Egg diameter ranged from 0.5 to 0.7 mm in maturity stage 4 and 5 respectively. The calculated b for the LWR indicated positive allometric growth ( $>3.00$ ) in both sexes. Sex ratio did not differ from the expected 1:1. The major food items in the diet of *L. victorianus* were detritus (50%), insects (22%), algae (14%), and plant material (12%). The results of this study would be useful for the sustainable conservation of *L. victorianus* in the Lake Victoria basin.

**Has the latest fish introduction in Lake Naivasha improved income of fishermen? The economics of Nile tilapia (*Oreochromis niloticus*) in Lake Naivasha****Keyombe, J.,<sup>1\*</sup> Lewo, R.,<sup>2</sup> Waithaka, E.,<sup>3</sup> Mutie, A.,<sup>3</sup> Boera, P.<sup>3</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Lake Turkana, Kenya<sup>2</sup>Nakuru County Fisheries Department, Naivasha Sub-County, Kenya<sup>3</sup>Kenya Marine and Fisheries Research Institute, Naivasha, Kenya

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Data used in this study was collected daily between January 2011 and April 2016 from four fish-landing beaches along the shores of Lake Naivasha; Central, Karagita, Kamere, and Tarambete beaches. The results revealed that the total landings of *O. niloticus* (Nile tilapia) have been gradually increasing, from 0% in 2011 to 42.7% (206.923 tons) of the total landings between January and April 2016 (422.613 tons) with projections of its surpassing carp by December 2016. These findings corroborate regular field observations which indicate that fishermen are abandoning carp fisheries and opting for Nile tilapia due to its high demand and increased market returns. Between January and April 2016, Nile tilapia had an average price per kg of KShs 147.52 compared to carp's KShs 122.93. The study therefore concludes that the re-introduction of *O. niloticus* in 2011 has achieved its main objectives of food security and improving livelihoods since the fish has completely established itself and is now the key driver of Lake Naivasha fishery.

**Have innovative technologies reduced post-harvest fish losses and improved food security along Lake Turkana? Case study of the polyethylene solar dryer****Keyombe, J.,<sup>1\*</sup> Bironga, C.,<sup>1</sup> Obiero, M.,<sup>1</sup> Malala, J.,<sup>1</sup> Olilo, C.,<sup>1</sup> Aura, C.,<sup>2</sup> Nyamweya, C.,<sup>2</sup> Njiru, J.<sup>3</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Lake Turkana, Kenya<sup>2</sup>Kenya Marine and Fisheries Research Institute, Kisumu, Kenya<sup>3</sup>Kenya Marine and Fisheries Research Institute, Mombasa, Kenya

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The geographical location of Lake Turkana in the northern semi-arid region of Kenya positions it as a major contributor to the economic development and source of livelihood for the communities living in the area. Fish from the lake provide an important source of proteins for these communities. Unfortunately, there are no large-scale fish processing industries in the area, thus leading to post-harvest losses. Consequently, there is a need for urgent measures to improve the fishing industry and develop innovative technologies to reduce these losses. To address the gap, polyethylene solar dryers have been built around the lake as a way of reducing post-harvest fish losses. The study investigated the effectiveness of the dryers at Nariokotome Beach Management Unit (BMU) situated on the north-western side of Lake Turkana. Data was collected through questionnaires, fish-drying trials, shelf-life trials, and physical count of solar dryers. When fish dried in the solar dryers were weighed after 44 hours, they had lost 55.98% of their weight while the samples dried on stones lost 61.3% of their weight. Physical observations on status of the dryers found that 54% of the dryers were in good working condition while the remaining 46% were dilapidated. The study revealed that polyethylene solar dryers are not effective for the reduction of post-harvest fish loss in Lake Turkana. Fishers were actually using only 30% of the solar dryers even though 54% were in good working condition. Furthermore, there was no evidence on improvement in income of fishermen or uptake of solar dryers by fish processors despite massive investment in their construction by various donors. The main weakness of the solar dryers was their small size. The authors recommend that alternative innovation for drying fish along Lake Turkana be developed and that it should factor in the challenges encountered in uptake of polyethylene solar dryers.

**Social and economic dimensions of the beach seine fishery in Lamu County, Kenya****Ochiewo, J., Kimanga, F.,\* Munyi, F., Owiti, H., Waiyaki, E., Karani, N.**

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This study was conducted in Lamu County in the northern coast of Kenya, where a rich biodiversity is threatened by the use of a destructive fishing practice: fishing using beach seines. The County also experiences numerous developmental challenges that conflict with fisheries management. The main objective of this study was to assess the socioeconomic dynamics of the beach seine fishery. Data was collected in Kiunga, Faza, and Kizingitini villages using purposive and random sampling, conducted through participatory approaches: direct observation, semi-structured questionnaires, and key informant interviews. The use of beach seine was found to have no association with the age and educational level among the fishermen. However, the beach seine was the preferred fishing gear in all the sites. The pull factors cited comprised long history of use, ease of entry with minimal screening in Kizingitini village, used mostly during the SEM season and it is mainly owned by the employers; a single beach seine employs an average of 10 to 25 fishers per fishing expedition. Fish catch landed is sold to either dealers or sold cheaply to the local fishmongers. The remainder, which is mostly unpalatable, is discarded at sea or fed to the cats around the village. Identified negative impacts associated with beach seine use included an increase in fishing pressure during SEM, overharvesting of fish stocks resulting in a large quantity of discards, and the destruction of corals and sea grass beds through use of the beach seine. These results imply the need for national policies and county regulations to be readdressed in order to support sustainable utilisation of the fisheries resources, along with the adoption of modern technologies to facilitate offshore fishing ventures. Additionally, investing in opportunities to promote alternative sources of income will reduce pressure on the existing fishery resources.



**Evaluation of the industrial longline fishery from Exclusive Economic Zone of Kenya****Kimani, E.,\* Okemwa, G., Athman, A., Ontomwa, M., Omukoto, J.**

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Marine fisheries resources and the activities that surround their use support Kenya's economy and provide livelihoods, income, and employment to thousands of people. Kenya marine fishery production totals about 24,000 mt, worth KES 4.6 billion annually. Eighty percent of the marine fishery production is from nearshore artisanal fisheries, while 20% is from industrial fisheries. The offshore industrial fishery for tuna and other pelagic species can significantly improve marine fish landings and land-based economic activities within the blue economy initiative. This report evaluates vessel licencing, commercial fisheries data from longline vessels registered in Kenya as well as fisheries observer data collected between 2016 and 2018 to determine the catches and potential for further development. Over 30 commercial fishing licenses are issued annually, allowing access to the fish resources within the Kenya EEZ. Tuna and swordfish dominate shallow water longline catches while swordfish, shark, and tuna dominate in deep water catches. The catches for 1,000 hooks range between 200 kg and 4,000 kg for each fishing event. Initial spatial analysis showed that most of the fishing effort is concentrated in the southern part of the EEZ. A marked seasonal pattern in the abundance of the catches was observed, where the highest catches are realised during the SEM months from April to June. The discarded species are dominated by shark and swordfish. The expansion of this sector may contribute immensely to the development goals of the coastal region through appropriate policies and bilateral agreement to maximize the rent benefits and improve data collection while developing a national fishing fleet and land-based infrastructure by encouraging investment in the sector.

**Growth rates of Eucheumoids (Rhodophyta; Gigartinales) cultured using modified off-bottom and floating raft techniques in the Kenyan coast****Kimathi, A.,<sup>1\*</sup> Wakibia, J.,<sup>2</sup> Gichua, M.<sup>2</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Kenya<sup>2</sup>Jomo Kenyatta University of Agriculture and Technology, Kenya

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Recent studies have shown that relocation of seaweed farms from shallow water to deeper water environments reduced the risk of 'ice-ice' syndrome on these seaweeds, thus improving their growth rate and biomass (Msuya et al., 2014). However, the studies have not been specific on the best culture technique for adoption in deep water environments. Recognizing the fact that seaweed biomass production could also be affected by other factors such as wind patterns (Hurtado et al., 2001) and water quality (Msuya et al., 2014), the present study determined the growth rates of *E. denticulatum* and *K. alvarezii* cultured using two deep-water culture techniques (floating raft [FR] and modified off-bottom [MB]) in the southern coast of Kenya. The impact of these factors on farmed seaweeds was also investigated. The results from the study were critical in enhancing seaweed production strategies, with a focus of formulating a sustainable national seaweed policy that can contribute to the expectations of Kenya's emerging blue economy.

### Influence of land use change on greenhouse gas emission (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O) in a tropical wetland in Kenya

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Wetlands exert effects on both global and regional climate change through the storage of carbon and the emission of potent greenhouse gases into the atmosphere. While greenhouse gas emissions have been well studied in the temperate wetlands, similar studies are almost absent in wetlands of sub-Saharan Africa, which are currently under intense anthropogenic pressure. Drive for economic growth, agricultural practices, and urban development have been reported to be the major threats to wetlands and their biota, mainly through drainage, clearing, and reclamation for subsistence crop production. Consequently, wetlands in Africa continue to be converted into farmland, thereby altering the hydrology of the wetlands and in turn resulting in less carbon sequestration leading to increased emission of GHG. Carbon sequestration in natural ecosystems such as wetlands is one of the options proposed to reduce the GHG effect. Hence there is a need to understand the emissions of the GHG from natural wetlands and whether conversion into farmlands influences their emissions. A study was conducted between December 2017 and January 2018 in Anyiko wetland, Siaya County, Kenya to assess the influence of wetland conversion into farmland on GHG (CH<sub>4</sub>, CO<sub>2</sub> and N<sub>2</sub>O) emissions using the static chamber method. The study compared CH<sub>4</sub>, CO<sub>2</sub> and N<sub>2</sub>O emissions between farmland (unfertilized cocoyam farms) and natural areas of a tropical wetland. Overall farmland had a tendency of higher greenhouse effect as compared to the natural wetland. The study found that farmland was a probable sink for CH<sub>4</sub> with flux ranging from -0.07 to 0.09 mgm<sup>-2</sup>h<sup>-1</sup>, and a source for CO<sub>2</sub> and N<sub>2</sub>O (221.86± 17.86 mgm<sup>-2</sup>h<sup>-1</sup>, 187.06±25.41 μgm<sup>-2</sup>h<sup>-1</sup> respectively). While unconverted area was a source for CH<sub>4</sub>, flux ranged from 5.32 to 40.59 mgm<sup>-2</sup>h<sup>-1</sup>. Conversion of wetland to farmland results in a reduction in CH<sub>4</sub> emission, while CO<sub>2</sub> and N<sub>2</sub>O fluxes increase.

### Occurrence and ingestion of microplastics by zooplankton in Kenya's marine environment: First documented evidence

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Microplastics can be ingested by marine organisms and may lead to negative impacts at the base of marine food chains. This study investigated the occurrence and composition of microplastics in the sea-surface water and sought evidence of ingestion by zooplankton. Surface seawater was collected using a stainless-steel bucket and sieved directly through a stainless-steel sieve (250-μm mesh), while a 500-μm mesh net was towed horizontally to collect zooplankton, at 11 georeferenced stations off the Kenyan coast in February 2017, on board the national research vessel *RV Mtafiti*. Microplastic particles were sorted and characterised using an Optika dissecting microscope. Polymer types were identified using an ALPHA Platinum attenuated total reflection—Fourier-transform infrared (ATR-FTIR) spectrometer. A total of 149 microplastic particles, with an average abundance of 110 particles m<sup>-3</sup>, were found in the surface seawater. A total of 129 particles were found ingested by zooplankton groups, where Chaetognatha, Copepoda, Amphipoda, and fish larvae ingested 0.46, 0.33, 0.22, and 0.16 particles ind.<sup>-1</sup>, respectively. Filaments dominated both the surface-water microplastics and the ingested microplastics, contributing 76% and 97% to those compositions, respectively. White particles were prevalent in the water (51%), whereas black was the colour found most commonly (42%) across the zooplankton groups. The sizes of particles that were in the water were in the range of 0.25–2.4 mm, and those ingested ranged between 0.01 and 1.6 mm. Polypropylene was predominant in the surface water, whereas low-density polyethylene was the most-ingested polymer type. The results provide the first documented evidence of

the occurrence, composition, and ingestion of microplastics by zooplankton in Kenya's marine environment, indicating that microplastics have the potential to enter pelagic food webs and cause pollution in the study area.

**KYULE, DOMITILA**

**POSTER**

### **Characterization and antibiotic response patterns of bacterial isolates from fish and fish products retailed in Kenyan markets: A case of Kirinyaga County**

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Ensuring safe aquaculture products has been one of the major challenges and concerns for many fish farmers, traders, and consumers in developing countries. This is attributed to contamination of fish and fish products by pathogenic and spoilage micro-organisms that are resistant to multiple antibiotics. Additionally, the use of antibiotics in fish farming for prophylaxis or therapy has resulted in the transfer of antibiotic-resistant genes, thus establishing a reservoir for resistant microorganisms. This study was carried out to determine the level of microbial contamination of fish products and antimicrobial response patterns of the isolated bacteria isolates using commonly used antibiotics. Fish and fish products samples were sampled from fish traders in five markets from Kirinyaga County. The bacteria cultures were enumerated and sub-cultured to obtain pure cultures used to describe their morphological and biochemical characteristics. The KIRBY-BAUER agar diffusion method was used to carry out the antibiotic susceptibility testing. Based on morphological characteristics, a total of 59 morpho-groups were obtained and were confirmed by biochemical characterization. There was a significant difference ( $p = 0.001$ ) and interaction ( $p = 0.037$ ) of average bacteria count obtained from different fish products and markets. Fish treatment resulted to a significant difference ( $p = 0.001$ ) on mean for CFUs. There was a significant difference in the action of tetracycline, streptomycin, ampicillin, ciprofloxacin, gentamycin, and penicillin against the bacterial isolates ( $P = 0.001$ ). The study suggest that fish and fish products harbor multi-resistant bacterial isolates that can aid in the dissemination of resistance genes. There is a need for continued research on the screening of antimicrobial resistance genes and horizontal gene transfer (HGT) in fish foodborne pathogens and correlation between antimicrobial resistance and virulence features.

**MAKAME, ALI**

**POSTER**

### **Diel patterns of macroinvertebrate drift in River Sosiani, Kenya**

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The unidirectional flow of rivers and streams continuously transports invertebrates downstream through a process of drift. The organisms that temporarily leave the streambed and do not resist the drag strength constitute the drift assemblage. Drift is an important aspect in the study of macroinvertebrate communities since it contributes to secondary production in rivers and therefore affects the distribution and abundance of insectivorous fish and other predators. Although there are a number of studies on drift in temperate rivers, similar studies are scarce in the tropics. They are important in understanding assemblage structure and ecological processes in tropical rivers. This study therefore aimed at bridging the gap. Drift patterns were studied in mid-reaches of the River Sosiani, a rural-urban river, in Kenya. Sampling for macroinvertebrates was done in three stations along the river, at repeated intervals of three hours, for a period of 24 hours during the dry season (March 2019). Macroinvertebrates were sampled at each station using three replicate drift nets of 0.6 mm mesh size. During each sampling occasion, the water quality parameters of temperature, dissolved oxygen, conductivity, TDS, salinity, and pH were measured in situ at each station. Data emanating from the study are being analyzed to determine the taxonomic groups in drift and their distribution between stations. Temporal patterns of abundance of the taxonomic groups will be related to water quality parameters through multivariate analysis to determine peak periods of drift and the drivers of drift for different macroinvertebrate taxa. The results will be used to infer spatio-temporal patterns of drift and the drivers of drift assemblages. The findings will have implications for the management of the River Sosiani catchment with regard to potential

anthropogenic influences on secondary production of the river, and will be complemented with rainy season data.

**MAREMWA, JULIUS**

**POSTER**

### **Wind energy conversion system in aquaculture initiatives in the conservation of great lakes of east Africa**

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There is a need to conserve the great lakes by initiating other fish-farming methods. The great lakes are overexploited by fishermen and pollution from agricultural and industrial activities. Lake Victoria has challenges with water hyacinth reducing fisheries and transport activities. Also, the emergence of cage fish farming has interfered with biodiversity. People are realizing that wind energy can serve as an alternative to fossil fuel in electricity generation. The technology advancement to harness power from wind energy would help in cost reductions in generation. Wind energy possess a unique opportunity to directly leapfrog the path taken by industrialized countries to renewable energy. A mathematical model of wind turbines is essential as it allows development of the comprehensive control algorithms required in optimal operation of a wind turbine. This paper attempts to address the general objectives of wind turbine modelling, and the model results are useful in fish and aquaculture generation by reducing costs.

**MASESE, FRANK O.**

**POSTER**

### **The Savanna River Ecosystem Model: The influence of large mammalian herbivores on the structure and function of savanna river systems**

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We present the 'Savanna River Ecosystem Model (SREM)' for rivers draining savanna and grassland ecosystems that have traditionally supported populations of large mammalian herbivores (LMH). It is well recognized that LMH significantly modify the structure and function of river ecosystems in these landscapes. This is achieved through the transfer of nutrients and organic matter from terrestrial landscapes to aquatic systems by various mechanisms, including excretion and egestion during watering or resting and drowning during migration. This lateral connectivity between savanna rivers and their terrestrial surrounding occurs at locations in the river network for which allochthonous inputs are traditionally rarely conceptualized. Thus, at a large spatial scale, savanna rivers may function differently compared to predictions by most existing models of riverine ecosystem functioning. Drawing from literature and data on savanna rivers in Africa, where wild LMH populations are still important, we have developed a conceptual model that recognizes the role of LMH as major drivers of ecosystem structure and function. The influence of LMH is dependent upon the characteristics of the LMH (e.g., species, number of individuals, behavior) which interact with the characteristics of rivers (e.g., stream size, flow regime) to drive trophic structure and important ecosystem functions like metabolism, nutrient processing, and outgassing of greenhouse gases. Such influences in the aquatic domain also produce feedback for LMH themselves, e.g., by affecting their distribution as a consequence of impacted water quality. We place our findings in a broader context that captures the role of LMH in rivers globally. Further, we explore implications of our findings for the understanding and management of rivers in increasingly altered landscapes, where large populations of wild LMH have either been lost or displaced by livestock. Finally, we make recommendations for future research and propose actions needed to preserve savanna rivers.

**Functional traits illuminate the selective impacts of different fishing gears on coral reefs****Mbaru, E.,<sup>1\*</sup> Graham, N.,<sup>2</sup> McClanahan, T.,<sup>3</sup> Cinner, J.<sup>4</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Kenya<sup>2</sup>Lancaster University, England<sup>3</sup>Wildlife Conservation Society, United States of America<sup>4</sup>ARC Centre of Excellence for Coral Reef Studies, Australia

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Unsustainable fishing is a major driver causing change in marine ecosystems. Interactions between different fishing gears and their role in targeting species abundance and associated ecological functions are unclear, particularly in complex, multi-species fisheries. Here, we examine whether artisanal fishing gears remove and potentially compete for fishes with unique combinations of functional traits (diet, body size, depth, position in water column, period of activity, schooling behaviour) in a coral reef ecosystem. We use coral reef fish landing data from 25 sites across Kenya over a seven-year period.

All gears seem to target a wide diversity of functional traits, but with some differentiation between gears. Fish assemblages captured by spearguns are significantly different from the other gear types, specialising on diurnal species that feed on sessile invertivores. Nets, including gillnets and beachseines, target the greatest breadth of functional diversity, whereas escape slot traps target the least functionally diverse assemblages. Basket traps and escape-slot traps target the most functionally similar species of all two-gear combinations. Of the 163 functional entities (unique combinations of functional traits) captured in the fishery, functional entities that make up only a small proportion of the catch account for most of the differences in gear selectivity. The identification of unique and rarely targeted functional entities illuminate the effect of specific fishing gear on assemblage functioning. Total catch provides weak insights on differences in gear selectivity, whereas dominant catch alone cannot be used as a broad-scale indicator of the potential impact of fishing on assemblage functioning. The findings highlight the need to disaggregate catch in proportions when examining potential ecosystem impacts of fishing.

**Effects of phytoplankton and water quality dynamics on Nile tilapia in breeding concrete ponds at KMFRI, Mombasa Centre****Mirera, D., Fulanda, A., Olando, J., Muendo, C\***

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In an effort to increase production from aquaculture in the coastal areas, hatchery systems have been established at the KMFRI centre in Mombasa to supply quality seeds. The hatchery facility use borehole water with a salinity of 3.5–4.0 ppt and has been observed to have high algae die-offs, which quickly cause deterioration of water quality in the breeding facilities. Therefore experiments were set to investigate the water quality and algae dynamics in the two breeding ponds with dimensions of 3 by 5 and 10 by 15. Nile tilapia brood fish were stocked, and feeding was done twice a day using formulated feeds provided by the center. Data on water quality was collected using a multi-parameter probe in mid-morning and mid afternoon. The parameters investigated were dissolved oxygen (D O), salinity, conductivity, PH, total dissolved solutes (TDS), and temperature. Algae sampling and identification was taken once a month to assess diversity and abundance of the species. Water quality parameters fluctuated between midmorning and midafternoon, as follows: dissolved oxygen 2.74–5.00 mg/l, temperature 29.8° C–34.3° C, pH 6.0–8.28, conductivity 7,659–8,322 µS/cm. Phytoplanktons were mainly dominated by brown algae (diatoms) that are not good for fish growth as they affect water quality. The research pinpoints the need to control the brown algae to enhance water quality in the breeding facilities.

**Challenges in management of fish protected areas in Lake Baringo, Kenya****Mugo, J.,\* Odoli, C., Nyakeya, K.**

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Lake Baringo fishery is currently under perturbation, with large annual fluctuations in the catches/species ratio. In an attempt to remedy the declining fishery, KMRFI, the Fisheries Department and BMUs identified and demarcated three fish-breeding areas for protection. To assess the impact of demarcated fish-breeding areas, three gangs of multifilament gillnets (1–8 inches) were set on a quarterly basis within demarcated areas and fishing areas. Fish species abundance, size structure, and maturity stages were analysed on fish samples caught. Fish species abundance was higher inside the demarcated areas (67.8%) than in the fishing areas (32.2%). *Barbus intermedius* was the most abundant (56.7%), followed by *Oreochromis niloticus* (26.0%) and *Labeo cylindricus* (14.5%). Even though higher sizes were recorded inside demarcated areas than fishing areas, they were not statistically different. The majority of the fish (more than 90%) were in gonad stages 1 and 2 both inside the demarcated and fishing areas, likely due to fishing pressure. The impact of the three demarcated breeding areas on lake fishery productivity is not fully appreciated. There is noncompliance by fisher folk who have continued to fish inside the demarcated fish breeding areas. It is recommended that stakeholders, especially BMUs and the Baringo County Department of Fisheries should focus their efforts to actualize the protection of demarcated fish-breeding areas in Lake Baringo. The fisher community should be sensitized on the need to embrace demarcated areas as no-fishing zones. More intensive studies and strategies for increasing fish production should be conducted.

**Developing ecosystem health indicators in large lakes: Lake Ontario coastal and pelagic zone example****Fitzpatrick, M., Munawar, M.,\* Niblock, H.**

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Biological indicators of ecosystem health are needed that move beyond traditional chlorophyll, transparency, and nutrient measures of trophic state. We explored a variety of structural and functional food web parameters in different habitats of Lake Ontario, ranging from oligotrophic to eutrophic habitats. The results indicated that the eutrophic habitats (in this case Hamilton Harbour and the Bay of Quinte) were remarkably similar in terms of total phosphorus (30–40  $\mu\text{g l}^{-1}$ ) and chlorophyll a (15–20  $\mu\text{g l}^{-1}$ ), but were quite different in terms of nitrogen (nitrate) and silica, which in turn affects phytoplankton biomass, composition, and productivity. For example, phytoplankton biomass in the Bay of Quinte averaged 4.1  $\text{g m}^{-3}$  over the growing season compared to 2.6  $\text{g m}^{-3}$  in Hamilton Harbour. Other factors, including microbial composition and bacterial growth rates, can also be used to characterize differences among habitats. Regardless, all factors have important implications for ecosystem health. This paper summarizes multiple biological (microbial and planktonic) indicators in relation to trophic state and discusses the utility of standardizing more comprehensive measures of ecosystem health for global applicability.

**Livelihood impacts and adaptation in fishing practices in response to changes in the upwelling region under East African coastal current****Ochiewo, J.,<sup>1</sup> Munyi, F.,<sup>1\*</sup> Waiyaki, E.,<sup>1</sup> Kimanga, F.,<sup>1</sup> Karani, N.,<sup>1</sup> Kamau, J.,<sup>1</sup> Mahongo, S.<sup>2</sup>**<sup>1</sup>Kenya Marine & Fisheries Research Institute, Kenya<sup>2</sup>Tanzania Fisheries Research Institute, Tanzania

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The study was carried out at Amu and Shela in Lamu County and Ngomeni in Kilifi County on the coast of Kenya, where small pelagic fisheries are an important source of livelihood. The study focused on the vulnerability, resilience, and adaptation options for fisheries dependent communities in the EACC upwelling areas. Multi-stage sampling was adopted where data was collected through direct observation, semi-structured interviews, key informant interviews, and oral histories. Descriptive and non-parametric approaches were used to analyze data. Results indicated that fishing effort was higher during the North East monsoon season (48.9%), South East monsoon season accounted for 27.2%, while others indicated both seasons (21.7%) and the inter-monsoon period accounted for 2.2%. Approximately 39% of the respondents cited calm sea and favourable weather as the best conditions for fishing. An association between location and responses on availability of small pelagics across seasons was evident,  $X^2(9, n=92) = 0.292, p=0.005, \phi=0.506$ . Seine nets and monofilament nets were the main fishing gear commonly used. Fifty-two percent of the respondents targeted small pelagics attributing changes in climatic and oceanographic conditions with negative impact. This resulted in increased fishing effort, instigating a decline in the quantity of fish caught per fisherman and changes in the composition of fish species. This further led to a decline in income, and increased prices of fish. The current study underscores the need for increased stakeholder engagement characterised by both government and traditional regulations targeting the management of the small pelagic fishery. Additionally, deliberate efforts should be made to introduce alternative livelihoods that will reduce pressure on the small pelagic fishing activities in the area. These recommendations will lead to improved livelihoods and income of the fishers, enhanced adaptive capacity to climate change, sustainable harvesting, and enhanced community participation in the management of small pelagic fisheries.

**The extent of cage aquaculture, adherence to best practices and reflections for sustainable aquaculture on African inland waters****Musinguzi, L.,\* Ogutu-Ohwayo, R.**

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Cage aquaculture is expanding on African inland waters and has the potential to close the fish supply deficit in the region and provide other social benefits such as employment and income. However, if not appropriately guided and regulated, cage aquaculture could become unsustainable, causing conflicts with other water uses, environmental degradation, and economic losses to aquaculture enterprises. To enhance sustainability of cage aquaculture on the African inland waters, we developed an inventory of cage aquaculture installations on the waters and used it to investigate the distribution and magnitude of cage aquaculture and adherence to best practices for sustainable cage aquaculture. Our results show evidence of spatial expansion of cage aquaculture on the African inland waters, with varying magnitude across and within water bodies and partial adherence to best practices. Cage aquaculture was confirmed on 15 water bodies which together share 242 installations with more than 15,000 cages. Lakes Victoria, Kariba, and Volta, and the River Volta host 89.7% of cage aquaculture installations on the African inland waters and are designated as hotspots of cage aquaculture. Contrary to best practices, evidence shows cage aquaculture installations entirely or in close proximity to protected areas, in eutrophic and hypertrophic waters, shallow water bodies and sites ( $\geq 5$  m average depth) and close to the shoreline. Cage aquaculture is qualified as an additional stressor to the African inland waters and since it is expected to continue expanding, adherence to best practices should be promoted for sustainability.

**A comparison of ecological attributes in degraded and healthy seagrass beds in coastal Kenya****Muthama, C.,<sup>1\*</sup> Uku, J.,<sup>1</sup> Kaunda-Arara, B.,<sup>2</sup> Daudi, L.<sup>1</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Kenya<sup>2</sup>University of Eldoret, Kenya

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Ecological attributes of degraded and healthy seagrass beds were compared in three sampling stations of Kenyan coast for five months (April–August 2016). Sampling was done off Mwaepi, Mvureni, and Kinondo in plots of 20 m<sup>2</sup> at a depth of 2–3 m during low spring tide. Two plots were targeted in each station, a degraded plot and a healthy plot, resulting in 6 plots sampled monthly. Seagrass cover, shoot density, and canopy heights were assessed alongside sediment macrofauna, organic matter, and nutrients. Healthy plots had higher cover (>80%) than degraded plots (<40%) and thus were significantly different (H=213.163; p=0.001). Healthy plots had higher shoot densities compared to degraded areas as well as a higher diversity of sediment macrofauna (Shannon-Weiner Diversity Index, p=0.0127). 27 taxa were encountered with higher abundance in healthy plots than in degraded plots (p=0.0051). ANOSIM showed higher faunal densities in healthy plots than in degraded plots (R=0.25; p=0.001), whereas an MDS showed a weak relationship of fauna densities to healthy plots compared to degraded plots. Organic matter and nutrients in sediments were not significantly different between degraded and healthy plots (H=2.892; p=0.089). CCA predicted that more fauna taxa in the sediments are controlled by organic matter content than by nitrates and nitrites. In conclusion healthy seagrass beds are better in fauna assemblages. Higher shoot density and percent cover of seagrass, provide high macrophyte complexity, to offer more space, microhabitats and resources for fauna. Proximity to degraded areas can influence the fauna and nutrients availability. We recommend restoration of degraded seagrass beds to help achieve the full benefits of healthy seagrass beds. If the degrading agent is managed, then natural regeneration is the best option economically to allow recovery through succession stages.

**Current health status, approaches to disease handling and biosecurity application in the cage culture of *Oreochromis niloticus*: A case study of Lake Victoria, Kenya****Mwainge, V.,<sup>1\*</sup> Ogwai, C.,<sup>1</sup> Mwamburi, J.,<sup>1</sup> Mulanda, C.,<sup>1</sup> Nyamweya, C.,<sup>1</sup> Mutie, A.,<sup>2</sup> Ombwa, V.,<sup>1</sup> Nyaboke, H.<sup>1</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Kisumu, Kenya<sup>2</sup>Kenya Marine and Fisheries Research Institute, Naivasha, Kenya

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Cage aquaculture has been on a rapid upward trend in Lake Victoria, Kenya since 2016, resulting in the current figure of over 3,600 cages culturing *O. niloticus*. Unfortunately, there has been limited if any focus on fish health aspects. A rise in intensification and commercialization predisposes fish stocks to disease due to rise in stress levels and consequent reduction in the fish immunity. This study encompassed studies from 2016 to 2018 using 1) standard procedures and protocols and socio-economic studies, and 2) structured questionnaires. Bacterial infections, fungal infestations, myxosporean parasites in the gills, parasitic infestations by copepods, and fin rot were recorded in the stocks. Biosecurity is seldom practiced, while sodium chloride is applied as a prophylactic for fungal infections. This review provides information on the health status of the stocks under culture and highlights the current approaches to disease management in the cages and gaps in disease management, proposes biosecurity measures, and suggests avenues for policy formulation towards sustainable utilization of the lake's resources.



**Towards sustainability: bio availability of zooplankton as a supplement to exogenous feeds in the cage culture of *O. niloticus*: A case study of Lake Victoria, Kenya****Mwainge, V.,\* Okechi, J., Mwamburi, J., Ogwai, C., Mulanda, C., Nyamweya, C., Ombwa, V., Nyaboke, H.**

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Cage farming of *O. niloticus* has picked up rapidly in the Lake Victoria, Kenya portion. However, there have been rising concerns on its environmental impact on the general ecosystem on a temporal scale. Fish feeds have been cited as one of the pollutants, since they increase the nutrient loads in the cages and consequently in the lake. This study was conducted to determine the impact of cage culture on zooplankton diversity and abundance by assessing the cages and control sites of selected cage establishments in Lake Victoria, Kenya. Data was collected from cage establishments between October 2016 and October 2017 by using standard procedures and protocols. Findings showed a higher diversity and abundance of zooplankton in cage sites as compared to non-cage sites ( $p < 0.05$ ). This would suggest that tilapia cultured in cages benefit from natural organisms which they feed on from the water column. These organisms are rich omega-3 and other essential fatty acids that confer protection to the fish - more so for the larval and juvenile stages of *O. niloticus*, since zooplankton are a critical component in their early development as it boosts their growth, development and immunity to fight infections by providing the essential omega-3 fatty acids (DHA and EPA). However, there is a need to closely monitor the nutrient load at the cages to avoid creating eutrophic situations. Moreover, since fish in cages feed on zooplankton in the water as a supplement, this would go a long way in reducing the influx of nutrients into the lake in the form of waste feeds hence protecting the ecosystem and cutting down on input costs for the investors.

**Fish cage culture in Lake Victoria (Kenya): Fisher community perspectives on the impacts and benefits for better decisions on management and sustainable development of the lake water resources****Mwamburi, J.,\* Yongo, E., Omwega, R.**

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Aquaculture is the future bridging gap for the declining capture fisheries. The fish cage culture in Lake Victoria (Kenya) is currently on the increase, according to the recent overview surveys of 2016–2017. To date, the majority of aquaculture practices have had few adverse effects on ecosystem. However, due to the potential positive and negative impacts, there are varied opinions on the actual social impacts and threats on the lake ecosystem. The fisher community perspectives on the nascent and growing technology on culture of Nile tilapia since its onset in 2005 were assessed using four selected sites. Both structured questionnaire and socio-economic activities along the fish landing beaches on Lake Victoria, Kenya were used, based on the presence of beach management units (BMUs), fishing and potential for cage activities, to assess the respondent's perception on and attitudes towards new fish cage culture method. Few people are involved in cage culture activities since this is a relatively new technology. Results from 78 randomly selected respondents from four sites of Ngore, Ragwe, Sindo, and Nyandiwa beaches showed that fishing and fish trading were the main types of occupation. All the respondents have used and benefited from fish and fishery products for 1–46 years, with a mean of 11 ( $\pm 8$ ) years. The notable positive impacts include creation of employment opportunities throughout the fish value chain; and development of new and improved rural infrastructure and road networks along the lake coastal zones. Potential impacts and advantages of cage farming over other fish culture methods are highlighted. From the preliminary socioeconomic surveys data and distribution of cages, valuable measures that management agencies should consider are outlined to support sustainable investment and development of cage culture in Lake Victoria.

**Population dynamics of *Otolithes ruber* from commercial prawn trawl by catch in Malindi-Ungwana Bay fishery, Kenya****Mzingirwa, F.,\* Nyamora, J., Omukoto, J.**

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*Otolithes ruber* belongs to the family Scianidae and is distributed throughout the Indian Ocean along the east coast of Africa and West Pacific ocean. *O. ruber* is being caught in large quantities as by-catch by commercial prawn trawlers and by gillnets and handline by artisanal fishers. Since this fish is being caught in such large numbers, there is a concern that the fish could be overexploited, hence the reason for the study. The study was therefore conducted to determine biological parameters of *O. ruber* in Malindi-Ungwana Bay, Kenya. Data was collected by observers from commercial trawl by catch from 2016 to 2018. FISAT – II software was used to analyse length frequency data and biological reference points. The asymptotic growth length ( $L_{\infty}$ ) and growth parameter (K) was estimated as 40.95 cm and 0.56, respectively. Total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation rate were estimated as 1.25, 1.08, 0.17 and 0.13, respectively. Biomass per recruit model estimated the following parameters: optimum sustainable yield (E50), economic yield (E10), and maximum sustainable yield (E<sub>max</sub>) as 0.278, 0.35, and 0.421, respectively. Results from the study showed that *O. ruber* had maximum recruitment during the month of October and November and minimum recruitment during the months of March and April. Low value in fishing mortality (F) showed that overfishing of these fish had not occurred in Malindi-Ungwana Bay, and fishing effort should be increased to achieve maximum sustainable yield. Natural mortality was the main cause of fish removal/decrease from the environment. It was concluded that *O. ruber* in Malindi-Ungwana bay is at its steady state and no threat of over-exploitation was observed.

**Co-existing with reality: Lessons learnt from a comparison of calibrated and uncalibrated Ecopath with Ecosim models****Natugonza, V.**

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There has been a rapid rise in the development of ecosystem models over the past two decades. Ecopath with Ecosim (EwE) is the most widely used ecosystem modelling tool globally, but also embodies the highest number of uncalibrated ecosystem models. A total of 20 EwE models exist on the African Great Lakes, but none of these models is calibrated with observational data (“reality”). There is a need to examine the scope and scale of differences between predictions from calibrated and uncalibrated EwE models. In this study: (i) we created a calibrated EwE model for Lake Victoria for the period 1960–2015; (ii) we created an uncalibrated model for the period 2010–2015; and (iii) we simulated future biomass changes in each model using five different fishing scenarios. Results showed limited capacity of uncalibrated EwE models with default parameters to predict similar outcomes as the calibrated model, largely due to inconsistencies in biomass accumulation parameter in Ecosim. We learned that predictions across models can be fairly consistent if: (i) the uncalibrated model is rigorously parameterised, utilising adequate knowledge about the system; (ii) adequate information exists on annual rate of biomass change for individual functional groups, especially for low productivity groups; (iii) representation of trophic interactions is precise, utilising robust stomach content data, and (iv) predator-prey interactions are controlled through mixed trophic control mechanisms. The importance of this work is in assessing the level of confidence that can be attached to any policy advice from uncalibrated models whenever time-series observational data are not available (“co-existing with the reality”).

**Sex reversal dynamics of Nile tilapia (*Oreochromis niloticus*) and impact on growth performance****Nduku, G.,\* Jared, N., David, M.**

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The Nile tilapia (*Oreochromis niloticus*) is one of the most economically important freshwater species for finfish aquaculture globally. In commercial farming of *O. niloticus*, over-reproduction during grow-out is a major problem. For this reason, production of all-male populations of tilapia is desirable and this has been identified as one of the most effective techniques to increase growth and production. Various methods have been used to produce all male tilapia, i.e. use of hormone treatment (17- $\alpha$  methyltestosterone), use of temperature shock, and the current YY technology. However, the latter two methods have limited documentation in Kenya. Therefore, the current study aimed at comparing the effectiveness of temperature and hormone sex-reversed *O. niloticus* fry and impact on growth in hapa nets for a period of 3 months. Nile tilapia fry of 3 days old after egg yolk were used in the experiments over a period of 14 days. Hormone use involved making a dose of 60 mg/kg of feed while temperature shock involved raising the temperature to between 30 and 34° C. Analysis for SGR using one way ANOVA showed no significant difference between hormone- and temperature-induced sex-reversed fish ( $F=0.0975$ ,  $P=0.7705$ ). Sex-reversal efficacy of 93.33% and 92.86% was attained using MT and temperature shock, respectively. In conclusion, temperature shock could be used as an alternative method to the use of hormone for sex reversal of *O. niloticus* fry.

**Multi-agent systems and distributed constraint satisfaction for decision support in aquatic ecosystems****Ngisiange, N.,<sup>1\*</sup> Rimiru, R.,<sup>2</sup> Okeyo, G.<sup>2</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Kenya<sup>2</sup>Jomo Kenyatta University of Agriculture and Technology, Kenya

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An aquatic ecosystem is a dynamic, complex system that is subject to certain constraints relating to its physical design, hence strategic decision making is a major problem. Its management is highly distributed, timed and resource constrained, and is based on the elements of scalability, complexity, balance, collaboration, and adaptability. So far none of the management initiatives achieve all of these elements.

Two strong computational paradigms can be used to engineer solutions to such complex real-world problems. Multi-agent systems have gained much, especially in nonlinear dynamics. Powerful techniques like Distributed Constraint Satisfaction (DCSP) can solve assignments whose problem variables are subject to constraints using a search algorithm. They are known to employ decentralized strategies in groups to manage a variety of challenging tasks quickly, accurately, robustly, and adaptively in a dynamically changing environment. This study applied a multi-agent system (MAS) model using the distributed constraint satisfaction search technique (DCSP) i.e. asynchronous back tracking (ABT), to explore the impact of different management decision strategies on aquatic ecosystems management problems for ex-ante assessments. The model starts with problem formulation using one economically important species i.e. Rabbitfish, its interaction within a one-kilometre square grid sample transect, and how multiple decision strategies affect the species state as they are implemented. The model was analysed while testing the decision strategies. The output was statistically validated using two paired T tests with an alpha of 0.05 showing a lower bias and a high variance with p value of 0.02, an indication of a lower prediction error. The results confirm improved decision support through the use of the proposed model, hence timely and less costly decisions.

**Macrophytes management for improved fisheries productivity: Winam Gulf**

**Nyaboke, H.,<sup>1\*</sup> Sudoi, V.,<sup>2</sup> Mbeva, D.,<sup>2</sup> Aura, C.,<sup>1</sup> Nyamweya, C.,<sup>1</sup> Mwamburi, J.,<sup>1</sup> Nyaundi, J.,<sup>1</sup> Ongore, C.,<sup>1</sup> Gichuru, N.,<sup>1</sup> Okechi, J.<sup>1</sup>**

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Several lacustrine ecosystems are being characterized by cyclical patterns of water hyacinth emergence, growth, disappearance, and reappearance. With specific reference to Lake Victoria, this has seen impacted areas record a deteriorating water quality environment. However, information on the effect on fish growth and the condition and diversity of the resultant water quality in water hyacinth hotspots is limited. Using trend data from trawl surveys (2011–2019), we assessed species richness, condition factor and length-weight relationship within Winam Gulf in known water hyacinth hotspots. We compared the impact of physico-chemical parameters on fish dynamics. The mid-gulf recorded more species diversity than the inner gulf, which was dominated by the indigenous *Synodontis victoriae*. Growth assessment for Nile perch was poor at  $b < 3$ , indicative of negative isometric growth compared to robust conditions observed in the least impacted open lake. The population of tilapia from wild catch dropped to near zero in trawl catches of 2019. The findings bring into question the Winam Gulf's fisheries productivity and potential to support diversification and investment in fisheries in the wake of continued macrophyte coverage that impairs water quality.

**A review of studies, and the way forward for sustainable exploitation of Lake Baringo resources: Is there a basis for collaboration and donor funding?**

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Lake Baringo became a Ramsar site in the year 2002 due to its rich biodiversity. Five fish species support artisanal fishery, and at least 500 bird species are found here. Other biodiversity includes hippos, crocodiles (*Crocodylus niloticus*), and snakes. Of significance is the presence of the endemic *Oreochromis niloticus baringoensis*. To the west of the lake lie Tugen escarpments. The lake has seven islands, one of which hosts a community conservancy, and at the central part of the lake lie hot springs. All these features attract thousands of both local and international tourists. Interestingly, it is a lake in an arid area supporting three pastoral communities (Pokot, Icchamus, and Tugen), a symbol of three “African cooking stones” hence a unifying factor of these communities. In spite of its ecological and socioeconopolitical role, the lake faces serious environmental stress that requires “first aid” before embarking on intensive research to understand the cause of degradation. This calls for partnerships and collaborations towards securing research funds from like-minded donors to save Lake Baringo. This study reviewed past and present studies in Lake Baringo in order to elucidate their achievements, failures, and/or challenges to inform management for sustainable exploitation via partnerships/collaborations. Several limnological studies have been conducted in the lake to guide management and inform decision making since the 1920s when the first expedition was undertaken by the Cambridge team of scientists. However, little has been achieved because the ecosystem's integrity is in jeopardy. The *Oreochromis niloticus baringoensis* fishery contributes <1% of fish landings from >70%. Siltation and sedimentation, along with high fluoride levels have taken a toll. Proposals have been made to address these challenges but with no yield, hence the need for collaborations to secure funds for research.

**Ecological modeling of the Lake Victoria ecosystem**

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Lake Victoria is faced with human-induced pressures such as overfishing, introduction of alien species, increased eutrophication, and climate change impacts. Its large spatial extent and complex ecology have also limited the understanding of the system dynamics. To address this challenge, Atlantis, the first end-to-end whole ecosystem model for the lake was developed. The model was spatially resolved into 12 unique dynamic areas based mainly on their biophysical attributes. A total of 38 functional groups constituted the biological model while fishing was implemented by four fleets with different targeting options. The model revealed complex inter-specific relationships among the biological groups. For example, the introduced Nile perch (*Lates niloticus*) exhibited a strong negative correlation with haplochromine cichlids (their prey) as well as most of other fish groups. This brings to the fore the significance of predator-prey relationships and the impact of introduced species; information that is critical for effective fisheries and ecosystem management. The model was then used to simulate the impact of different fishing scenarios on the ecosystem. The effects of these scenarios were tested using six common ecosystem-level indicators. Predictions showed that no particular scenario excels in all the six indicators. However, halting harvesting of haplochromines results in the highest yield of commercially important species and possibly causes minimal disruption to fishing activities. The findings of this study reinforce the need for an ecosystem approach to fisheries management in Lake Victoria.

**Numerical simulation of long term circulation patterns in Nyanza Gulf, Lake Victoria**

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Nyanza Gulf is a large embayment in the north-eastern part of Lake Victoria. The gulf was constricted at Mbita point following the construction of a causeway link to Rusinga Island in the early 1980s. The artificial blockage limited the exchange of water between the gulf and the main lake, occasioning considerable physico-chemical and socio-ecological changes. Whereas the causeway enhanced transport and communication, a challenge at the time, buildup of organic and inorganic material altered water quality within the gulf that coincidentally hosts major river mouths and large urban settlements through which nutrients, sediments, and pollutants enter the lake. In the aforementioned backdrop, the causeway was decommissioned in 2017, ostensibly to reignite significant exchange between the gulf and the rest of the lake to improve the water quality of the former. We simulate the physics and circulation of Nyanza gulf using a 3D Regional Oceanographic Modeling Systems in the periods before and after decommissioning of the causeway. Simulations show enhanced water exchange between the gulf and the open lake after the decommissioning of the causeway as well as higher current velocities within the gulf. Predictions of the long-term impacts on water quality and productivity presented herein provide useful insights on knock-on effects of impounding channels in lacustrine systems.

**Organochlorine pesticide (OCP) residues in cultured fish from earthen fish ponds in the heavily populated areas of south western Kenya****Nyaundi, J.,<sup>1\*</sup> Getabu, A.,<sup>2</sup> Mwamburi, J.,<sup>1</sup> Kinaro, Z.,<sup>3</sup> Ogendi, G.,<sup>2</sup> Ombua, V.,<sup>1</sup> Mwainge, V.,<sup>1</sup> Miruka, B.<sup>4</sup>**<sup>1</sup>Kenya Marine & Fisheries Research Institute, Kisumu, Kenya<sup>2</sup>Faculty of Agriculture & Natural Resource Management, Kisii University, Kenya<sup>3</sup>School of Spatial Planning & Natural Resource Management, Bondo, Kenya<sup>4</sup>Kenya Marine & Fisheries Research Institute, Baringo, Kenya

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Concentrations of organochlorine pesticide residues were determined in cultured Nile tilapia (*Oreochromis niloticus*) fish in the target stations within the first-order wetland of River Kuja, Kenya, during the period between February and October of 2016. Biota samples were analysed for selected HCH, DDT and cyclodiene pesticide residues using gas chromatography equipped with electron capture detector. Most of the OCPs observed were below detection limit (BDL) to detectable levels in all the samples. When comparing the levels of DDTs and HCHs, a larger percentage (>50%) were BDL yet some exhibited consistency in samples analysed. There were significantly ( $p < 0.05$ ) marked differences in contamination levels in fish species within the wetlands, with average concentrates in fish muscle tissue ranging between 3.5 and 5.2 mg Kg<sup>-1</sup> for tilapia. The most dominant pesticide in all the stations was in the target species was the persistent organochlorine  $\beta$ -HCH isomer and endosulphans. Endosulphan sulphate was in the range of 0.82–5.62 mg Kg<sup>-1</sup> d.w. and was the most frequently detected residue. Aldrin and dieldrin were in the ranges of 0.22–12.96 and 0.94–7.18 mg Kg<sup>-1</sup> d.w., respectively. DDT and its metabolites lay between 0.21–3.59 for p, p'-DDE, 0.36–5.02 for p, p'-DDD, 0.06–1.76 for p, p'-DDT, 0.07–4.72 mg Kg<sup>-1</sup>. Taking  $p < 0.05$  as the alpha level, results between different sites indicated a significantly higher recorded difference. These observations indicated a potential of persistence in the target environment over the period of use in the area. They also indicated that relevant interventions and monitoring need to be upscaled to minimize health risks that may be posed by continuous exposure and consumption.

**The occurrence of organochlorine pesticides (OCPs) residues in water samples from rivers in the densely populated areas of South Western Kenya****Nyaundi, J.,<sup>1\*</sup> Getabu, A.,<sup>2</sup> Onchieku, J.,<sup>2</sup> Gichuru, N.,<sup>1</sup> Nyaboke, H.,<sup>1</sup> Babu, J.,<sup>1</sup> Kinaro, Z.,<sup>3</sup> Nyakeya, K.,<sup>4</sup> Aura, C.,<sup>1</sup> Basweti, G.<sup>1</sup>**<sup>1</sup>Kenya Marine & Fisheries Research Institute, Kisumu, Kenya<sup>2</sup>Faculty of Agriculture & Natural Resource Management, Kisii University, Kenya<sup>3</sup>School of Spatial Planning & Natural Resource Management, Bondo, Kenya<sup>4</sup>Kenya Marine & Fisheries Research Institute, Baringo, Kenya

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A study was conducted periodically in which organochlorine pesticide (OCP) residue surface water samples were collected from purposefully selected riverine representative sites within Lake Victoria, Kenya, catchment. Extrusion liquids were analyzed for contamination levels using gas chromatograph (equipped with an auto sampler and an electron capture detector (ECD) and confirmed using GC/MS. The main aim was to find out if locally banned or restricted pesticides still find their way into our environment, hence their implication on the fragile aquatic ecosystem and human health. Mean concentrations of DDTs, cyclodienes, and HCHs in earthen fish ponds' waters were undetectable to 0.27±0.03mg L<sup>-1</sup>, undetectable to 0.11±0.00 mg L<sup>-1</sup>, and 4.39±1.01 mg L<sup>-1</sup> levels, respectively. Further, those in receiving waters were undetectable to 0.23±0.01 mg L<sup>-1</sup>, 1.20±0.005 mg L<sup>-1</sup>, and 1.71±0.02 mg L<sup>-1</sup>, respectively. An obvious spatial distribution pattern was noted in sample water readings over the assessment period. Results demonstrate that cyclodienes are the predominant contaminants from some non-point sources in water courses. Taking  $p < 0.05$  as the alpha level, it was observed that there was a statistical significant difference in the residue levels between seasons. The pollution levels in study sites were compared with other studies, suggesting the extraction and analysis method is suitable for long-term on-line monitoring of trace OCPs in aquatic ecosystems. Therefore, continuous studies monitoring OCPs in upstream

catchment areas is needed to further understand the future trend of contamination for appropriate policy and management in harnessing blue economic growth.

**ODADA, ERIC**

**POSTER**

### **Building a resilient future through water - connecting the 2030 Agenda and Paris Agreement**

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The African Great Lakes region has been experiencing extreme rainfall. Sometimes, it might result in floods or it might be very dry weather. But by 2050 the whole region will be experiencing significant changes in the water cycle. Water is the lifeblood of this region with large lakes and rivers. The state of water resource affects all natural, social and economic systems. Water serves as the fundamental link between the climate system, human society and the environment. Climate change is severely impacting the hydrological cycle and consequently, water management in the region. This will in turn have significant effects on human development and security of the people of the Great Lakes region. Last year, the United Nations reached an historic agreement on the “2030” Agenda for Sustainable Development”, which includes a dedicated Sustainable Development Goal on water and sanitation that calls for ensuring the availability and sustainable management of water and sanitation for all. The world now has also a universal, fair, flexible and durable climate agreement. The countries of the Great Lakes Region are now moving towards development models that are more sustainable, protecting the environment and addressing climate change in the region. But climate change threatens to undermine or even roll back gains we have made in the management of Great Lakes and their basins. And its impacts are expected to be felt more clearly on our water resources-resulting in increased or more frequent flooding and drought-which threaten the very foundation of our ability to ensure food, energy, health, and jobs for all the people of the African Great Lakes region. This paper addresses emerging and persisting challenges to improve water quality, pollution and better waste management. In addition, the proposed water SDG that includes targets on increased water-use efficiency, integrated water resources management and the protection of water –related ecosystems in the African Great Lakes region.

**ODOLI, CYPRIAN**

**POSTER**

### **Effectiveness of co-management regime in African Great Lakes Fishery: A case study along Lake Victoria, Kenya**

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There is a common agreement that establishment of co-management through beach management units (BMUs) could be of benefit to fisher communities and other stakeholders across the African Great Lakes as regards promoting community livelihoods and sustainability of the fishery and lakes ecosystem. However, the effectiveness of established co-management regimens remains unknown. This study evaluated the effectiveness of established co-management units, specifically the Beach Management Units (BMUs) along Lake Victoria (Kenya). Information and data were collected through site observations and through questionnaire-led interviews involving the key informants and BMU members. The study reported the presence of illegal gears (5.7%), pollution (10.2%), insecurity (3.4%), and targeting of undersized fish (1.1%), among others. In order to manage the aforementioned, it was noted that the role of BMUs to curb or minimize such challenges was overall below 36%, i.e. enforcement (17.6%), conflict resolution (33.8%), welfare (35.5%), and awareness creation (13.2%). The existence of such measurable attributes are indicative of lack of effectiveness of co-management in Lake Victoria- Kenya. Furthermore, key registers and records were known to most of the members although there were no signs of progressive growth in the BMU themselves, due to lack of continuous awareness creation amid the changing lake environmental conditions and dynamics in the specific species fishery. There is a need to sustain the achievements so far attained in promoting improved co-management and ecosystem sustainability, as enforcement of laws and regulations can be a challenging undertaking without government support. County governments should ensure financial and material support in expanding capacity in co-management units to perform, promoting alternative livelihoods, establishment of good educational and health facilities for easy

access by fishing communities, and provision of solar power, electricity, and better road networks to existing and new co-management units before establishment.

**ODOLI, CYPRIAN**

**POSTER**

### **Post-harvest management interventions in small-scale fisheries: A boon or bane to food and nutrition security**

**Odoli, C.,<sup>1\*</sup> Owiti, H.,<sup>2</sup> Nyakeya, K.,<sup>1</sup> Nyamweya, C.,<sup>2</sup> Aura, C.<sup>2</sup>**

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Small-scale fisheries in Kenya contribute about 4.7% of the Gross Domestic Product (GDP) in spite of high post-harvest losses. Post-harvest management interventions in fisheries enable fishers and fish processors to reduce waste, maintain nutritional aspects, and meet stringent demands in food quality and safety. This review highlights benefits and pitfalls of various fish post-harvest management interventions to drive policy dialogue and formulation of a regulatory framework for future interventions. It relies on data obtained from the Kenya Marine and Fisheries Research Institute and the State Department of Fisheries and Blue Economy. The data comprised mainly that of the Kenyan inland water bodies (Lakes Victoria, Turkana, Naivasha, and Baringo, and Lake Kenyatta at the coast). The results depict abundant interventions in both handling and processing, but low utility (<40% of installed cold rooms, dryers, and kilns) and proliferation by fishers. However, fish targeting the export market have well-organized structures, portraying a weak regulatory framework as a key constraint in addressing post-harvest management of fish intended for the domestic market. Under-utilization of installed interventions results in continued fish waste and losses, contributing to food and nutritional insecurity. This review recommends the development of an effective and integrative policy framework that entails interactions across different domains, institutional mechanisms that monitor and address those interactions, analytical bases for decision making, and multi-stakeholder dialogue for post-harvest management. Such a policy will enhance the adoption of improved technology in small-scale fishery, which dominates in all the African Great Lakes.

**ODUOR-ODOTE, PETER**

**POSTER**

### **Possibilities of using water hyacinth extracts to influence lipid and protein oxidation during storage of solar dried *Siganus sutor* fillets**

**Oduor-Odote, P.,<sup>1\*</sup> Ruwa, R.,<sup>1</sup> Ogombe Cyprian, O.,<sup>1</sup> Obiero, M.,<sup>1</sup> Cyprian Odoli, O.,<sup>1</sup> Farah, B.,<sup>2</sup> Howell, N.<sup>2</sup>**

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Dried fish undergoes deterioration during storage. Although it is not easy to detect and describe deterioration in dried fish, the changes in physical and biochemical parameters that lead to alteration in the functional properties of the muscle can be analyzed. The key factor affecting deterioration in marine solar dried fish during storage is lipid oxidation. Lipid oxidation results from the presence of highly unsaturated fatty acids that are susceptible to oxidation during storage. Synthetic antioxidants are used to control lipid oxidation in foods, but some have been reported to be carcinogenic. In this study, fish fillets were solar dried after being soaked in water-soluble natural antioxidant extracts from water hyacinth, and lipid oxidation was monitored during a 60-day storage period. The total phenolic content of water hyacinth was initially determined. The antioxidant activity of water hyacinth-treated muscle as well as the percentage of inhibition of free radical formation was determined during the 60-day storage period. The physical-chemical properties of muscle proteins during storage, as an indicator of protein oxidation, were also determined using rheological (elastic modulus  $G'$ ) and thermodynamic properties by Differential Scanning Calorimetry.

The lipid oxidation indicators evaluated were peroxide value (PV) and Thiobarbituric Acid Reactive Substances (TBARS). The efficacy of antioxidants to reduce lipid oxidation products PV and TBARS was in the order Butylated Hydroxy Anisole (positive control) > water hyacinth > control and significant ( $p < 0.05$ ). Small deformation rheology of stored (up to 60 days) solar dried fish fillets treated with natural antioxidants had lower



G' values compared to the control, reflecting desirable texture qualities. The thermodynamic properties (denaturation temperature ( $T_m$ ) and heat enthalpy change ( $\Delta H$ ) altered significantly only after 60 days' storage.

**OKELLO, JUDITH**

**POSTER**

### **Women in science as agents of positive change amidst the threats of climate change**

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Climate change has variable footprints across the globe. Similarly, different groups of people will experience these impacts in varying ways. Gender disparity means that women are more affected by climate change, partly due to the fact that they are often restricted from powerful positions that connect vulnerable populations with climate monitoring information and also because they (and children) are normally on the frontlines of suffering when natural calamities strike. These groups of people thus face unique challenges round the globe with the issues being escalated in developing countries. Women are still subjected to societal gender-based discrimination, thus limiting their participation even as scientists in contributing to coming up with sound policies that would drive a given nation. Women in science work towards effecting positive change, especially in the lives of fellow women and the marginalized groups supported by researched facts. This could imply ensuring a transformation or adaptation towards a more efficient lifestyle, including but not limited to working towards environmental sustainability. However, driven by culture, people will always want to do different things in the same way. This makes it difficult for scientists to put their thoughts into action. There are however a host of opportunities in helping drive science home by working *with* the people rather than *for* the people. In this case study, an example of a local community mangrove conservation women's group who believed entirely in planting mangroves (as the only way to reverse degradation) are taken through baby steps to reap the fruits of ecological mangrove restoration.

**OKEMWA, DOUGLAS**

**POSTER**

### **Innovative methods of improving fish feed stability and flotation using local ingredients**

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Fish feeds accounts for almost 80% of total aquaculture costs, thus indicating significance and centrality in fish farming as a business. However, most of the farmers in Kenya use sinking feed pellets that increase the chances of wastage and water pollution and also bring about impaired growth due to poor feed conversion ratio. This is associated with the inability to access extruded diets that are considered to be stable in water and to have good flotation capacity, minimal water pollution, and an improved feed conversion ratio. In most rural fish farming areas such feeds are not available and are considered to be expensive by farmers. In an effort to improve the feed stability and flotation without the extruder, an innovative approach has been developed by scientists at KMFRI Mombasa using locally available ingredients using the Pearson square method. Modifications were done on the feeds to include yeast and melon shell at different proportions, i.e. 15%, 25%, and 45%. Pelleted feeds were sun-dried and tested for stability and flotation over a period of 60 minutes. Yeast having appropriate inclusion levels produced the most stable and longest-duration floating feed. The feeds are under experiment to assess consumption by fish and impact on growth. The results obtained provide a solution to enhancing the flotation of fish feeds locally and without expensive extruder machines, which may not be available to farmers.

**Water pollution and its impact on blue economy initiative: A lesson learnt from the Kenyan coast****Okuku, E.,\* Wanjeri, V., Kiteresi, L., Owato, G., Mwalungha, C., Mwangi, S.**

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Marine contamination arising from land-based sources is on the rise along the Kenyan coast. We carried a decadal pollution survey between 2008 and 2018 to determine the levels of contaminants in water, sediment, and biota collected from selected locations in Kenya. Nutrient levels in water ranged between <0.10 and 1,560.00, <0.10 and 1,320.00, and <0.10 and 3280.00  $\mu\text{g L}^{-1}$  for  $\text{PO}_4^{3-}$ -P,  $(\text{NO}_2^- + \text{NO}_3^-)$ -N and  $\text{NH}_4^+$ -N respectively, while Chl-a values ranged between 0.02 and 119.37 mg/L. Higher Chl-a and  $\text{PO}_4^{3-}$ -P revealed higher Chl-a was attributable to nutrients origination from waste and riverine discharge. Total PAH, PCBs, and OCPs in sediment from the studied locations ranged from BDL-37800 ng/g, 0.012 to 7.99 ng/g and BDL-6.10 ng/g respectively, and were primarily from petroleum sources. DDD+DDE/DDT ratio was above 0.5, suggesting historical input. Sediment trace metal concentration had various ranges.  $^{210}\text{Po}$  Activity in the top 5 cm sediment ranged between 30.16 and 43.44; between 20.29 and 37.99, and between 24.59 and 36.55  $\text{Bq Kg}^{-1}$  dw for Mtwapa, Tudor, and Makupa Creeks respectively, and were relatively elevated compared to the other coasts in Africa. The reported concentrations of trace metals and POPs, although low (compared to WHO guidelines) in most Kenyan locations, have a potential risk of bioaccumulation of these contaminants in marine biota. Microbial contamination analysis indicated the presence of *E. coli*, *Salmonella typhi* and other *Salmonella* spp., *Vibrio cholera*, *Enterobacter* spp., *Citrobacter* spp., *Proteus* spp. etc., in fish, oysters, and shrimps from Makupa, Tudor, and Mtwapa creeks.  $^{210}\text{Po}$  contamination of oyster samples ranged from  $291.61 \pm 21.94$  to  $514.24 \pm 32.74$   $\text{Bq/Kg}$ . The presence of contaminants in fish could jeopardize Kenya's attempts to promote fisheries as one of the sectors of Blue Economy.

**Lake Victoria Basin invasive macrophytes and their impact on the environment****Omondi, R.**

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This paper reviews the status of macrophytes in Lake Victoria and adjacent water bodies. These are characterized into different life forms depending on the habitat. The distribution of alien invasive species and their impact on the environment are presented. The occurrence of *Egeria densa* in Lake Victoria is reported for the first time. A few shoots of *E. densa* observed at Usenge beach in 2008 have now spread and it is fast choking the nearby shallow shoreline and bays of Lake Victoria. The submerged weed has also found its way into small water bodies in the hinterland, where some people were deceived that it was good for fish in ponds. The impact of this weed in the lake, together with those of the already established water hyacinth, will be enormous considering that it will impact on fish distribution, disruption of gillnet setting, and choking of outboard boat engines. It also highlights the need for the establishment of surveillance and monitoring centres in the basin to help control the spread of aquatic weeds.

**Future demands and supply of proteinous aquaculture ingredients: Strategies to commercialize non-conventional dietary protein ingredients for enhanced aquaculture production in sub-Saharan Africa****Ondiba, R.,<sup>1\*</sup> Ogello, E.,<sup>2</sup> Kembenya, E.,<sup>1</sup> Gichana, Z.,<sup>3</sup> Obiero, K.<sup>1</sup>**<sup>1</sup>Kenya Marine & Fisheries Research Institute, Pap-Onditi, Kenya<sup>2</sup>Maseno University, Maseno, Kenya<sup>3</sup>University of Natural Resources and Life Sciences, Vienna, Austria

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The protein component of aquafeeds relies to a great extent on fish meal, which continues to become costly due to its multiple uses and its scarcity. A remedy to this situation appears to be use of non-conventional protein ingredients in aquafeeds. These sources include plants such as tomato and tomato byproducts, potato, pawpaw leaves, cocoyam peels, amaranth leaves, lupins, banana leaves, sweet potato leaves, duckweed, cassava leaves, water hyacinth, leucaena, *Prosopis juliflora* seeds, crushed beans, etc. Meanwhile non-conventional animal proteins are derived mainly from terrestrial sources such as insects (termites, locust, fly larvae), earthworm, snails, freshwater atyid shrimp, etc. From the literature, the authors demonstrate the potential of non-conventional ingredients for aquaculture. Nutritional profiles of some ingredients have been determined, and others are under investigation. In particular, the impacts of these protein sources in terms of fish growth, nutrient digestibility, Feed Conversion Ratio (FCR), and fillet quality traits among the prominently farmed fish species, are currently under evaluation. The authors have singled out the presence of antinutrients as the main challenge, especially in use of plant-based proteinous ingredients. In respect to technologies to remove the unwanted factors and enhance inclusion of non-conventional ingredients in aquafeeds, the authors suggest dietary enzyme inclusion, defatting, heat treatment, extrusion cooking, solvent extraction, dehulling, fermentation, ensiling, and genetic modification, among others, as some of the most efficient methods. Appropriate and low-cost treatments to increase nutritional value should be tested in diets for farmed fish species to make aquaculture feed production in sub-Saharan Africa sustainable. Further, provision of quality aquafeeds will reduce pollution levels in natural ecosystems where aquaculture activities prevail.

**Recent trends in limnological conditions of Lake Victoria (East Africa): Can climate change be extricated?****Ongore, C.,<sup>1\*</sup> Nyamweya, C.,<sup>1</sup> Mlaponi, E.,<sup>2</sup> Mangeni-Sande, R.,<sup>3</sup> Kashindye, B.,<sup>2</sup> Natugonza, V.,<sup>3</sup> Kayanda, R.,<sup>4</sup> Taabu-Munyaho, A.<sup>3</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Kenya<sup>2</sup>Tanzania Fisheries Research Institute, Tanzania<sup>3</sup>National Fisheries Resources Research Institute, Uganda<sup>4</sup>Lake Victoria Fisheries Organization, Uganda

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The aquatic environment of Lake Victoria has recorded prominent changes in recent decades, manifesting in dramatic episodes of changing water conditions like receding water levels, nutrient enrichment, sedimentation, solid waste pollution, and loss of habitat. An insight into recent data collected from 54 sampling points lakewide, alongside the hydro-acoustic surveys for fish biomass estimation between 2012 and 2018, indicate minor yearly fluctuations in key physico-chemical characteristics of this ecologically and economically important aquatic ecosystem, possibly in response to direct anthropogenic influence and the climate change rhythms. Notable variabilities in mean physico-chemical parameters occurred between the inshore and deep offshore areas, whereby the gulfs and bays exhibited characteristics widely different from the observations generalized for the other strata. The mean temperatures have remained generally steady at ca. 24° C with no indication of changes in the thermal regimes within the water column. Other key parameters that indicate productivity and state of ecological health have recorded unsteady but gradual changes of a 0.5 m overall increase in the mean Secchi depth and a decrease of 1.5 mg L<sup>-1</sup> for DO over the six-year period. This trend depicts a system that is in the path of slow recovery following recent restorative measures taken by the riparian states. There is therefore a need for a trans-boundary and multi-sectoral strategy where responsible environmental champions and agencies work together to sustain these restoration gains.

**Hook size selectivity in the handline fisheries of Shimoni, south coast Kenya****Ontomwa, M.,<sup>1\*</sup> Fulanda, B.,<sup>2</sup> Kimani, E.,<sup>1</sup> Okemwa, G.<sup>1</sup>**<sup>1</sup>Kenya Marine and Fisheries Research Institute, Mombasa, Kenya<sup>2</sup>Pwani University, Kenya

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Handlines are common gears in the Kenya coastal marine fisheries. However, information on hook selectivity for handline fishery is lacking. Hook selectivity information is required for handline fishery management. This study aimed at assessing hook selectivity for handline fishery at Shimoni, south coast Kenya, specifically to determine species composition for the handline fishery, size frequency distribution of the species captured by different hook sizes including seasonal and spatial variation, and to evaluate the impact of handline hooks on fish stocks. This study was conducted from the Mpunguti, Waga, Nyuli, and Wasini sites using hook sizes No. 16, 15, 10, 9 and 8. Selectivity was determined using Holt's 1963 model as explained by Pauly, 1984. A total of 966 fish of 65 species and 23 families were caught. *Lethrinus borbonicus*, *Lethrinus lentjan*, *Lethrinus rubrioperculatus*, *Lutjanus fulviflamma*, and *Aprion virescens* were the dominant species. The number of fish captured increased with decrease in hook size, but the large-sized hook gave the highest CPUE. The diversity of species caught was high during NEM and for hook size No. 15. The sizes of fish caught by hook sizes No. 9 and 10 significantly differed from those of fish caught by hook sizes No. 15 and 16 ( $p < 0.05$ ). There was high similarity in species caught by hook sizes No. 16 and 15, while species caught by hook size No. 8 were similar to those caught by hook size No. 9. Overlap in the selectivity of the different hook sizes made it difficult for decision making since the fishery is of multispecies. However, hook size No. 8 was recommended for handline fishery as they gave high CPUE and had narrow selection ranges. Future studies should consider hook-lose, duration of fishing, and the effect of bait type and size.

**Effectiveness of management strategies in conservation and restoration of critical ecosystems: A case study of coral reef ecosystems in southern Kenyan coast****Otwoma, L.**

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Management regimes in aquatic environments differ in purpose, design, and approach, and may thus differ in delivery of positive social and ecological outcomes. Biophysical features such as benthic cover can be good indicators of management effectiveness, with an efficient system viewed to be able to increase or maintain key ecosystem parameter and resilience to disturbance. In this study the author presents results of an evaluation of effectiveness of three management strategies (area closure, gear management, and open access) in conservation and restoration of coral reef habitats in three years (2007, 2008, and 2009) using the conventional line intercept transect method. Hard coral cover was highest in the park and was significantly different in the management schemes ( $P = 0.0002$ ), while macro algae was high in the open access site and was also distinct in the management schemes ( $P = 0.0024$ ). The other substrate categories were not significantly different. Using the Simpson diversity index, the park had the highest diversity, followed by the reserve, then open access, which corresponded to the number of genera recorded in each site. The high presence of functional fish species is cited by this study to be the main reason for high coral cover in the marine parks and reserve, while poor fishing methods and management weakness might be responsible for low coral cover and fleshy algae domination in the open-access site.

**Enhancing project planning education for cage fish farmers in the African Great Lakes: The case of Lake Victoria****Shitote, Z.,<sup>1\*</sup> Munala, N.<sup>2</sup>**<sup>1</sup>University of Eldoret, Eldoret, Kenya<sup>2</sup>Department of Fisheries, Kakamega, Kenya

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The Great Lakes of Africa are a series of lakes in and around the Great Rift Valley. They include Lake Victoria, Lake Malawi, and Lake Tanganyika, with a host of middle-sized and small lakes nearby. Despite their beauty, the Great Lakes also rank as one of the world's most endangered water systems as a result of both anthropogenic and natural activities. While fish catches in Lake Victoria are declining mainly from overfishing and pollution, demand for fish protein has been on a gradual increase as a result of rapid human population growth and awareness of the health benefits of fish. To bridge the gap, aquaculture production, mainly in ponds and tanks, has tremendously increased. Recently, cages have sprung up in Lake Victoria, Kenya to augment the growing demand. However, these cages are greatly influencing the biodiversity of the lake. Site suitability for the installation of cages is poorly regulated, with most developments (>45%) located within 200 m of the shoreline, which are breeding grounds of fish and conflict with other lake users. The unplanned placing of cages poses a challenge to the flora and fauna of the lake. A good project plan should provide a roadmap for every aspect of the project. Inadequate project management skills are exposed to chaotic management, with unclear objectives and poor-quality deliverables. This paper analyses the effect of project planning education for cage fish farmers in the Great Lakes in view of emerging cage fish farming in Lake Victoria for sustainable aquaculture production.

**The status of seagrass beds in the coastal county of Lamu, Kenya****Uku, J.,\* Daudi, L., Alati, V., Muthama, C.**

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The assessment of marine and coastal critical habitats for biodiversity status provides important baseline information. This information is an important decision-making support tool that is critical for the provision of effective inputs in areas that are targeted for development. Biodiversity information also forms a critical data base support for marine spatial planning and can be used to effectively guide in aspects of sustainable development.

Biodiversity assessments within the seagrass beds were conducted in 7 sites, namely, Iweni, Tauzi, Wange, Ntopate, Manda Toto, Manda Maweni, and Ngoi. Nine out of the twelve seagrass species found in Kenya were encountered. The dominant seagrass species *Thalassodendron ciliatum* was found to occur in deeper subtidal areas, while the pioneering species occurred in intertidal shallower areas. Average shoot densities per site ranged from  $291 \pm 33$  shoots  $m^{-2}$  in Tauzi to  $865 \pm 123$  shoots  $m^{-2}$  in Ngoi. Canopy heights ranged from  $10 \pm 0.3$  cm in Manda Toto to  $18.5 \pm 0.5$  cm in Ngoi. Few herbivorous sea urchins, *Tripneustes gratilla*, were observed, signaling the high densities of seagrass. A total of 48 fish species were indexed. Some of the sites are shielded from human impacts, which may have resulted in the high species diversity and abundance of marine life observed as compared to some sites suffering from impacts such as sedimentation (Manda Toto) and dugong grazing (Tausi, Ngoi, and Manda Toto).

### Tapping into the Blue Economy through research innovations for marine fish feed development

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Mariculture development in Kenya has previously relied on culture of fish in intertidal earthen fishponds that are fertilized to enhance primary production and use of limited supplementary feeds. Most of the supplementary feeds used have previously been obtained from those of freshwater fish due to lack of marine fish feeds in the country. With the introduction of cage culture to utilize the open space in the sea and the introduction of more species for farming, new strategies are needed since fertilization and use of freshwater based feeds may not be applicable if profitability is to be achieved. Therefore the need is to develop marine-based fish feed formulations and feeding strategies with provision of species-specific feeds that address the nutritional requirements of different growth stages in fish life cycle. To allow for diversification, crustaceans and fin fish have been cultured in the Kenyan marine environment, including marine shrimps (*Penaeus monodon*), mud crabs (*Scylla serrata*), milkfish (*Chanos chanos*), marine tilapia (*Oreochromis niloticus*), and rabbit fish (*Siganus sutor*). Taking this into consideration, KMFRI has developed a feed formula that brings ingredients from the coastal environment that are unique i.e. seaweeds, coconut husks, and artemia for development of a marine feed. Initial assessments of the developed feed indicate that growth of marine tilapia takes place at 1.2 g/day, rabbit fish at 1.9 g/day, and milkfish at 1.4 g/day. The formula is to be refined and validated over time before being given out for commercial use in the feed industry to enhance production from mariculture.

### Development of a biodiversity database case study: The African Register of Marine Species (AfReMaS)

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The African Register of Marine Species (AfReMaS) is a recently-launched taxonomic database of marine species found along the African coasts. It was originally developed as the Marine Species Database for Eastern Africa (MASDEA). It extended thereafter to include species from the entire African coast. Currently it has 24,016 accepted species and aims to compile and manage an authoritative list of species occurring along the African marine coasts. It is intended to be used as support for biodiversity research for conservation and sustainable management of marine environment. The data mining process was conducted under ODINAFRICA project on three identified taxonomic groups (Molluscs, Porifera and Decapods) with information from books, publications, grey literature, and other databases.

Currently records in the database show Mollusca (12,514), Arthropoda (10,727), Chordata 9,413, Porifera (4,698), Annelida (2,736), Echinodermata (2,612), Cnidaria (2,340), the least reported species being Acanthocephala (13), Ctenophora (8), Gastrotricha (8), Phoronida (8), and Myxozoa (5). The animalia kingdom had 91% representation followed by plantae and Chromista (97%), bacteria at 90%, fungi at 96%, and protozoa at 81%. The list currently includes species belonging to mollusks, sponges, and decapods, updated from data mining workshops conducted by ODINAFRICA work package III. From the literature, information covering taxonomy, distributions, specimen information, and common names (vernaculars) was collected. Distribution records were filed under the Vlamar, a marine gazetteer. Authorized taxonomists confirmed the classification before species lists were uploaded onto the database. Content from AfReMaS is shared with the World Register

of Marine Species (WoRMS), OBIS, and AfrOBIS. AfReMaS aims to compile and manage an authoritative list of species occurring along the African marine coasts. All freshwater species are noted and are also uploaded to Global Biodiversity Information Facility (GBIF). This work is managed by VLIZ. <http://www.marinespecies.org/afremas/>. Similar efforts should be made for freshwater species.

**WANJERI, VERONICA**

**POSTER**

### **Heavy metals distribution in surface sediment in Athi-Galana-Sabaki River and its ecological implications**

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Heavy metals are widely distributed pollutants in the environment, with sources mainly from weathering and soils. However, the level of these metals in the environment has increased tremendously in the past decades as a result of intense industrialization and urbanization. The Athi-Galana-Sabaki River is the second largest river system of Kenya, originating from the Ngong hills in central Kenya (as the River Athi). It flows mainly through sand and rocks and mining industries for cement and other inorganic products as Athi River and further flows through areas with major industries, coffee and tea farms where agrochemicals and fertilizers are used in large scale, before discharging into the Indian Ocean. The aim of the study was to determine the distribution of heavy metal (Al Mn As, Cu, Zn, Pb, Cr, Ni, Co, Cd, and Fe) in surface sediment and its ecotoxicological implications to sediment-dwelling organisms. Based on the mean concentration of heavy metals in the surface sediment in Sabaki river were as follows: Al>Fe>Mn>Zn> Pb > Cr >Ni>Cu>Co>Cd>As. There was a significant distribution ( $p<0.05$ ) of heavy metal. The concentration of Al, Cd, Co, Cu, Fe, Mn, Pb, and Zn was reported to be higher than the background levels. A moderate enrichment of Pb was observed at some stations in the Sabaki River, which may be as a result of the previous use of leaded fuel. The effects-range low (ERL) of Cd, Ni, and Pb in the surface sediment were above the standard values in SQG, showing that these elements pose a biological effect to sediment-dwelling organisms. Hence both natural and anthropogenic processes controlled heavy metal accumulation and distribution in the Athi-Galana-Sabaki River environment.

**ZULFICAR, ANICETO**

**POSTER**

### **Assessment of catches of fish in Lake Niassa**

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Fisheries on African lakes have been threatened by a number of impacts, including the introduction of exotic species, under-exploitation of fishery resources, entry of untreated domestic sewage, diffuse entry of nutrients from agriculture, urban growth and industrialization, and tourism growth. Lake Niassa is characterized by a wealth of fish species. Fishing together with tourism and recreation are important potential activities of Lake Niassa. At present, studies indicate a reduction in catches on Lake Niassa, calling into question the current status of species belonging to Mozambique. The objective of this work was to characterize the catches of artisanal fishing in Lake Niassa. During the month of October 2018, catch data were collected from fishermen at the Chuanga 1, Chuanga 2, Seli, Mecuio, and Thungo fishing disembarkation centers. To this end, for each vessel, the total catch was weighed and a sample was taken, in which the species composing the sample were identified, weighed, and measured. Sixteen species corresponding to 3328 individuals were identified, of which the species *Engraulicypris sardella* was the most abundant species with 2623 individuals, and the species *Labeo mesops* and *Nimbochromis polystigma* were the least abundant with 9 and 1 individuals respectively. Overall, catches of fish were good and range from 60 kg to 220 kg. The final destination of the fish is trade.



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