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AFRICA'S INLAND AQUATIC ECOSYSTEMS

HOW THEY CAN INCREASE FOOD SECURITY AND NUTRITION

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Africa's inland aquatic ecosystems: how they can increase food security and nutrition

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Fisher in Lake Tana Wetlands, Ethiopia

Message to readers

Abebe Haile-Gabriel[1]

Inland aquatic ecosystems are diverse and are part of 42 wetland types recognized by the Ramsar Convention Annex B[2]*, including lakes, oases, swamps and marshes, wet grasslands, peatlands, estuaries, deltas and tidalflats, nearshore marine areas, mangroves and coral reefs, and human-made sites such as fish ponds, rice paddies, reservoirs, and salt pans.*

This special issue which aims to enrich knowledge of the sector all over the African continent, covers the value and contributions of diverse aquatic systems to food security, nutrition and livelihoods. The editorial quantifies the significance of the potential of Africa inland fisheries for food and nutrition and goes significantly beyond food security as narrowly perceived to view it also beyond direct provision of food to include through income and employment.

The core issues relevant to successful management of Africa's inland aquatic ecosystems resources include the biological realities of water insufficiency and invasion by water weeds but are also about community participation. The experience of the Senegal River Delta and its wetland management with local populations attests to this. Jean-Claude Micha also stresses the importance of involving communities in Protected Areas of the Congo Basin in decision-making about resources they depend upon. Similarly, a Sierra Leonean study exposes transboundary estuary resource management challenges.

The sequencing of articles in this issue prioritizes at the beginning those which inform readers on what and how big Africa's inland aquatic ecosystems are and what their potential contributions are economically, socially, and environmentally.

The article contributed by Gitchuru *et al* on poor management of Lake Victoria fisheries in Kenya being a threat to the nation's food security fits with that of Dismas Mbabazi *et al*. on the economic value of small-scale fisheries in the Victoria Nile-Lake Albert Delta in Uganda and its implications for nutritional food security, one from the ecological and the other from the economic perspective. Diida Karayu Wario gives a peek view into Lake Turkana in the Kenyan Rift Valley, in northern Kenya, with its far northern end crossing into Ethiopia, the world's largest permanent desert lake and the world's largest alkaline lake. This article presents information on a lake in a geographical area that has received very little study and furthermore deserves special attention given the current and future pressures on Lake Turkana itself.

This special edition in addition includes several papers that highlight the fact that fishing techniques and pollution threaten the continent's fish resources. Nestory Peter Gabagambi and Arne Skorping report on another type of threat by their observation of infestation by the tapeworm *Ligula intestinalis* in Lake Nyassa/Malawi, and its possible effect on Usipa production.

Africa has a large number of projects with potentially substantial positive outcomes regarding improved management of the continent's inland aquatic resources. Case studies of some of these projects give an overview of actions and lessons learned with a view to encouraging interested people elsewhere in the world to connect with kindred efforts in the region. A few examples include the *"Building Resilience of Lake Bosumtwi to climate change (RELAB)"* project in Ghana reported by Adelina Mensah

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[2] http://archive.ramsar.org/cda/en/ramsar-documents-guidelines-strategic-framework-and/main/ramsar/1-31-105%5E20823_4000_0__#B

et al., which shares knowledge and especially gaps in the implementation of an integrated management approach. The article offers suggestions for the adaptive management of Lake Bosumtwi in the context of climate change and anthropogenic pressure. Another example is a review by Feka *et al*. of factors that undermine inland river freshwater quality and supply to estuaries for food production in Sierra Leone.

Cameroon is the country under focus in this special edition, through a combination of papers. Junie Albine Atangana *et al* reflect on what the future holds for fish farming in Cameroon. Tchinda, Ajonina and Nguinguiri present some lessons learned and an analytical assessment of gender in community management of mangrove ecosystems in Cameroon.

Read about the current and emerging debates and issues on Africa's inland aquatic ecosystems and how they can increase food security and nutrition. This edition is as much about "practice" as "theory". Pore over the analytical assessments, and peruse intriguing stories and experiences of smallholder resource users and much more.


Boats docked at Wichlum Beach on Lake Victoria. Bondo District, Kenya

EDITORIAL

Unleashing the potential of Africa inland fisheries for food and nutrition security

Eshete Dejen[1], Hamady Diop[2], Mohamed Seisay[3], and Bernice McLean[4]

Africa has extensive inland waters from both natural and artificial rivers, lakes, streams and ponds, swamps, mangroves, salt marshes, coastal lagoons and reservoirs. These water bodies contain fish resources and a wealth of other aquatic and other biodiversity. For local populations in Africa, inland water fisheries contribute significantly particularly in terms of nutrition and food security, economic development, as well as cultural and recreational aspects. Fish is by far Africa's most important animal protein source at 36% of all animal protein. The percentage contributions of fishery subsectors to the overall protein supply are as follows: inland fish 11%, marine fish 21% and aquaculture 5%.

Despite these benefits, insufficient attention is given to proper management so that fish can be sustained as a key element in food security and nutrition strategies at the regional and national levels and in wider development discussions. The fisheries and aquaculture governance issues, together with the prevalence of poverty and increased populations around water bodies, contribute to excessive pressure on the inland fisheries resources and their basin ecosystems. Multiple and often conflicting use of inland water bodies has exacerbated over-exploitation and degradation of these ecosystems. Furthermore, decreasing aquatic resources in inland waters are exacerbating the threats to the social and economic development of many countries. Despite the importance of fish and aquatic products in food and nutrition security, existing challenges provide a barrier to maximising their contribution to livelihoods and wellbeing.

Improved management and responsible use and development of inland water bodies and their associated catchments, is critical to the health and wellbeing of those who are most dependent on them for livelihood. A greater emphasis is therefore needed by decision-makers on strengthening the governance of these valuable assets to continue providing the goods and services they supply.

The African continent has extensive water bodies, both internal to individual countries and (quite often) on the borders of two or more countries. These water basins contain large fisheries resources and a wealth of aquatic and other biodiversity (AU-IBAR, 2018). These inland water bodies and their catchment areas provide goods and services for other human activities such as hydroelectric power generation, agriculture, urban development and transportation. Africa has approximately 80 inland water basins that serve multiple functions. The inland water basins cover around 64% of the continent's land area, contain 93% of the water resources, and are inhabited by 77% of Africa's population. Of these, water

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bodies shared by more than one country include Lake Victoria, Lake Tanganyika, Lake Albert, Lake Nyasa/Malawi, the Zambezi River, and the Nile River.

Although most fish and aquatic resources from inland water bodies are consumed locally, products from inland water fisheries are also important export commodities. An example of this economic importance is evident in the value of the catch from Lake Victoria that alone was estimated at USD 589 million, with a further USD 400 million generated by the export of Nile perch (LVFO, 2015).

A review article of published reports and secondary data from different sources at regional and continental levels and experiences from fisheries projects (*"Strengthening institutional capacity to enhance governance of the fisheries sector in Africa"*, commonly referred to as the Fisheries Governance or Fish-Gov Project; "*Strengthening Policies and Development Strategies for Inland Water Bodies in Africa*"; and "*The Fisheries Governance Project*"

implemented by AU-BAR in collaboration with NEPAD Planning and Coordination Agency with support from the European Union from 2014 to 2018) have led to much of following analysis and discussion into which elements have also been integrated from several other papers in this special edition of Nature & Faune journal

The importance of fishery and other functions of inland water bodies

Fish production and consumption

Africa's total annual fish production is estimated at 11.3 million tons (FAO, 2018) to which marine fisheries contribute 57% (6.4 million tons), followed by inland fisheries (2.9 million tons) and aquaculture (2.0 million tons). These totals are considered conservative estimates of actual landings, as they are based on official reports to FAO, given that many countries lack appropriate data collection and management systems for inland fisheries and some fishing may be unregulated, unreported and /or illegal. The average contribution of the inland fisheries subsector to national GDPs is estimated at 0.33%and to Agricultural GDP at 1.62% (de Graaf, G. & Garibaldi, L. 2014) and it is of immense importance to rural communities in Africa, particularly concerning food and nutrition security.

Fish contribution to food and nutrition security

There is growing recognition of the nutritional and health-promoting qualities of fish. Fish and fishery products represent a valuable source of nutrients that are fundamental for diversified and healthy diets. Regardless of its origin, fish is a good source of protein and essential nutrients that are particularly necessary during the first 1000 days of life (Longley *et al*. 2014).

Fish is by far the most important animal protein source at 36% of all animal protein sources. As illustrated in Table 1 below, the contribution of the different fish production subsectors to this total include: inland fisheries 11%, marine fisheries 21% and aquaculture 5% (AU, 2014). In several African countries and particularly among riparian communities along major rivers and lakes, fish is the principal protein source. The *per capita* annual fish consumption for Africa in 2018 was estimated at 9.9kg, less than half of the global average of 20.2kg (FAO, 2018 Table 1). While demand for fish continues to grow, fish consumption on the continent is projected to decline further to 9.6 kg by 2030 due to insufficient supply to meet growing populations (FAO, 2018). In most rural areas, particularly in landlocked countries, inland fisheries are critical for food security and income generation.

Table 1. Inland Fisheries contribution to fish production and socio-economic indicators

Parameters	Inland fisheries	Marine fisheries	Aquaculture
Production (tonnes) (FAO 2018) in thousands ('000)	2 864	6 416	1 982
Employment (de Graaf and Garibaldi, 2014) in thousands ('000)	4 958	6 391	920
% National GDP (de Graaf and Garibaldi, 2014)	0.33	0.79	0.15
% Agricultural GDP (de Graaf and Garibaldi, 2014)	1.62	3.44	0.96
% Contribution to protein intake of animal protein source (AU, 2014)	11	21	5
Average Per Capita Consumption for Africa (FAO, 2018)	9.9 kg/yr		

Ecosystem services from freshwater environments together with inland capture fisheries, contribute to human wellbeing by alleviating poverty and contributing to food and livelihood security. Inland capture fisheries and their ecosystem services provide a broad range of benefits for development and contribute directly to the Sustainable Development Goals (SDGs) (SDG 1- no poverty and SDG 2- zero hunger). These benefits deserve but do not get matching attention both at regional and national levels or in wider development discussions. Despite this, the inland fisheries sector is typically neglected or overlooked in policy and global debates on food security (Funge-Smith, 2018). Debates have centred more on questions of biological sustainability and on the economic efficiency of fisheries. These debates are important, but fail to recognise the contribution of fish in reducing hunger and malnutrition, as well as in supporting healthy development, improved livelihoods and wellbeing.

Inland fisheries and biodiversity

Aquatic ecosystems (both inland and marine), represent the most biodiverse sources of food consumed by humans. These include vascular plants and algae, and animals such as crustaceans, molluscs, reptiles, amphibians and finfish. Freshwater ecosystems cover only about 1% of the earth's surface, but provide habitat for over 40% (13 000) of the world's fish species. Another 2 000 species of fish can also live in brackish water. In general, the level of knowledge on freshwater biodiversity (i.e. species richness, endemism, production, level of endangerment and value), particularly in Africa, is poor or outdated (Funge-Smith, 2018). Freshwater ecosystems and their surrounding catchment areas are most heavily impacted by humans. Major causes of adverse impacts on aquatic biodiversity include pollution, habitat loss, degradation and transformation, deforestation and draining of wetlands, river fragmentation and poor land-management. Biodiversity of fish and aquatic organisms serve as important indicators of ecosystem health. Freshwater biodiversity is threatened and has declined in many areas as a result of the above-mentioned impacts.

Many freshwater species are important to the aquaculture industry as sources of brood stock for spawning and early life history stages (e.g. eggs, larvae), and for out-growing. Non-native aquatic species also contribute significantly to the production and value of inland fisheries and aquaculture, if managed correctly. The potential impacts of introducing non-native species on biodiversity needs to be mitigated through the use of precautionary measures and effective environmental assessment.

Employment in inland fisheries

Inland capture fisheries employ an estimated 5 million people. A recent estimate of employment and income of seven major river basins, found that in West and

Central Africa alone fisheries provides livelihoods to more than 227 000 full-time fishers and yields an annual catch of approximately 570 000 tons with a first-sale value of USD 295 million (Eyiwunmi, 2018). Inland fisheries are characterised by predominantly rural, small-scale fisheries with limited commercial large-scale fisheries. While inland fisheries are generally considered less dangerous as an activity than marine capture fisheries, the poverty levels of small-scale inland fishers, contribute to concerns around child labour and unsafe working conditions within the subsector.

The involvement of women and youth in inland fisheries

Women represent an estimated 27% of the workforce in inland fisheries (de Graaf and Garibaldi, 2014). The engagement of women in inland fisheries is often invisible despite their significant role in many fisheries. Women are often narrowly associated primarily with post-harvest processing and marketing activity, despite the fact that they do also engage in fishing and aquaculture production. The access of women to income from fish processing and marketing may have a stronger and more beneficial impact on household incomes than income from fishing by men. Despite their dependence upon the fishery, this may be poorly reflected in fishery management decision-making processes. Vulnerable women engaged in post-harvest marketing of fish are often dependent upon male fishers for access to fish, some having to rely on transactional sex for preferential supply of fish.

The *Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa* (PFRS), as well as the *Voluntary Guidelines for Small-scale Fisheries*, identified the empowerment of women and youth as major strategic policy reform areas to ensure the recognition of the importance of women and youth. The establishment of a continental network of women fish traders and processors (AWFishNET) in 2017, is a significant development towards strengthening their participation in the sector through improved coordination and advocacy capacity.

Other multiple uses of inland waters and threats

The living resources as well as use of water for power generation, transport etc. are all often developed and implemented without appropriate Environmental Impact Assessment (EIA) procedures. As a result, there is a lack of reasonable consideration to fisheries and fish production or to non-fishing functions of water bodies that rely on the healthy functioning of the ecosystems to deliver at full potential. Notwithstanding, African Union Member States recognize the importance of understanding the multiple-use nature of these water bodies and the need to balance the interactions of fisheries and aquaculture with the other economic functions for achieving sustainable exploitation of these aquatic resources. Management of water bodies however, rarely adopts a holistic governance mechanism that captures this interconnectivity. It is important therefore, to stimulate efforts towards achieving a balanced governance of these diverse sectors and user interests.

Challenges facing the effective management of inland fisheries originate both from within and external to the fisheries. For instance, invasive species such as exotic aquatic weeds like the water hyacinth, among others, affect oxygen levels in the water and cause habitat changes. Irresponsible construction of dams interferes with natural processes in and adjacent to the water bodies, changing turbidity levels, temperature and water levels and reducing the health of ecosystems. Moreover, excessive use of fresh water from these inland water bodies to promote agriculture through irrigation, as well as the use of pesticides in agricultural lands riparian to the inland water bodies, may result in serious threats to fish and other aquatic species. Nowadays, climate variability and change have added to challenges to the productivity of ecosystems. These among other factors negatively affect fish recruitment and thereby fish supply. It is important such factors are taken into account and a balance is achieved between uses of these water bodies and their catchment areas, rather than emphasizing selected uses at the expense of the others which are equally important.

Many inland water bodies in Africa are shared water bodies. Fish species in these bodies are not restricted to the national borders. The management challenges facing inland fisheries management are also compounded by this reality. These includes factors such as movement of fish species across territorial boundaries, pollution, illegal fishing and habitat degradation.

Management issues

Current management approaches and challenges

Inland water bodies are highly productive natural capital assets which must be effectively managed to both maintain existing goods and services (food security, livelihoods and income), and to significantly increase the sustainable contribution of the sub-sector to the blue economy of countries and regions. The current benefits from inland water bodies are however under threat from a variety of sources. Key management challenges include poor governance frameworks, incoherent policies and legislative frameworks and weak institutions. The underlying challenges include the open access nature of inland fisheries, weak capacity for governance under these circumstances, threats from climate variability and change, receding water levels, extractive industries with resulting effluents and habitat degradation, hydroelectric development, invasive species invasion, and declines in species diversity, coupled with the associated taxonomic and life history challenges.

Invariably the existing national and regional instruments for inland fisheries and aquaculture management have not, as compared to those for marine fisheries, proportionately focused on redressing the issues in inland fisheries. A notable few instruments represent the exception, such as the *FAO Code of Conduct for Responsible Fisheries* (FAO, 1995), the *Voluntary Guidelines for Securing Sustainable Small -Scale Fisheries* (FAO, 2015) and the *Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa* (AU, 2014). In general, however, where inland fisheries management measures are included, the focus is mainly on technical measures which include seasonal or area closures to fishing activities, fishing gear restrictions and mesh size regulation, annual registration of fishing gear and vessels, licensing, catch assessment surveys (including annual frame surveys and collection of data on catches and fishing effort in few cases). Amidst low catches, high poverty levels and weak surveillance and a lack of alternative livelihood options, these regulations are seldom enforced or adhered to.

Access rights for fishers

Fishery management in small scale fisheries focuses mainly on issues of access, harvesting and management approaches itself (i.e. use rights and management rights). Access rights, which permit the rights holder to participate in a fishery (limited entry), or to fish in a particular location (territorial use rights or 'TURFs'), are among the most important management tools (FAO, 2015). Clear access rights therefore improve management by identifying the stakeholders in a certain fishery. Clear access rights also assist stakeholders - whether fishers, fishers' organizations, fishing companies or fishing communities. They provide some security towards access to fishing areas, and to the use of an allowable set of inputs, or harvest levels of a quantity of fish. If access rights are well established, fishers know who may access the fishery resources, the size of the catch allowed, and time period within which these rights are applicable.

A well-defined and implemented set of fishing or aquaculture rights also protects vulnerable user groups such as women, the youth and other marginalised groups. In the wake of increasing demands for development in tourism, housing, minerals extraction and energy-related developments, agriculture, and other sectors, fishing communities often face evictions and marginalisation. This is particularly true where fishers do not have written, registered titles to the lands that they occupy or the waters that they exploit. Subsequently this threatens their livelihoods. It is therefore important to secure and protect rights to secure the livelihoods of inland fishers on a long-term basis.

Conclusions and recommendations

While many of the fish and aquatic resources from inland fisheries and aquaculture are consumed locally, revenues from the sale of part of the catch are also used to purchase other types of food. Despite the importance of fish in food and nutrition security, challenges still persist. Acceptable fish and aquatic products for use as supplementary foods for young children are as yet undeveloped in Africa. Furthermore, efforts by countries to strengthen aquaculture and fisheries programmes by mainstreaming nutrition in their community-led projects, have not resulted in a common approach or well-implemented initiatives. Consequently, if African countries wish to optimise the role of fish in food and nutrition security, it is critical to:

- Undertake research to gain a better understanding of the role of fish in decreasing malnutrition and improving the health of the sick;
- Deepen the understanding of the value/benefits of fisheries and aquaculture resources to livelihoods and food security and to ensure that reforms are undertaken within the context of food and nutrition security considerations;
- Support member states to adopt or implement measures for trade-off between fish export and local fish landings as a means of maintaining adequate fish supplies in local markets;
- Strengthen consideration in a balanced manner of marine, inland fisheries and aquaculture in national and regional policies and actions on food security and nutrition; and
- Given that many water bodies are transboundary in nature, implement already existing agreements or develop new ones to ensure consultative and clearing-house mechanisms for utilisation, investment and management interventions in such water bodies.

The improved management and responsible use and development of inland water bodies and their associated catchments is critical to the health and wellbeing of those who are most dependent on them for livelihood and for local and national economic security. A greater emphasis is therefore, needed by decision-makers on strengthening the governance, including financial and human resource allocations, of these valuable assets and the goods and services they provide.

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Senegal river delta: wetland management with local populations

Patrick Triplet[1], Seydina Issa Sylla[2] and Babacar Faye[3]

Introduction

The Senegal River delta is generally associated with the Djoudj Birds National Park, one of the easiest to access national parks where, without effort, any visitor can admire hundreds of thousands of water birds (Triplet *et al*., 2014). But the delta is actually rich in other protected areas with very different statuses. Within the delta biosphere reserve, which also extends to Mauritania, there is, for Senegal alone, a marine protected area, two national parks (Djoudj and Langue de Barbarie), two special wildlife reserves (Gueumbeul and Ndiaël), a community reserve (Tocc Tocc) and a regional heritage area (Les Trois Marigots) created in 2007, at the initiative of the Saint-Louis Regional Council (Triplet *et al*., 2018a). This conservation system is the second most important asset of the delta after rice farming. Harmonious coexistence of these two modes of exploitation of local resources is not implicit, as shown by (Triplet *et al*., 2018b). Local common sense indicates that rice cannot be grown everywhere because it is necessary to leave space for fish production. This evidence justifies initiatives to conserve natural areas where renewable natural resources can be exploited in one way or another, whether through fishing, subsistence farming, wildlife tourism or even hunting. In this context, two neighboring sites have different trajectories but are based on the same need to conserve or restore the integrity of natural areas. These are the special bird reserve of Ndiaël, which was reactivated in 2018 and the "Trois Marigots", a site with no current conservation status but whose isolation from Saint-Louis has so far made it possible to maintain habitats that have not been exploited by humans.

These two sites have particular characteristics that explain their value but also their fragility, which makes it necessary to carry out major interventions in order to restore their ecological functions and the ecosystem services provided to local populations.

This analysis is based on two studies conducted to develop management plans for these two sites (Sylla *et al*., 2017; Triplet *et al*., 2018), as part of two projects (Figure 1). The first one on the Ndiaël rehabilitation was supported by the African Development Bank and received technical support from IUCN and the "Office des Lacs et Cours d'eau". The second, on the "Trois Marigots", is part of a study on the understanding and experimentation of management measures to be carried out on a pilot site. It is funded by FAO as part of the "RESSOURCE" project aimed at strengthening of expertise in the south of the Sahara on birds and their rational use for the benefit of communities and their environment. The authors have been involved in both projects since their inception.

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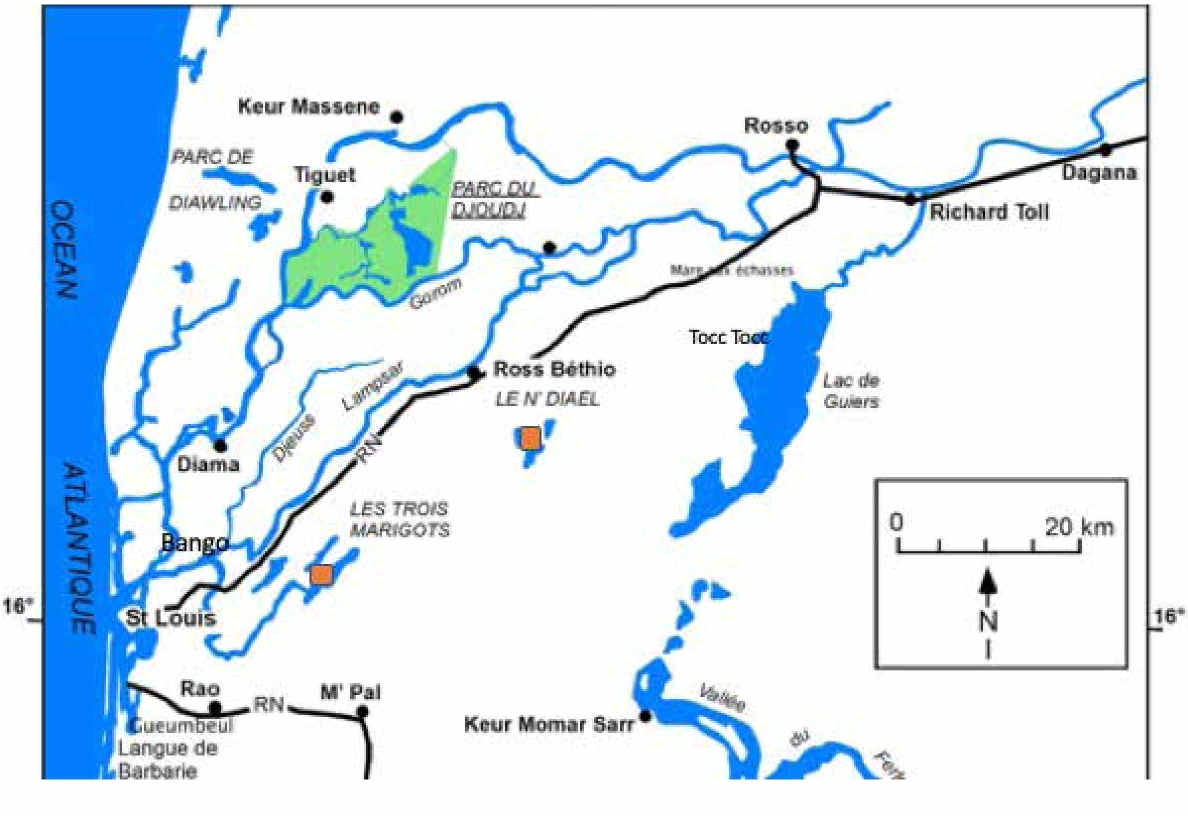

Figure 1: Location of the two sites (Le Ndiaël, and Les Trois Marigots") in the delta
Source: OMPO / European Institute for the Management of Wild Birds and their Habitats

Description and discussion of the Ndiaël depression

Ndiaël is a depression of about 10 000 ha that was cut off from its water supplies in the early 1960s by the partial blocking of its link with Lake Guiers and by the construction of the road linking Saint-Louis to Richard-Toll (Sylla and al., 2018) (Figure 1). Before it dried up, Ndiaël offered an environment comparable to that of Djoudj National Park today. It was rich in numerous and diverse animal populations, particularly for birds, whose numbers were in the thousands (Morel and Roux, 1973). Its more or less brackish water resources harboured large quantities of fish for the surrounding populations, while its banks were favorable for grazing. The Ndiaël basin was put out of reach of floods since 1965 by reinforcing the road linking Saint-Louis to Richard-Toll and filling in the marigots, i.e. stream channels, that led to the basin, as well as by silting up the "Nieti-Yone marigot" that connected the lake Lac de Guiers to Ndiaël. Inevitably, the site dried up. It hosted large numbers of birds until the early 1970s that enabled it to acquire Ramsar site status, but since then it has lost most of its value. In 2005, UNESCO integrated the Ndiaël Reserve as one of the core areas of the Senegal-Mauritania Transboundary Biosphere Reserve (RBTDFS), which shows that the objective of restoring the site is not new and is based on strong site values.

The problems of water supply were therefore known and were even the subject of one of the articles of Presidential Decree No. 65 053, signed on the 2 February, 1965, creating the reserve. Since 1985, there have been successive attempts to restore the water levels, with various types of funding and involving various non-governmental organizations. The water supply was restored in 2018 after an unprecedented operation to clean the supply channel from Lac de Guiers, by the "Office des Lacs et Cours d'eau", with a loan from the African Development Bank (ADB) and a grant from the World Environment Fund (WEF).

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Figure 2: The Nieti Yone canal which allows the arrival of water on the Ndiaël

The reserve is managed by a coordinator based at the Regional Water and Forest Inspectorate. With the support of the Mauritania-Senegal Biodiversity Project, the populations living on the periphery of the reserve have been organised to do the work required to maintain the reserve (Bos *et al*., 2015). Thus the Inter-Village Association (AIV) of Ndiaël was created in 2004 and includes 32 villages. Its headquarters are in Ross-Béthio and it has 800 members. Its structure is based on a committee composed of three representatives per village. The Executive Board consists of four men and three women. The work is done on a voluntary basis and is essentially based on the Ndiaël basin watering project to restore the site's bio-ecological and economic functions. The association has thus contributed to the success of the water-release project, by itself clearing part of the water supply routes on a pilot basis. It also supports local populations in the improvement of pastoral activities by facilitating access to water and fodder, with the creation of tusks (large enclosures) allowing a high production of plant biomass that can be used by herds when all vegetation has been grazed everywhere else. In addition, in its work program, it provides for the development of fishponds to compensate for the fishing ban resulting from the protected area status of the site. The development of ecotourism is based on the creation of a camp and the organization, in the long term, of discovery trips to the reserve, in addition to other sites already offering this type of service in the delta. All these initiatives are intended to benefit the local populations for whom vocations should emerge, such as managers of rangelands, fish farms or protected birdlife areas, as well as visitor reception staff, ecoguides, managers of reception facilities, etc.

Description and discussion of the "Trois Marigots"

The "Trois Marigots" are a parallel series of interdunary lakes fed with water from the southwest by a marigot (river) called the Ngalam. The Trois Marigots are also a reservoir of biodiversity in the delta and are complementary to the nearby Ndiaël, with which they are linked by a series of depressions. Unlike Ndiaël, the Trois Marigots are inundated with water every year, and therefore have diversified surrounding vegetation.

Thirty years ago, the Three Marigots were only supplied with water when it was necessary to drain the water supply in Saint-Louis. The Trois Marigots thus became its outlet and had a limited quantity of water, sometimes not available, on the needs of Saint-Louis. For much of the year the site was dry and when it was supplied with water by the overflow from the Saint-Louis water supply, it offered vast open water bodies frequented by thousands of ducks (Anas querquedula Garganey and Anas acuta Pintails, in particular).

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Figure 3.Typical landscape of the "Trois Marigots" in the foreground, an area of water free of cattails occupied by the water lilies. In the background, the strong presence of cattails.

The optimal functioning of the Diama dam from 1992 onwards resulted in a more frequent filling of the Saint-Louis water reserve, thus increasing the volume and duration of flooding in the Trois Marigots. As along the banks of the Senegal River Cattail (Typha domingensis), a wetland plant commonly known as bulrush in Britain, Canada, USA and Australia, has established itself and has gradually invaded water bodies. Although the harmful impact of the lack of periodic drying of the Trois Marigots is now known, water outlet gates are opened at any time according to individualized needs, particularly agro-business, to the detriment of the general interest that resides in biodiversity and the utilization of natural resources.

Although it does not conservation status, the Trois Marigots can be sustainably utilized in different ways. Subsistence fishing, market gardening and hunting have long been practiced here, while bird tourism is in its infancy but seems promising and visits by tourists are increasing.

Until the 1990s, the Trois Marigots supplied Ross Béthio with fish. Each fisherman caught an average of 20 kg of fish per day (Triplet *et al*., 2018) and thus managed to satisfy his financial needs with the sale. Now, due to the presence of aquatic plants invading the marigot, and the decreasing the volume of open water, and with fishing pressure remaining constant, there is a decrease in the number of fish species such as *Lates niloticus* (the Nile Perch locally called Captain) and a decrease in the quantity of fish caught (catches of 5 kg per day have become regular). Access is no longer easy in marigot, and only Tilapia (*Tilapia* spp) and Catfish (*Silurus spp*) are caught. In addition, invasive plants (*Typha and Ceratophyllum*) provide shelter for fish that take refuge in them and prevent the nets from spreading.

Moreover, without hosting such large bird numbers as the Djoudj Bird National Park, the Ndiaël Avifaune Special Reserve or the Diawling National Park in Mauritania, the Trois Marigots are home to some very rare species (crowned Crane Balearica pavonina, Denham's Bustard Neotis denhami, Temminck Courser *Cursorius temminckii*, Quail-Plover *Ortyxelos meiffrenii* for example), which is a delight for ornithologists looking for rare bird sightings.

Thus, this site, away from the national road and therefore difficult to access, has been forgotten for decades, but what was previously a handicap could turn into a huge advantage as long as it is well managed.

This "Lost Paradise", in the words of Jean Larivière (2008), was the only major natural site in the delta not to benefit from management measures. In 2018, a management plan was drafted (Triplet *et al*., 2018a) and the goal is now to have the Three Marigots designated as a Ramsar site. The ambition is also to restore the ecological functioning of yesteryear, when periods of drought prevented the development of cattails, in order to allow a better production of the natural resources and an improvement of the well-being of the local populations. The management plan also provides for the organization of the various activities so that they remain compatible with the ecological functioning of the site and do not compete with each other.

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Figure 4: Industrial crops (agro-business) are set up on the edge of the "Trois Marigots" and are likely to have a significant impact on their functioning without the adoption of management rules.

Management of the two sites

We can, here, draw a parallel between the two sites (Table 1). Both sites show their value in terms of biodiversity, in terms of economic development through the exploitation of natural resources and the development of tourism. They also show that poor water management has significantly altered their ecological functions, which can now only be restored by major operations, but necessary to maintain the well-being of the inhabitants of the site.

Table1: Characteristics of the two studied sites

Descriptive item	Ndiaël	Trois Marigots
Protected area	Wildlife Reserve	Regional heritage area
Administrator	Regional Water and Forestry Service.	Lack of organization, management carried out by the farm owners through a set of specifications under the control of the Water and Forests Department. There is no manager with resources available as they are only made available for protected areas such as reserves or national parks
Biodiversity	In the process of being restored by the impoundment.	In the process of becoming commonplace and with numbers of different species decreasing due to the development of typhoons
Hunting and fishing	Prohibited by the decree creating the 1965 special bird reserve	Authorized with bag limits.
Ecotourism	To be developed, but the material resources are in place, with a tourist camp and boats. Eco guides still to be trained	Under development. The tours are organized by a few eco-guides and are very successful because of the beauty of the landscapes and rare species found here.
Ramsar Site	On the so-called Montreux list of threatened wetlands from 1977 to 2018, now included in the list of wetlands	In the process of being created. Ramsar site designation is expected in 2018
Role of local populations	Inter-village association with premises and resources made available at the time of the site's watering project	A village association without premises or resources, created as part of the FAO RESOURCE project, and still requiring strong support to be decisive in management decisions
Partners	Rehabilitation provided by the Office of Lakes and Rivers through PREFELAG, a project of the State of Senegal carried out on a loan from the African Development Bank and a grant from the Global Environment Facility	Search for a partnership, based on the management plan. Ongoing initiatives at the Office des Lacs et Cours d'Eau with the development of a request for funding for a project for the Trois Marigots
Management Plan	For the Period 2018-2022	For the Period 2019-2023

The management plans of both sites share the same vision of forming an ecological and socio-economic complex that combines conservation objectives, improved ecosystem services and economic development for the benefit of local populations. Both still lack the quantified and detailed knowledge of ecosystem goods and services, which will help to guide the management to be applied even more precisely. This aspect was initiated in 2019 in the Trois Marigots in order to have quantified data on the different modes of exploitation of natural resources.

The challenges and opportunities are immense. Rehydration of Ndiaël will improve the socio-economic functioning of the site, by improving the production of natural resources, including for simple contemplation, and thus by a possibility of creating many jobs for the utilization of these resources. The Trois Marigots must find a water management regime that will limit the development of invasive aquatic vegetation, or even utilize it. Fishing is prohibited on Ndiaël, but the natural production of fish induced by re-watering should, if water management allows regular connection with peripheral wetlands, lead to spreading of fish into the waters surrounding the reserve, which will increase the possibilities of fishing in these unprotected waters.

Lessons to be shared

Lessons can be learned from each of the two sites to improve management of the other. In such sites, the excess and permanence of water is as dramatic as its lack. In Ndiaël, to avoid the development of invasive aquatic vegetation, effective management, with regular drying, is necessary to conserve the various natural productions. For the Trois Marigots it means that, from now on, for the local populations to continue to live from the site, it is necessary to carry out a strong intervention aimed at eliminating cattails or restricting them to limited areas in order to allow the other uses of the site to survive (fishing, ornithological tourism and hunting). This action will have to be followed by a new water management, so as not to lose the benefits of restoration, with the installation of diversion channels to allow farmers to continue to use the land. This is a key factor because if they do not have water, farmers will oppose any ecological management initiative for the site. This error made at the Trois Marigots should not be repeated at Ndiaël, even if, sometimes, it can be tempting to put water back in to extend the period of presence of the birds and therefore the tourist visits of the water body.

On the other hand, the experience of fruitful relations between the administrations and the populations of Ndiaël must serve as an example to the Trois Marigots, where the Inter-Village Association does not have, unlike that of Ndiaël, sufficient resources to set up projects by itself. Developing a partnership between the IVA, the administrations and all the structures that carry the message of the restoration of the Trois Marigots, launched as part of the RESOURCE project, as was the case for Ndiaël, is a guarantee of the projects' success. The association representing the villagers must be involved in the management of water supplies, vegetation and even activities based on the use of natural resources.

For the global vision for the two sites to become an achievable goal, it will be necessary to consider common governance, with appropriate tools. Management plans are one of them, especially when both sites are designated for the Ramsar Convention. The Biosphere Reserve of the Senegal River Delta offers the ideal framework for the effective management of these two central cores, taking into account their specificities and for the benefit of local populations and biodiversity. To this end, the Biosphere Reserve must develop governance methods that take into account the specificities of each site and stimulate the search for ways to finance actions that promote the conservation of natural resources.

Thus, the management of protected areas, according to a well-established program and taking into account local needs, can simultaneously conserve biodiversity, generate revenue and improve the well-being of local populations through an increase in renewable resources and the creation of ecotourism products. The way is therefore open to management approaches that more closely combine conservation, meeting the needs of local populations and respecting natural biological cycles. This is a major challenge for the proper balance of the delta, which must not be transformed into a vast rice monoculture but must maintain its status as a world center of bird biodiversity.

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Gelgufishers, Northern Gondar, Ethiopia

A proposed transboundary approach to improve the quality and supply of freshwater to estuaries for food production in West Africa: a Sierra Leonean case study

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Summary

Across developing countries, coastal communities depend on water supply from river networks from upstream to the coast for various livelihood activities, including food production. However, the ability of these rivers to ensure food security to coastal communities is increasingly challenged by human activities, weak policies and poor governance system.

This paper proposes the application of a coordinated approach in planning policy development and reforms at the landscape scale to improve upstream to downstream water quality and flows and ensure food security in West Africa. Elements of the proposed strategy comprise an ecological landscape-watershed combination that could guarantee the quality of rivers, ensure connectivity, avoid conflicts between institutions/nations and subsequently reduce human and climate induced risks to river systems. The strategy also recognizes the role of river ecosystems as important assets for poverty reduction and food security and calls for adoption of a cross-sectoral approach to the management of water resources in the context of achieving development whole including the vulnerable poor.

Introduction

Inland rivers are essential for food production and the sustainability of ecosystems (Nguyen *et al*., 2015). Inland rivers flow from upstream to the coast, with some forming estuaries as they discharge into the sea. The mixing of sea water and fresh water provides important levels of nutrients both in the water column and in sediment, making estuaries one of the most productive natural habitats in the world (NOAA, 2028).

Human activities, including, population growth, establishment of extractive industries along and within rivers, large scale farming and the effects of climate change undermine the connectivity, water quality and flow of rivers to estuaries, with implications on livelihoods and food security for coastal communities (Dandekar,2012). Considering the significant role of estuaries as "nurseries of the sea" (Nagelkerken *et al.,* 2008) it is urgent that effective actions are taken to ensure that the ecological balance between inland rivers and estuaries is maintained to enable inland terrestrial and freshwater bodies to maintain reasonable levels of quality and flow to estuaries (Lopoukhine *et al.,* 2012).

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Various strategies have been proposed to support the management of water resources for food security (Willemen *et al*.,2014; HLPE, 2015; Nguyen *et al*., 2015). This paper argues that an ecological and landscape-watershed approach, might not only guarantee fresh water quality and supply to estuaries but would also boost the contribution of these systems to food security. To enhance inland and coastal food production, it is therefore essential to ensure ecological connectivity between upland and downstream coastal systems, which calls for urgent need for a holistic and transdisciplinary approach that embrace the principles of social-ecological systems at the landscape scale (Nguyen *et al*., 2016).

This paper reviews available information and suggests strategies to sustain food security for coastal communities in Sierra Leone and other coastal West African countries. Specifically, it (1) proposes some strategic orientations on key elements for developing an ecological transboundary landscape-watershed approach, and (2) highlights practices to ensure food security for coastal communities through maintaining ecological balance from upstream to estuaries.

The proposed transboundary landscape-watershed management approach

Various policy and legislative provisions have been developed by many developing counties. However, the continuous degradation of inland rivers' water quality and reduction of water volumes flowing to coastal areas, as exemplified by the case of Sierra Leone (Feka *et al*, forthcoming), probably implies that the legislative and policy provisions are failing. In recognition of these failures, various activities have been undertaken by multiple stakeholders to implement holistic actions that could guarantee the management of water from upstream to downstream (See DAI, 2013- Pp 32-37).

A watershed is a management unit within which "all water" flows to a single river system and whatever happens in a watershed, regardless of location, can affect the river basin receiving the flow. River catchments in Sierra Leone, and West Africa in general are threatened by various human induced activities such as mining or poor agricultural practices and therefore, there is need to understand human behavior, values, culture, beliefs, norms and governance systems as well ecological systems to inform and build resilience (Nguyen *et al*., 2015).

Most rivers in Sierra Leone are transboundary in nature and do not align with jurisdictional boundaries. For instance, some of the major rivers namely Great Scarcies, Little Scarcies, Rokel, Taia or Jong, Sewa, Moa and the Mano (Figure 1) originate from neighboring Guinea, Liberia or from highlands within the country and activities happening up stream impact the quality of water in the Sierra Leone estuaries. The extended geographical and political scope presents the greatest challenges to any landscape watershed-management approach in terms of stakeholder engagement.
To facilitate an ecological landscape-watershed approach, it is critical to bring together all stakeholders within a given watershed unit and beyond, to understand '*how human wellbeing depends on the products and services of riverine ecosystems*' (GWP, 2012).

Figure 1: Map of Sierra Leone, showing political boundaries and rivers
Source Sierra Leone (http://www.un.org/Depts/Cartographic/map/profile/sierrale.pdf)

A watershed could be confined or extent beyond a landscape, depending on the defined management unit. For this paper a Landscape refers to the visible features of an area, resulting from either the integration of manmade (e.g. settlements, dams) and natural features or a variety of natural geographic features such as hills, mountains, estuaries, valleys etc. At the landscape level, governance will require multiple level considerations for the stakeholders where governments will be required to understand the socio-ecological vulnerabilities to be able to allocate the various human activities such as mining, logging or agricultural concessions appropriately (Nguyen *et al*.,2016). At the community level, governance will imply that both individuals and community-based institutions will be involved in making choices about priority activities such as farming, fishing and wood harvesting and cultural practices like the preservation of mangrove forest shrines practices at the local level. Local government levels will require support to invest in the creation and maintenance of green infrastructure[1] to protect river banks and limit evaporation of water from water bodies using local customary or regulatory laws and policies on natural resource use.

Beyond country boundaries, a coordinated regional or sub-

[1] Green Infrastructure refers to natural and semi-natural artifacts (such as tree planting, water-bank restoration, developing urban green spaces etc) designed and managed to deliver a wide range of ecosystem services

regional approach which strives to bring countries together for the common goal of sustainably managing inland rivers will be bear numerous advantages. For instance, in 2013, the Mano River Union (MRU) countries (Sierra Leone, Guinea, Liberia, and Cote d'Ivoire)[1], pursued water resources management within the Mano River basin (Prefecture of Faranah—Guinea). Similarly, the International Water Management Institute (IWMI) has promoted food security through analyzing the factors that enable adoption for different farming technologies at the basin-scale. Additionally, the IWMI has developed decision-making tools that promote the protection of ecosystem services in West Africa (DAI, 2013)

The success of such an approach depends on collaboration among stakeholders at various levels within a watershed and beyond. A recent report (Feka *et al.*, forthcoming) highlight how poor coordination and collaboration can threaten the system. At the landscape level therefore, it is critical to promote integration among all water and water-using sectors that offers a timely opportunity to view, value, and manage aquatic ecosystems as an integral part of water security planning (GWP, 2016).

In the case of Sierra Leone, existing provisions to do environmental impact assessment is often followed but implementing the recommended actions from the assessments is not always effective (Gormallyn and Tahsildar, 2017). Moreover, these provisions often need to be supported by research. It is, for instance, often challenging to know the quantity of water that might be needed by downstream systems to maintain minimal ecological functions, like reproduction for fish or rice production. However, in the absence of scientific evidence that a given action will undermine the quality of water or reduce water flow, the precautionary principle should take precedence. The burden of proof and subsequent follow up must be placed on the developer under the strict supervision of a designated ministerial agency. The challenge in most West African countries is that follow up on mitigation actions to guarantee water quality and flow during implementation of extractive industry activities is scant because of lack of qualified personnel or financial resources. Considering the ecological landscape-watershed approach, therefore, there is need for neighboring countries in West Africa to develop a sub-regional water management framework like the European Water Framework Directive (EU, 2018). This could guarantee that companies and other stakeholders protect and ensure that fresh water bodies remain in good ecological and chemical status within a specified period of their activities. At country level, such a Directive could prescribe the need for essential information and clearing-house mechanisms to ensure all stakeholders know the river basin/watershed's water abstraction, retention, discharge rates on based on which licensing or other government control can be exercised and adjusted as net situation changes. Similarly, between country initiatives need to be coordinated both at the country and sub-regional scale to ensure that plans, policies and field interventions are not conflicting at the landscape scale. An effective delivery of this approach is likely to guarantee the quality of rivers and ensure connectivity, avoid conflict between institutions/nations and hence reduce human and climate induced risks to river systems. This coordination between countries is critical because the causes of water quality decline at the landscape level can be both local and external (Figure 2). For instance, poorly implemented agricultural expansion and mining practices in Liberia continuously deteriorate quality and quantity in Sierra Leone (Figure 3). To overcome some of these poor practices the Directive could institutionalize incentives that promote responsible behavior such as the polluter-pays tax amongst others along the river basin/watershed between and within both countries.

[1] The MRU is an international organization established in 1973 between Liberia and Sierra Leone and later joined by Guinea in 1980. Its aim is to foster economic cooperation between the member countries. Ivory Coast Joined the Union in 2008 to benefit from its development objective and secure its political boarder because of the fragile nature of the region. The Mano River begins in the Guinea highlands and forms a border between Liberia and Sierra Leone.

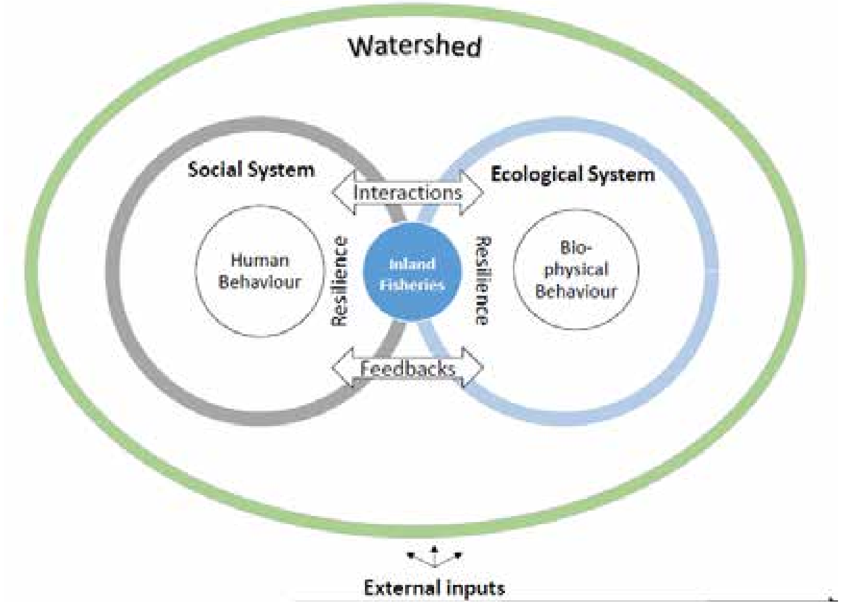

Figure 2: Socio-ecological dimensions to be considered in a watershed approach. Source culled from Nguyen *et al*., 2015

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Figure 3: Un-regulated activities across borders effecting water quality and quantity for food security in Sierra Leone / MRU Estuaries. a- Mining in Fulah camp river in Liberia leading to Moa and Manor River flowing through Liberia and Sierra Leone and b-Swamp rice farming in Gola forest area by communities in Sierra Leone

Trade-offs

In applying the ecological landscape watershed approach, there will always be a need for tradeoffs between maintaining a viable ecological system and meeting economic and social development needs (Nguyen *et al*.,2015). However, within, and between countries, there are disparities in socio-economic needs and targets, including governance challenges that might contradict the way natural resources are managed across borders. Regardless, most of the externalities that undermine the quality and quantity of water develop because of poor understanding of the socio-ecological systems' (SES) complexities at a watershed scale. For this reason, it is critical for development purposes to understand the interactions at the landscape level, through in-depth research to get the big picture (Figure 2) within and beyond the watershed unit. This will give a better understanding of the value of ecosystem services, how they contribute to functionally supporting aquatic ecosystems, as well as the symbiotic relationships between upstream water provisioning to the natural environment, downstream systems and sustainable economic growth (GWP, 2016). The reconciliation of people's development needs with conservation objectives poses the question of whether a win-win outcome is practically possible and specific to situations. The win-win outcomes therefore must be characterized by trade-offs and strategies to offset the developmental implications of such trade-offs through viable alternate income schemes (Senaratna Sellamuttu *et al*, 2008). And because of the disparities in socio-economic needs and targets between countries, it is essential to institutionalize an arbitration system between and within a country because conflicts will arise where shared water resources are concerned (See DAI,2014).

Maintaining equity for the vulnerable

When extractive industries undermine water quality and flow of fresh water to estuaries, the immediate impact is on the vulnerable and less powerful coastal communities that are threatened by polluted water and food insecurity. According to Willemen *et al*., (2014), there are three pathways through which vulnerable people in the landscape can be considered to benefit from a good ecological watershed management approach in line with development goals. These include (1) developing a management plan that promotes a sustainable and equitable distribution of provisioning ecosystem services that are of direct importance to human health and well-being, (2) promoting reduced risk and severity of impacts from shocks on lives and livelihoods, using appropriate risk mapping tools; and (3) promoting alternative opportunities for livelihood diversification and income generation.

Building resilience

Building resilience of depreciated ecological systems at the watershed scale (i.e. returning them to their original state) becomes imperative to ensure their sustainability in terms of quality and quantity of water that flows from upstream to downstream and neighboring countries. This can be done by promoting best practices at the landscape level. In this regard, WA BiCC has been promoting sustainable forest management practices and the implementation of green infrastructure[1] at both the forest landscape and coastal landscape levels across Sierra Leone, Guinea, Liberia, and Cote d'Ivoire (Tetra Tech, 2018)

Conclusion

Managing fresh water resources at the landscape level across national boundaries to guarantee water flow and quality for food security in coastal estuaries is an increasingly daunting task, but various emerging concepts have been proposed on how such challenges can be addressed.

This paper proposes an ecological watershed-landscape approach; a combination of principles that results in coordinated efforts in the development and implementation of plans, policies and legislative reforms at the landscape scale. The approach further recognizes the need for governance efforts to transcend country to improve upstream to downstream water quality and flows to attain full potentials in ensuring food security in West Africa. The approach also recognizes the role of river ecosystems as important assets for poverty reduction and food security and calls on stakeholders to adopt a cross-sectoral approach to the management of water resources that emphasizes securing river ecosystem services in the context of achieving development.

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Gelegu River, Northern Gondar, Ethiopia

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OPINION PIECE

Understanding wetlands and the food security nexus in Africa

Samuel Dotse[1]

Summary

Nearly 27.4% of Africa's population are currently food insecure. The continent is vulnerable to hunger because 65% of its labour force is involved in agriculture which is predominantly rain-fed. The predominance of rain-fed agriculture results in food systems that are highly sensitive to rainfall variability. Local farmers with limited options to increase food production in times of weather and rainfall variability rely on wetlands for their food security and income for sustaining their livelihoods. While the environmental importance of wetland ecosystems is widely documented, its contribution to food security is overlooked in global and national economic and sustainable development planning. This article aims to bring to the fore the interconnections and interdependencies between wetlands, water security and food security. It provides useful information to the national and international community on the need to integrate inland aquatic ecosystems into discussions on sustainable ocean and sea development if they earnestly want an opportunity to reduce food insecurity. The paper further recommends that though the goal for protection of wetlands should continue to be conservation of endangered and fragile sites, greater efforts should be focused on the concept of "wise use" to harness their contribution to food security.

Introduction

Acknowledged as the foundation for human and economic development (Lisa *et al*, 2006), food is the basic human need for survival, health and productivity. Food security is therefore a universal goal to ensure that "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences to live an active and healthy life" (FAO,2001). Therefore, as the world population is projected to increase to 9 billion by 2050, the FAO (2014) recommends an increase in food production by 60% to be able to feed the diverse population.

Ensuring food security depends on sustainable food production, which further relies on human capital, land and water resources. But as it stands now, the erratic and unreliable precipitation in critical periods of rain-fed crops (Laker, M.C. 2008) threatens food security in Africa for the reason that 65% of Africa's labour force is involved in agriculture which is predominantly rain-fed. The predominance of rain-fed agriculture in Africa, and especially Sub-Saharan Africa, results in food systems that are highly sensitive to rainfall variability (Jones, 2006; FAO, 2006 cited in Nelson *et al*, 2013). The effect of the amount of rain during the critical period of rain-fed crops is illustrated by the results for the 1980/81 and 1981/82 seasons in an on-farm field trial in Ottosdal district, Northwest Province of South Africa in Table 1.

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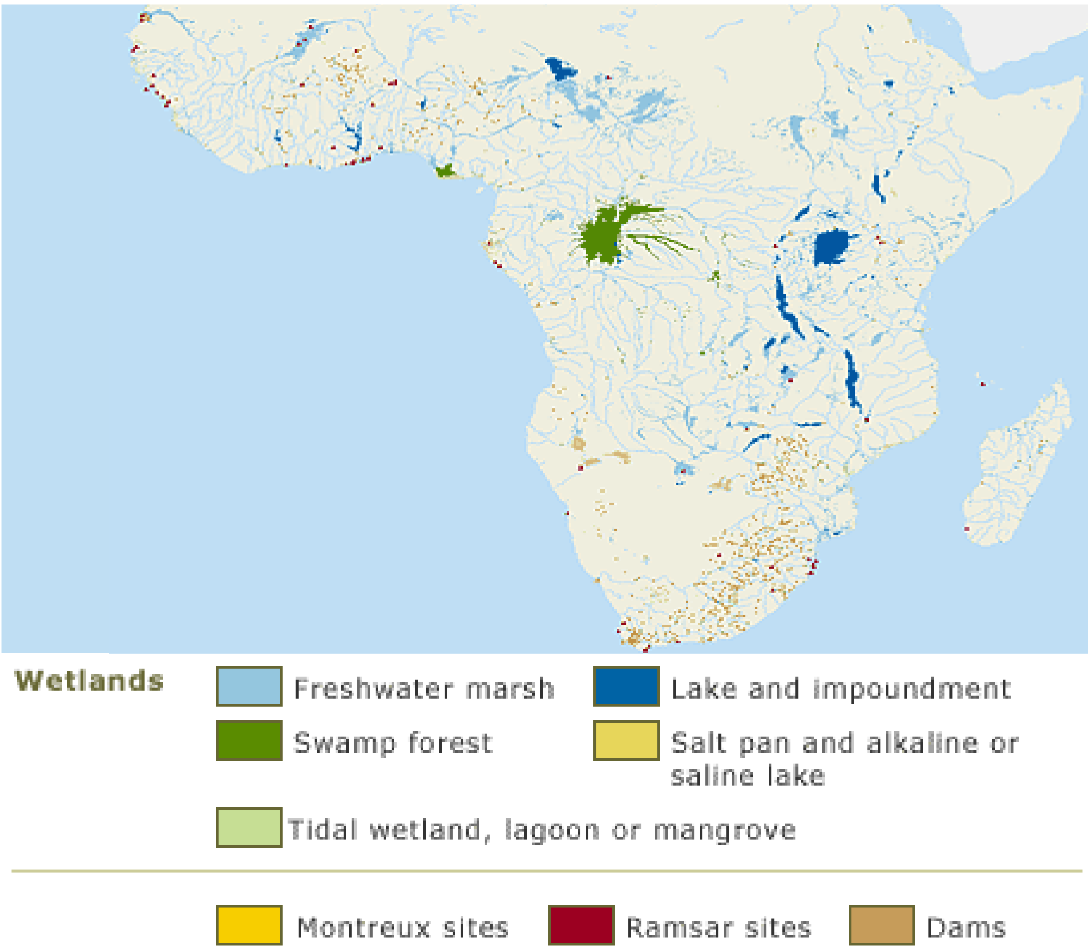

Figure 1. Wetland Distribution in Africa
Source: World Resources Institute, 2002

Table 1 – Maize yields in an on-farm experiment in Ottosdal district, South Africa

Season	Maize yield (t.ha-1)
1978/79	7.1
1979/80	5.4
1980/81	7.4
1981/82	1.1
1982/83	1.3
1983/84	NY*
1984/85	NY

Source; Fertilizer Society of South Africa, 1995 (Note: *NY = No yield, i.e. total crop failure due to drought)

Although 1980 was the only dry year (423 mm rain) in the wet cycle and the 1980/81 crop had to survive a dry December (only 39.5 mm rain) after good planting rains in November (83 mm), the season had a fantastic yield (7.4 t.ha-1) for this marginal cropping area, because the abnormally high rainfall (1074 mm) year 1981 started with 218.5 mm in January and 75 mm in February. In contrast, the 1981/82 season started promising, with 112 mm rain in December after good planting rains (72 mm) in November. It all went wrong when the dry (402 mm) 1982 started with only 60 mm rain in January and 28.5 mm in February, resulting in a yield of only 1.1 t. ha-1 and starting the five-year drought and sequence of low yields and crop failures. Although the total rainfall in 1980 was almost as low as in 1982, it started with adequate rain in January (96.5 mm) and February (74.5 mm) to give a yield of 5.4 t. ha-1 in the 1979/80 season, far above the average for that area (Laker, M.C. 2008).

To preserve food security and provide income-generating options, livelihood strategies may need to change. As Africa becomes increasingly marginal for crop production, livestock and fishing may provide an alternative to cropping. Unless strong measures are taken to find new means to reverse the trend, the quest for zero hunger in Africa and the world will be a mirage.

Nearly 27.4% of Africa's population are food insecure (FAO, 2017) as it was in 2002 (FAO, 2004). For the Central sub-region of Africa, the figure at that stage was 55% (FAO, 2004), mainly due to the fact that 71% of the population of the DRC, the biggest country in the sub-region was at that stage undernourished (AU, 2006). Africa compares very poorly with the rest of the developing world regarding undernourishment (Sanchez & Swaminathan, 2005; FAO, 2012),

Table 2 – Trends in undernourishment in different regions from 1990-92 to 2010-12

	Number (millions) and prevalence (%) of undernourishment		
	1990-92	1999-2001	2010-12
World	1 000	919	868
	18.6%	15.0%	12.5%
Developed regions	20	18	16
	1.9%	1.6%	1.4%
Developing regions	980	901	852
	23.2%	18.3%	14.9%
Africa	175	205	239
	27.3%	25.3%	22.9%
Asia	739	634	563
	23.7%	17.7%	13.9%
Latin America and the Caribbean	65	60	49
	14.6%	11.6%	8.3%
Sub-Saharan Africa	170	200	234
	32.8%	30.0%	26.8%
Southeast Asia	134	104	65
	29.6%	20.0%	10.9%

Source: State of Food Insecurity in the World, 2012, FAO.

Susceptible to hunger in times of environmental crisis, most smallholder farmers (63.6% in Sub-Saharan Africa) who also lack financial capital to venture into large scale irrigation, move into fragile areas like wetlands to increase food production (Bernard D. & Kurt A.R., 2016; Douglas Golin, 2014) Consequently, Africa has lost about 43% of its wetlands since 1900 (Davidson, 2014). The potential of wetlands to meet sustainable development needs is enormous in terms of productivity, purchasing power from income and employment; but only if they can be wisely used. This article aims to bring to the fore, the interconnections and interdependencies between wetlands, water security and food security. It addresses the need to integrate and include inland aquatic ecosystems into the discussion on sustainable ocean and sea development if the international community earnestly want to create an opportunity to reduce food insecurity.

Why wetlands matter to food security

While the international community recognises the role of oceans and seas within the context of blue economy to improve livelihood and to address the problem of food security, inland aquatic ecosystems such as wetlands, which guarantee livelihoods for the majority of Africans, have received little commitment if not having been left out. One very important means to ensuring food security is the understanding of the value or contribution of wetlands. The potential contribution of wetlands to food security and their role in support of the livelihood of large human populations is very clear. Although wetlands constitute only around 1% of Africa's total surface area they are home to around 100 000 aquatic species, including 3200 of all fish species belonging to 94 families, among nearly 11 000 fresh water species in the world (Nelson, 1994; Froese et Pauly, 2000; Ramsar Convention; Food and Agriculture Organisation). Recognised as the most diverse area in Africa for its fishes, in the Congo River Basin (formerly Zaire River Basin) over 1 200 fish species have been identified (Harrison *et al*, 2016), of which 560 are endemic to the basin.

Whilst the Congo basin is estimated as having a potential catch of 520 000 tons/year, with a value of USD 208 million/ year (Neiland and Béné 2008 cited in Harrison *et al*, 2016), the total economic value of the Zambezi Basin, and the Lake Chilwa within the SADC region are both estimated at over USD 201 million per year, with their respective fishing values estimated at USD 78 6 million (39.1% of the total value) and USD18 7 million (88.7% of the total value) per year (Kirsten,2002). Besides the economic benefits, wetlands guarantee food supply for humans who consume about 19 kg of fish each year on average, and livelihood support to the 61.8 million people who directly earn their living from fishing and aquaculture (Ramsar Convention). FAO (2014) revealed that the fisheries and aquaculture sector employs about 12.3 million people in the African continent. Half of the 12.3 million people employed (6.15million) are fishers (50.1percent), 4.9 million (42.4 percent) are processors and 0.9 million (7.5 percent) are fish farmers. More than half of the fishers (55 percent) are employed in inland fisheries whereas the largest share of processors (42 percent) is in marine artisanal fisheries followed by 30 percent in inland fisheries and 28 percent in industrial fisheries (FAO, 2014). Table 2 Summarizes the total figures and shares by subsector and within subsectors.

Table. 3 Employment by subsector

	No. of employees (thousands)	Share subsector (%)	Share within subsector (%)
Total Employment	12,269		
Total Inland Fisheries	4,958	40.4	
Fishers	3,370		68.0
Processors	1,588		32.0
Total Marine Artisanal Fisheries	4,041	32.9	
Fishers	1,876		46.4
Processors	2,166		53.6
Total Marine Industrial Fisheries	2,350	19.2	
Fishers	901		38.4
Processors	1,448		61.6
Aquaculture workers	920	7.5	

Source: FAO, 2014, Employment in Fisheries in the Whole Africa

Also, in the Inner Delta of the Niger River, over 550 000 people with about a million sheep and a million goats use the floodplains for post-flood dry season grazing (Kabii, Undated) and the region also provides annual catches of around 75 000 tons of fish (FAO, 2007-2018). The most interesting feature of wetlands is that they provide conditions that enable a wider range of crops than dry lands, and therefore provide ready food supplies to wetland fringe communities during unfavourable conditions (Mwakubo & Obar, 2009 cited in Nelson *et al*, 2013). Crops commonly grown at the edge of wetlands include: yams, beans, maize, sweet potatoes, cassava, vegetables, sugar cane and low land rice. Till date, rice is the staple diet of more than half of humanity, "nearly three billion people", and accounts for "20% of the world's nutritional intake" (Ramsar Convention).

Despite the contribution of wetlands to rural livelihoods, the resource has been overlooked in global and national economic and sustainable development planning. For instance, whilst SDG 14 only seeks oceans and seas based sustainable development, the mention of wetlands under Goal 6 (Target 6.6) concentrates on conservation of endangered and fragile sites, overriding the quest to ensure food security. Meanwhile, of the 19.7 million tonnes of fish produced every year (excluding fish caught by foreign fishing vessels) inland fisheries produce 6.2 million tons fish, second to marine (10.2 million) (FAO, 2014), an account that cannot be overlooked. If the global goal is to eradicate poverty, improve livelihoods and ensure food security, then other very important resources mostly used by the very poor people whose lives the world seeks to improve, must be taken into consideration. Sustainable ocean and sea economy should be integrative and inclusive of inland aquatic ecosystems, such as wetlands, for a holistic discussion. The interconnections and interdependencies between wetlands and food security can no longer be underestimated.

Conclusion and recommendations

With rain-fed agriculture being the primary food production option for Africa, local farmers with limited options to increase food production in times of weather and rainfall variability, will continue to rely on wetlands for their food security and income for sustaining their livelihoods, which in most cases are not sustainably carried out. Therefore, understanding the degree to which wetlands contribute to food security may be vital in steering decisions that minimize negative impacts or enhance the benefits that wetlands contribute to communities.

Planning for food security and wetlands management needs deliberate harmonisation of efforts of different policies and legislations at all levels. However, if the current consideration on oceans and seas for sustainable development continues to underestimate the significance of wetlands, the world and especially Africa will miss the opportunities for reducing food insecurity and sustainable management of wetland systems. Although the goal for protection of wetlands should continue to be conservation of endangered and fragile sites, greater efforts should be focused on the concept of "wise use" to harness their contribution to food security. The fact that many wetlands function do not have a market price and as such are not recognized as having an economic value by decision-makers, its contribution to food security and livelihoods for local communities in Africa cannot be underestimated. Economic valuation and trade-off analysis tools should be used as justification for continues investment in wetlands to maintain its food production function.

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Economic value of small-scale fisheries in the Victoria Nile-Lake Albert Delta, Uganda: implications for nutritional food security

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Summary

Despite the enormous worldwide contribution of small-scale fisheries in terms of nutritional food security, employment and poverty reduction, they are often marginalised because their economic value is poorly quantified. The study provides an analysis of the levels, methods and profitability of small-scale fishing in a remote area in the Victoria Nile-Lake Albert Delta, Uganda. The study also looks at both the legal and illegal methods of fishing and the impact of fishing on the diversity of the fish stocks. The highest value per kg was found to be for Alestes baremose (Angara) and Hydrocynus forskahlii (Ngassia/Ngassa) although the biggest contribution to the total annual catch was Brycinus nurse. The study clearly illustrates how the above contributions are realised, estimates the quantity and value, the fish assemblages that dominate the fishery, fishing costs, net value (benefit), profitability and return on investment for the different fishing methods or gears. The study revealed the management implications of the results for fisheries managers, fishers and sustainability of the small-scale fishery benefits.

Introduction

In this paper, small-scale fishery refers to traditional fishing households, using relatively small amounts of capital and energy, and making relatively short fishing trips, close to the shore, mainly for local consumption. Small-scale fisheries contribute to affordable quality nutrition to some of the world's most vulnerable populations (FAO, 2016; Funge-Smith, 2018).

Despite the world-wide contribution of small-scale fisheries in terms of nutrition and food security, employment and poverty reduction in fishing communities (Batsleer, Poos, Marchal, Vermard & Rijnsdorp, 2013), they are often marginalised because their economic value is poorly quantified. The purpose of this study was therefore to contribute to filling the above gap by determining the economic value of the small-scale fisheries at beach level in

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a remote area in the Victoria Nile-Lake Albert Delta (Figure 1), using a mixed method, namely the multi-stage stratified random sampling technique and snowball/theoretical procedures (Levitt, Creswell, Josselson, Bamberg, Frost & Suarez-Orozco, 2018).

A total of 1780 fishers, operating 689 active fishing vessels in seven landing sites in the vicinity of the delta (Figure 1) were active in the area based on a Frame Survey (FS) of 2016 (MAAIF, 2016). In this study, the fishing vessel represented the sampling unit and was defined as "a group of fishers in one fishing vessel and the overall leadership of the owner" (Penello *et al*., 2017). Due to the limited finance and time resource, this study focused on two landing sites, including a total of 224 individuals, comprising 210 fishers operating in 105 fishing vessels, representing 12% of the population of fishers in the seven landing sites, and 14 other stakeholders (02 beach leaders; 05 fish buyers, and 07 government employees). The Catch Assessment Survey (CAS) focused on costs of fishing, catch and value and lasted three months between April and June 2018. The study used the observed market economic valuation approach to measure the monetary value that societies or communities attach to small-scale fisheries (Chiwaula & Witt, 2010).

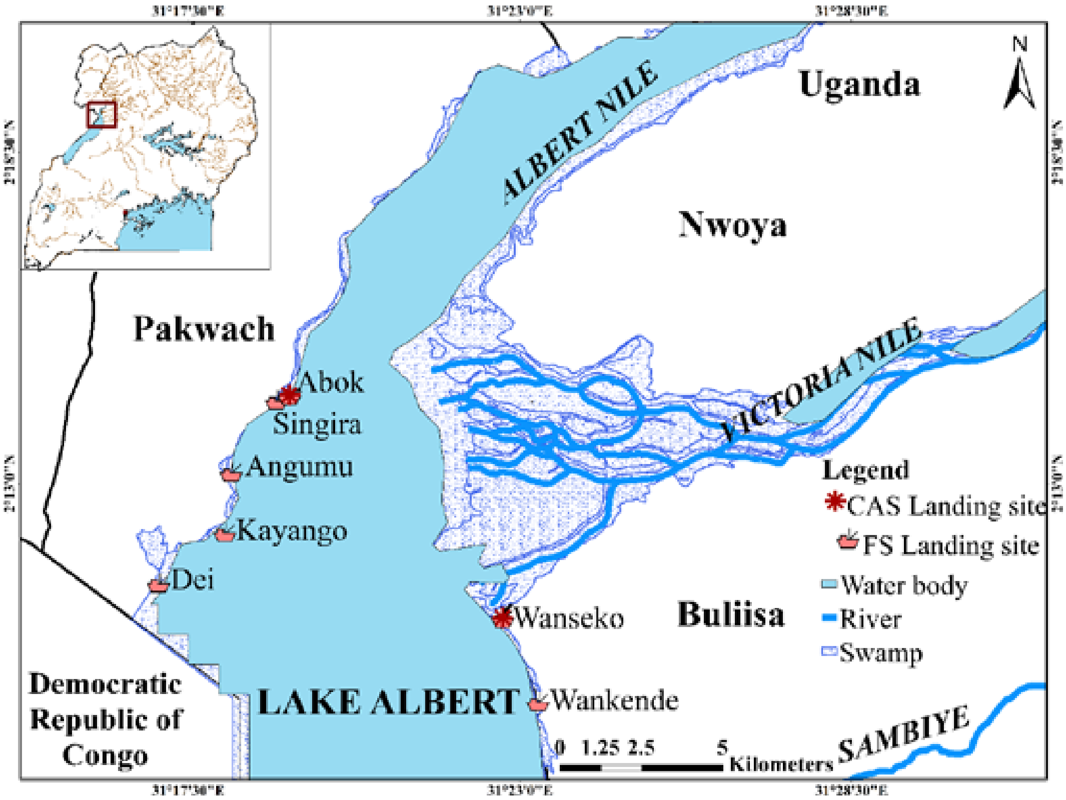

Figure 1: A map showing the studied landing sites in the Victoria Nile-Lake Albert Nile Delta with an inset map of Uganda showing its location.

Source: Dismas Mbabazi 2019

The small-scale fisheries in the delta comprise a multispecies Western Africa fisheries fauna which is rare elsewhere in Uganda (e.g. *Citharinus latus*, *Hydrocynus forskahlii, Alestes baremose, Lates macropthalmus* and *Neobola bredoi*) but is abundant in most rivers in West Africa (Dumont, 2009). The delta is a major spawning ground for many economically important fish species (Achere & Mwene-Beyanga, 1990). The fish is harvested using multiple gears and fishing strategies, at the same or different times of the year, to target a wide variety of fishes that are highly cherished by communities near the delta and in the various districts surrounding Lake Albert and Albert Nile (Mbabazi *et al*., 2012).

The key challenges to successful management of small-scale fisheries have been that most regulatory strategies focus on protection of the resource base and rarely consider the economic losses of the fishers. Successful management is also impeded by lack of information on reasons for failures of most management interventions and lack of the necessary data and/or information to determine optimal management (Eaurastat, 2018). This study generated economically valuable data/information on the resource base and harvesting methods required to contribute to development of appropriate management strategies for the small-scale fisheries in the Victoria Nile-Lake Albert Delta to ensure their sustainable benefits. It specifically, estimated the quantity and beach value of the landed fish catch per year by fishing method or gear; identified the fish assemblages that contribute to the value of the small-scale fisheries and estimated the fishing costs and determined the net economic benefit or income to the fishers (Profitability and Rate of Return on Investment) in the Victoria Nile-Lake Albert Delta

The fishing capacity, quantity and value of small-scale fisheries by fishing method

The study confirmed that the small-scale fisheries in the study area was a multispecies fishery. Fishing was done using multiple fishing methods/gears (Figure 2), operated throughout the year and provided full time employment to at least 1780 fishers (15% women) as indicated by an average of 7 fishing days for most fishing methods (Table 1).

Table 1: Selected indicators on fishing capacity in the small-scale fisheries of the Victoria Nile-Lake Albert Delta 2016.

Boat-Gear combination	Legality of usage	No. of fishing vessels	No. of fishers	Average boat length (m)	± sd	Average of No. of crew	± sd
CB-BES	Illegal	41	321	6.4	1.0	7.8	2.6
CB-CN	Illegal	60	120	8.2	2.5	2.0	0.0
CB-GN	Legal	460	974	6.3	2.0	2.1	0.3
CB-LL/HL	Legal	39	78	7.7	2.4	2.0	0.0
CB-SS	Not defined	66	241	7.0	2.2	3.7	1.0
CB-TR	Illegal	23	46	5.8	2.3	2.0	0.0
Grand Total	Multi gear	689	1780	6.9	2.2	2.6	1.6

Source: (MAAIF census survey data for 2016); CB-BES (Congo barque using beach seine nets); CB-CN (Congo barque using cast nets); CB-GN (Congo barque using gillnets); CB-LL/HL (Congo barque using hooks); CB-SS (Congo barque using small seines and light) and CB-TR (Congo barque using basket traps)

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A. Congo barque (CB) and the only type of fishing vessel used in the study area

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B. Gill nets (GN) and netted fish (Dominant fishing method and recommended)

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C. Basket trap (TR) and trapped electric fish (Illegal fishing method)

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D. Long line hooks (HL or LL), a common fishing method in the study area

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E. Cast net fishing (CN)

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F. A typical fish catch in the study area

Figure 2: Selected fishing inputs and outputs from small-scale fisheries of Victoria Nile-Lake Albert Delta

The study further estimated that in 2017 the annual quantity of fish landings from the small-scale fisheries at beach level in the study area was 8 413 metric tons, worth a gross value of USD 11.5 million. The fish landings were 95% dominated by the fish catch from the gill net fishery, while other fishing methods combined contributed less than 5% (Table 2).

Table 2: The quantity **± SD** (tons), percentage contribution and value **± SD** (USD) of the various -gear combinations in the small-scale fisheries of the Victoria Nile-Lake Albert Delta (2017)

Boat gear combination	Legality of usage	Quantity (tons)	± sd	%	Value (USD)	± sd
CB-BES	Illegal	-	-	-	-	-
CB-CN	Illegal	164	66	1.9	249 343	94 328
CB-GN	Legal	8 043	7 047	95.6	10 995 571	9 614 781
CB-LL/HL	Legal	185	32	2.2	263 364	44 165
CB-SS	Not defined	-		-	-	-

Boat gear combination	Legality of usage	Quantity (tons)	± sd	%	Value (USD)	± sd
CB-TR	Illegal	22	12	0.3	32 243	17 982
Overall	Multi gear	8 413	7 157	100	11 540 521	9 771 256

CB-BES Congo barque using beach seine nets; CB-CN Congo barque using cast nets; CB-GN Congo barque using gillnets; CB-LL/HL Congo barque using hooks; CB-SS Congo barque using small seines and light and CB-TR Congo barque using basket traps.

Source: This study through examination of fishers catch landed at selected landing sites between January and April 2018 and frame survey census data for MAAIF 2016.

The contribution of fish assemblages/groups to the value of the small-scale fisheries

Despite the dominancy of the silver fish Brycinus nurse in the Victoria Nile - Lake Albert Delta small-scale fish catch by quantity, it was only the fourth valuable species. In order of importance the most highly valued fish being the D. rostrus, D. niloticus, Barbus bynn (Kisinja/Oshoi) and Alestes baremose (Angara) (Table 3). A further analysis based on value per kg revealed that A. baremose (Angara) and Hydrocynus forskahlii (Ngassia/Ngassa) were the most valued fish species followed by B. bynn. The high value of these groups of fish was likely due to high demand by consumers in the area, driven by a high preference for the species but also due to their scarcity evidenced from their low overall quantities (Table 3). The largest contributors to the value of the catch in the delta were therefore the species that mature at large sizes such as Distichodus spp, B. bynn, A. baremose and H. forskahlii. The study indicated a shift from dominance in abundance of large sized fishes to the small sized species, but noted that dominance in value was still with the large sized species. Further analysis showed a similar trend over the past five decades up to the collapse of the Citharianus citharus stock (Cadwalladr & Stoneman, 1966).

Table 3: The contribution of the various fish taxa/group, CPUE, Mean value (Shs/kg) to the estimates of annual quantity ± sd (tons) and value ± sd (USD) of the small-scale fisheries in the Victoria Nile-Lake Albert Delta.

Fish taxa/group	CPUE	± sd	Mean Price (Shs/Kg)	Quantity (tons)	± sd	Value (USD)	± sd
Alestes baremose	2.8	3.5	8430	462	569	1 062 792	1 307 951
Alestes macrolepidotus	1.4	0.2	6400	187	75	325 703	130 280
Auchenognalis occidentalis	0.9	1.6	3500	249	521	237 207	497 027
Barbus bynni	2.5	1.9	6766	731	609	1 348 513	1 122 995
Brycinus nurse	8.3	10.0	3559	1 352	640	1 312 211	1 591 896
Clarias gariepinus	3.2	1.3	5375	333	200	488 406	293 352
Distichodus niloticus	5.9	6.0	5200	955	984	1 353 974	1 395 569
Distichodus rostratus	6.5	-	5000	1 061	-	1 446 553	-
Hydrocynus forskahlii	2.7	2.4	7467	448	391	912 782	796 817
Labeo coubie	1.8	1.5	5357	299	238	462 402	367 526
Labeo horie	1.0	0.8	5667	222	179	324 536	262 044
Lates niloticus	2.8	0.5	5358	335	238	493 867	351 121
Mormyrops anguilloides	1.4	1.1	5125	230	185	321 778	257 948

Fish taxa/group	CPUE	± sd	Mean Price (Shs/Kg)	Quantity (tons)	± sd	Value (USD)	± sd
Malapterurus electricus	2.0	0.8	4250	26	11	30 642	12 223
Oreochromis niloticus	2.5	1.7	5358	367	284	535 795	415 189
Protopterus aethiopicus	1.1	0.8	2667	184	124	133 726	90 052
Polypterus senegalis	2.2	1.1	500	351	173	47 848	23 605
Synodontis frontosus	2.2	3.8	4400	359	628	430 850	753 320
Schilbe intermedius	1.0	-	4000	163	-	178 037	-
Other	0.4	0.4	3426	99	110	92 898	102 342
Overall	2.6	2.0	4893	8 413	7 157	11 540 521	9 771 256

Source: This study through examination of fishers catch landed at selected landing sites between January and April 2018.

The fishing costs, net incomes (benefit) and profitability in small-scale fisheries

The fixed, investment, variable and salary costs varied across the fishing methods in the study area (Table 4).

Table 4: Estimates of the annual fishing costs (USD) by the various -gear combination in the small-scale fisheries of the Victoria Nile-Lake Albert Delta Area.

Fishing input/cost indicator	CB-CN	CB-GN	CB-HL/LL	CB-TR	Overall
Fixed costs (Depreciation)					
Opportunity cost (TR*R)	730	19 857	726	384	21 697
Fishing boat	1 249	22 456	1 026	727	25 458
Propulsion (Oars/Paddles)	38	588	39	16	681
Fishing Gear	475	44 869	180	439	45 963
Sinkers/Floats	-	7 585	-	-	7 585
Total	2 492	95 353	1 971	1 565	101 382
Investment costs (TC)					
Fishing boat	6 938	77 117	7 330	2 854	94 239
Propulsion (Oars/Paddles)	229	3 526	235	94	4 083
Fishing Gear	949	124 823	498	1 317	127 588
Sinkers/Floats	-	15 169	-	-	15 169
Total	8 116	220 634	8 063	4 265	241 079
Variable costs					
Bait	-	-	8 561	-	8 561
Fish advance to fishers (laborers)	19 457	1 316 752	18 487	45 792	1 500 488
Total	19 457	1 316 752	27 048	45 792	1 509 049
Salaries and wages					
Salaries	29 455	795 065	7 036	16 937	848 493
Wages	245	6 626	59	141	7 071

Fishing input/cost indicator	CB-CN	CB-GN	CB-HL/LL	CB-TR	Overall
Total	290 701	801 690	7 095	17 078	855 564
Overall costs (A+C+D)	178 612	2 213 507	41 180	79 806	3 213 106

CB-BES- Congo barque using beach seine nets; CB-CN- Congo barque using cast nets; CB-GN- Congo barque using gillnets; CB-LL/HL-Congo barque using hooks; CB-SS-Congo barque using small seines and light and CB-TR- Congo barque using basket traps.

Source: This study through examination of fishers catch landed at selected landing sites between January and April 2018 and frame survey census data for MAAIF 2016.

Table 5: Estimates of revenue, fishing cost, net benefit or income (USD), profitability (%) and Rate of Return on Investment (ROI) from the small-scale fisheries by -gear combination in the Victoria Nile-Lake Albert Delta.

Boat gear type	Per individual fishing boat			Total fishing vessels	Victoria Nile-Lake Albert total			Profit	ROI
	Revenue	Cost	Net		Revenue	Costs	Net		
CB CN	4 156	2 977	1 179	60	249 343	178 612	70 731	0.28	(60)
CB GN	23 903	6 334	17 569	460	10 995 571	2 913 507	8 082 064	0.74	177
CB HL/LL	6 753	1 056	5 697	39	263 364	41 180	222 184	0.84	440
CB TR	1 402	3 470	(2 068)	23	32 243	79 806	(47 563)	(1.48)	(160)
Overall	36 214	13 836	22 378	582	11 540 521	3 213 106	8 327 415	0.72	159

CB-BES (Congo barque using beach seine net)s; CB-CN (Congo barque using cast nets); CB-GN (Congo barque using gillnets); CB-LL/HL (Congo barque using hooks); CB-SS (Congo barque using small seines and light) and CB-TR (Congo barque using basket traps).

Source: This study through examination of fishers catch landed at selected landing sites between January and April 2018 and frame survey census data for MAAIF 2016.

Tables 4 and 5 confirm that the fishery was profitable and registered a return of investment of about 38%. Using legal fishing methods was more economically profitable, e.g. gill nets giving 40% and hooks 28.4% return on investment, compared to the illegal fishing ones such as cast nets (12.3%) and traps (-7.3%). Overall the gill net fishery contributed over 97% to the net income (benefit) or to the value of the Victoria Nile-Lake Albert small-scale fisheries and was estimated at about 9 million USD. It is also important to note the ROI supports the ministry's recommended gears in the Lake Albert and Albert Nile and the low ROI of cast nets and traps justify them not being permitted to operate in the system.

Conclusions and implication for management

The small-scale fisheries in the study area were based on a multispecies fishery (>30 fish species), dominated in quantity by the low value fish such as Brycinus nurse. The study noted the continuous reduction of high value species such as Distichodus spp., B. bynni, A. baremose and H. forskahlii due to their differences in market prices. The study further noted that the highly priced fish species tend to be over-exploited, and therefore empirical measures of compositional control should be useful to fisheries managers, scientists, policy analysts, working on management of multiple species fisheries. Further research is required to establish how best to ensure the sustainability of the higher valued species in ways that the fishers themselves agree with

It was apparent that the main factor limiting the fish available for sale was on advance payment for fishers in form of fish food as part payment for salaries and wages. The observation confirmed the contribution of small-scale fisheries to nutritional food security and full time employment. The study also found that fishing small-scale fisheries was profitable, especially using the legal fishing gears such as gill nets and hooks. The study also provides some justification that regulations on fishing modes/gears could form part of the development of cost effective management measures to ensure sustainable utilization of the fishery. However less than 5% of the fish catch Table 2 uses illegal methods so it would not have a significant impact. Furthermore, it is unclear why fishers would use the illegal methods if the legal methods were so much profitable and further research to understand why some fishers using illegal methods do not switch is needed. This research showed the profitability and its importance to the fisher population in the Victoria Nile-Lake Albert region.

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Poor management of Lake Victoria fisheries (Kenya): a threat to sustainable fish supplies

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Summary

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 at 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 the three institutions managing the same resource: the beach management units (BMUs), county government and national government. This is 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 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.

Introduction

Lake Victoria, the second largest fresh water lake in the world, covering an area of about 68 800 km^2 (Kimani *et al*., 2017, Natugonza *et al*, 2017), supports the largest inland freshwater fishery in the world. The Kenyan portion is about 4 128 km^2 (6%) producing 80% of all annual fish landings from Kenyan waters, both marine and fresh waters (Kimani *et al*., 2017). The main commercial species are *Rastrineobola argentea* (Omena/Dagaa/Mukene) 53%, *Lates niloticus* (Nile Perch) 33% and *Oreochromis niloticus* (Nile Tilapia) 4% (Kimani *et al*., 2017). Fish is highly perishable and needs to be utilized immediately or

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properly preserved (Odoli *et al*., 2013). The Lake's fishery is faced with high post-harvest losses, a nutrient and economic loss that renders the commodity unavailable or nutritionally deficient to humans (Tesfay and Teferi, 2017), especially for Omena fishery (Bengwe and Kristofersson, 2012). Post-harvest losses of fish caught in Lake Victoria are estimated at 20-40%, translating into 32 million USD annually (IOC, 2012). This needs to be reduced (Mgawe and Mondoka, 2008; Bengwe and Kritofersson, 2012). The other factor affecting the fishery is the use of undersize gears, which catch immature fish species of commercial importance, especially the big predator fish, the Nile Perch. Nile Perch was deliberately introduced in the 1950s to 60s (Ogutu-Ohwayo, 1990a, Welcomme, 1967). This predator fish changed the fisheries scenario in the 1990s into a multimillion-dollar commercial fishery, accounting for 90% of the fish exported by the East African countries, Kenya, Uganda and Tanzania (Odongkara *et al*., 2005; Yongo *et al*., 2005). This windfall came with an ecological price to pay, the fish is blamed for the disappearance of more than 200 species of Haplochromines, and decline of other native species like *O. esculentus; O. variabilis; Bagrus docmak; Alestes* spp, *Barbus* spp; mormyrids (Ogutu-Ohwayo, 1990a, Witte *et al*., 1992). Haplochromines were substituted by the pelagic *R. argentea* and the freshwater shrimp, *Caridina nilotica* (Marshall & Mkumbo, 2011). The two species today form an important diet for Nile perch. The fisheries provides employment, income and export earnings to the lake-edge communities (Nyamweya *et al*., 2016). The lake provides services like water for domestic and industrial use, transport, hydro-power generation and food to about 40 million people (Nyamweya *et al*., 2016)

The fishing gears used are gill nets, small seines, beach seines, boat seines, cast nets, monofilament nets, handlines, longlines and traps. The total number of gill nets decreased by 10% from 2010 to 2016. During this period, the proportion of undersize gill nets (below 5 inch mesh) increased from 22% to 40%. The legal mesh size for catching Nile Perch is 6 inches and for tilapia is 5 inches, Dagaa is caught using a 10 mm small seine at night, with light being used to attract fish. Beach/boat seines nearly doubled in the same period, monofilament gill nets increased almost 14 fold. The number of hooks, used as hand-line and longlines decreased by 75% and 7.5% respectively.

The lake currently faces a myriad of problems of increased fishing pressure, eutrophication (excessive nutrient loading), excessive water abstraction, sedimentation due to erosion, environmental degradation, climate change, invasive species, loss of biodiversity and ecological alteration (Nyamweya *et al*., 2016). The lake has become highly eutrophic, leading to 'algal blooms' and invasion by *Eichhornia crassipes* (Water hyacinth).

Cage farming is a new challenge that needs to be regulated to protect fish breeding and nursery grounds. Trials on cage farming started in 2005 at Dominion farm ltd. The first commercial trials were done in small water bodies around Lake Victoria in 2007 by 'BOMOSA', a EU (European Union) funded project, while commercial cage farming in the lake started in 2012, with 5 cages. This attracted great interest, resulting in the current 3 696 cages deployed in the lake. Some cages are located in fishing and breeding grounds as well as navigation routes (KMFRI, unpublished report, 2018). Increased demand for aquatic resources threatens sustainability of the resource but can also stimulate wise use of the resource. Food security is considered achieved "when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active healthy life" (FAO, 2014). Lake Victoria Fisheries Organization (LVFO 2016) observed that ecologically and economically important fish stocks are declining at an alarming rate, a situation that could exacerbate poverty and food security problems in the Lake Victoria region. The impact of fishing pressure and post-harvest losses on available fish stocks is vital in drawing an effective fisheries management plan to sustain the fishery. The aim of this study is to explore ways of reducing fishing pressure and post-harvest losses.

Preliminary results

A hydro-acoustic survey showed that Nile Perch biomass in the Kenyan portion of the lake has been declining steadily since 2014. The biomass declined by about 31% from 58 374 tons in 2015 to 40 173 tons in 2016 (Table 1) with Nyanza Gulf registering the highest decline (50%). Similarly, Dagaa and Haplochromines/other species biomass declined by 40% and 72% respectively. The contribution of Nile Perch to the total catches in 2015 was 26 293 tons, the lowest ever recorded since 1992 (Table 2). Considering biomass, catch and fishing effort results, the maximum sustainable yield (MSY) for Nile Perch and Tilapia was estimated to be 86 096 tons and 27 892 tons respectively. To achieve the desired MSY, would immediately require about 40% reduction in fishing effort (Table 2)

Table 1: Estimated fisheries potential within the Kenyan part of Lake Victoria

Standing stock and biomass estimates of Nile Perch Dagaa Haplochromines/others fish species and *Caridina nilotica* from the last three acoustic surveys by locality				
		Nile Perch		
Year	Littoral zone	Inshore	Nyanza Gulf	Total
2014	33 207	31 152	1 402	65 761
2015	16 424	38 596	3 354	58 374
2016	9 661	28 827	1 685	40 173
Dagaa				
2014	30 621	34 907	14 285	79 813
2015	43 457	51 654	11 478	106 589
2016	16 595	18 890	28 578	64 063
Haplochromines and others				
2014	3 863	13 416	4 806	22 085
2015	10 432	29 186	9 092	48 710
2016	1 545	7 968	4 058	13 571
Caridina				
2014	772	1 230	82	2 084
2015	1 554	2 234	410	4 198
2016	5 409	23 135	22 737	51 281

**other species includes Nile Tilapia, whose catches had drastically decreased. Currently, most Tilapia is being imported from China to cater for the deficit estimated at 80 % (Ntiba pers. com)*

The current reference points and the current effort and catch levels for the commercial fish species are shown in (table 2). The maximum sustainable yield (MSY) was calculated using the Schaefer Model.

Table 2: Exploitation status of commercial fish of Lake Victoria, Kenya.

Species	Exploitation rate	$C_{current}$	C_{MSY}	$E_{current}$	E_{MSY}	Proposed reduction in effort (%)
L. niloticus	0.45	26 293	86 096	7 714	4 474	40
Dagaa	0.63	67 457	-	3 189	2 047*	36*
Tilapia	0.50	3 203	27 892	2 672	1 499	44

Legend:

C = Catch in tons

MSY = Maximum Sustainable Yield

E = Effort (no. of crafts, gears& fishers)

**uncertain parameter due to the schooling behavior of the species, hence Catch Per Unit Effort is not accurate representation of abundance.*

***Catch per person per year in kg*

*The most recent MSY for the entire lake using hydro-acoustic, catch assessment survey and frame survey data estimates the available fish stock for 2019 to be 138 448 tons, a 16% reduction from that of 2015. It is suggested that if we can maintain fishing pressure at that level for 2 to 3 years, a sustainable MSY of 260 000 tons will be achieved for Nile Perch fishery (LVFO report under review).

Illegal use of gillnets (catches immature fish) is prevalent in 5 sub counties: Rachuonyo North (23%), Rarieda (14%), Kisumu West (13%), Seme (12%) and Mbita (7%). In total, the 5 sub counties are responsible for 69% (almost 70%) of all the illegal fishing in the lake.

Discussion

The current analysis relied on single species models that do not capture other drivers of ecosystem change. The decline in Dagaa biomass appears to have favoured an increase in biomass of freshwater shrimp *Caridina nilotica*, but Nile perch is known to feed on the shrimps in the absence of Haplochromines (Katunzi, Van Densen, Wanink, & Witte, 2006; Ogutu-Ohwayo, 2004; Outa, Yongo, & Jameslast, 2017). Future studies should clarify the reasons behind this scenario. Previous studies had shown a direct relationship between Nile perch increase with a corresponding Haplochromine decrease in population. This was attributed to predation pressure on Haplochromines by Nile perch (Ogutu-Ohwayo, 1990a, 1990b, Goudswaard, Witte, & Katunzi, 2008, Downing *et al*., 2014, Kishe-Machumu, Nkalubo, Chapman, & Muyodi, 2014). Equally complex are the ecological processes that govern ecosystem structure and function as the inherent variability in biophysical processes and the interactions between ecological, economic and social processes (KMFRI, unpublished stock assessment report). Understanding this complexity is a prerequisite for effective management. In addition, cage farming needs policy and regulations to guide its investment (Aura *et al*. 2018).

Conclusions

The fish stock is currently overexploited and suffers high post-harvest losses of 20-40% and a further 40% lost through illegal fishing. This is as a result of poor management strategies and lack of cost effective technologies for preserving landed fish. Only 5 out of 32 (15.6%) sub counties account for almost 70% of the illegal fishing, an issue that needs to be addressed objectively.

Recommendations

- Post-harvest losses should be reduced by employing cost effective technologies to preserve landed fish and keep PAH levels low for improved health and for facilitating export to premium markets.

- To allow fish stocks to recover and maintain ecological health, a reduction of fishing effort by about 40% is recommended.

- Haplochromines and the freshwater prawn, *Caridina nilotica* needs to be protected as they are prey for the Nile perch (the only inland fish exported to Europe and Far East).

- There is need to *set al*lowable catch and effort annually for a particular fishery.

- For timely and prudent management of the fishery, regular monitoring of fish stocks and improvements in the provision of evidence-based advice for fisheries is critical and highly recommended.

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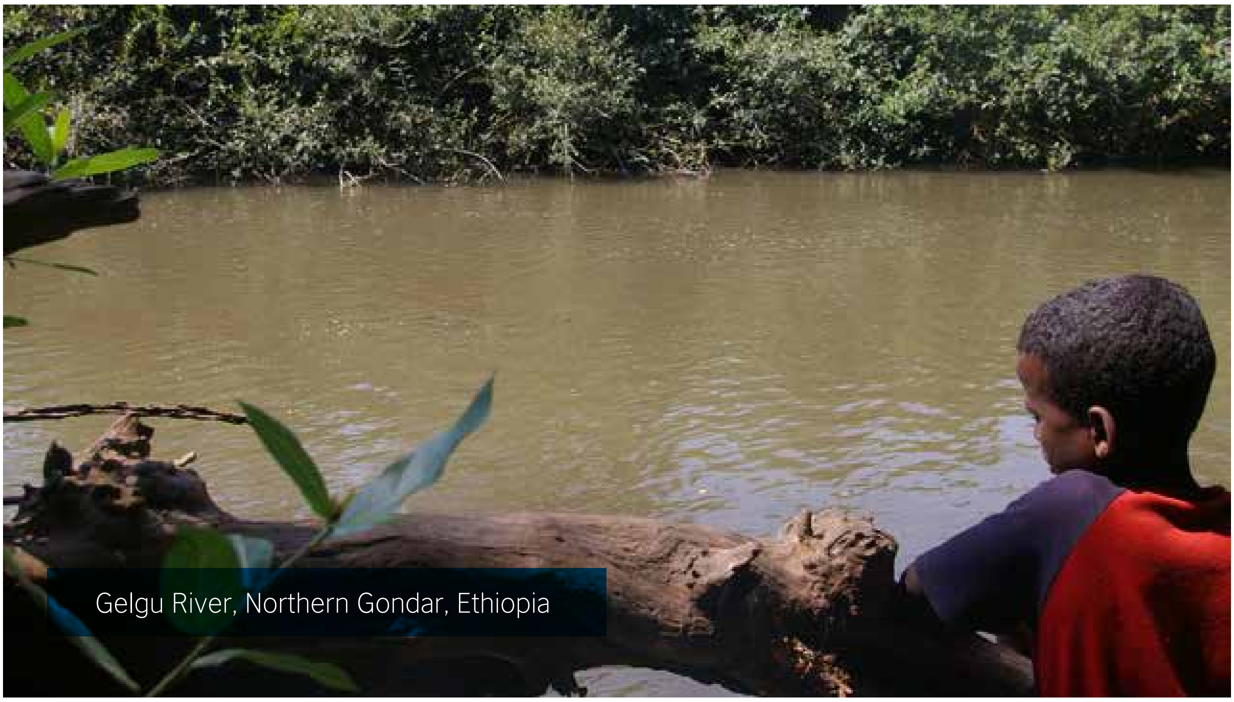

Gelgu River, Northern Gondar, Ethiopia

Lake Turkana can support food security in northern Kenya and beyond

Diida Karayu Wario[1]

Summary

Lake Turkana is a lake in the Kenyan Rift Valley, in northern Kenya, with its far northern end crossing into Ethiopia. It is the world's largest permanent desert lake and the world's largest alkaline lake. Marsabit County is located in northern Kenya, bordering the shore of Lake Turkana. It is the largest inland water mass in Kenya, with a total length of 265 km and a width of 48km. The Chalbi Desert makes up much of the center region of the county, and mount Marsabit is a major feature in the eastern section of the county. The county's main sources of livelihoods are pastoralism - 81%; agropastoralism - 16%; others, including fishing - 5%. Despite the lake Turkana being home to many fish species, not many residents of Marsabit County consume fish. Instead, the residents, who are mainly pastoralist communities, prefer animal-based protein. For this reason, this paper discusses the opportunities that exist to upscale fish consumption and marketing. The paper concludes that Lake Turkana has a huge potential for fish production. Further, the paper recommends that Kenya's Government increases investment in a project to increase consumption and marketing of fish products from Lake Turkana.

Introduction

The aim of this article is to emphasize the huge unexploited potential of Lake Turkana in terms of increasing food security for the residents of Marsabit County and other parts of Kenya. Marsabit County is located in northern Kenya, bordering on Ethiopia (Figure 1). Lake Turkana is the most saline lake in East Africa and the largest desert lake in the world. Despite the huge potential of this lake, which can provide alternative diet in the form of fish products, most of the pastoralist population do not consider fish as an essential food commodity. The majority of the pastoralists prefer consuming livestock meat as part of their main diet. Yet, there is increased demand for food as the population of Marsabit keeps on growing. Climate change and the arid nature of the environment continue to affect food availability to meet the demand of the growing population. Youth unemployment is also high in the county. At the time of collecting information for this article, a young man (Figure 2) was among the fishermen at the lake. Fishing time happens early in the morning and extends late in the evening as shown in Figures 3 and 4. There is urgent need to identify alternative sources of food in order to meet the increased food and nutritional demand of Marsabit County. Lake Turkana occurs in two northern counties of Kenya, namely Turkana and Marsabit Counties (Figure 1). More than half of the lake is in Marsabit County. It is a saline lake surrounded by an arid, desert environment and has been supporting human life from pre-historic time. Geographically, the lake starts from the Ethiopian border southwards in Kenya along the Great Rift Valley. Its length is 249 km from north to south with a width of 44 km at its widest point and a depth of 30 meters. The lake supports numerous aquatic life like fish. The lake is the main source of fish in the county, supporting 1 400 fishermen and 400 fish farming families. The main species of fish available

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are tilapia (genus *Oreochromis*), labeo (*Labeo rohita*) and Nile perch (*Lates nilotidus*). The lake has 10 landing beaches, but only four are gazetted. There are 2 000 fishing nets, 500 longlines, 10 motorized boats and 20 canoes (Marsabit County Integrated Development Plan 2013-2017). The data recorded by the Kenya government's fisheries department in 2017 shows that 13 244 kg (13.244 metric tonnes) of fish from the lake was sold in that year or on average 1 104 kg of fish sold per month (Table 1). About half of the fish was sold by cooperatives[1] and half by private fisheries [2]

Figure 1 Map of Kenya showing the boundaries of Turkana County, Marsabit County, and position of Lake Turkana

Source: Kenya National Bureau of Statistics (2009)

1 Cooperative is a formal group registered under Kenya Cooperative Societies act, cap 490 of 2012, with the aim of promoting the welfare and economic interest of members. In the case of cooperative dealing in trade of fish, they are registered to carry out fish business as their main economic interest.

2 Private fisheries are private traders or companies dealing with trade of fish

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Figure 2: A young boy with his catch of Fish at the shore of Lake Turkana

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Figure 3: Sunset over Lake Turkana

Figure 4: Fishermen carrying out their fishing activities in Loyangalani at sunset

Table 1 – Amount of fresh fish sold per month from Lake Turkana in 2017

Month	Nile Perch fillets (kgs)		Tilapia (pieces)	
	Cooperative	Fisheries	Cooperative	Fisheries
January	75	214	0	49
February	291	0	76	0
March	197	17	111	19
April	334	81	261	17
May	210	203	170	0
June	130	0	90	0
July	63	209	243	589
August	220	309	193	539
September	97	112	912	969
October	68	202	724	1 088
November	233	95.5	708	494
December	424	596	807	805
TOTAL	**2 342**	**2 038.5**	**4 295**	**4 569**

(Source: County government of Marsabit, Department of Agriculture, Livestock and Fisheries status report 2017)

The upsurge in the amount of fresh fish sold from the month of September to December were due to a number of factors: spirited fish-eating campaign by the county government of Marsabit; improvement of Loyangalani road to an all-weather road; and relocating and posting of fisheries officer to the area to work with fisher folks on good fishing practices.

Discussion

Increase in the frequency of droughts have a considerable impact on the livelihood of pastoral households, especially those households with fewer animals than the threshold considered as a viable herd. Droughts affect herd recovery and induce food insecurity. In northern Kenya, food security continues to deteriorate due to recurrent regional droughts. Historically, Marsabit county experiences refugee influx from neighbouring countries like Ethiopia, South Sudan and Somalia. Kenya hosts over 595 000 refugees, one of the largest refugee populations in the world (WFP 2016b). In early 2017, some refugees from Ethiopia crossed over to Marsabit to flee from conflict in their country. To date, there is an informal short-term refugee camp in Dambala Fachana in Moyale Sub-county of Marsabit county. The people flee politically induced conflict in their country. Due to the prevalent arid and semi-arid conditions, the economic investment opportunities in northern Kenya are limited mainly to herding of livestock such as cattle, sheep, goat and camels, and retail trade (Barrow & Mogaka, 2007).

Marsabit County has a total land area of 70 961.2 sq km (7 096 120 ha), excluding the Lake Turkana, making it the largest county in Kenya in terms of land area[1] The proportion of the population that practise farming during favourable seasons is a paltry 2% out of the projected population of 322 567 in 2018, which is normal in such arid environment. The total area under cash and food crop production in Marsabit County is only 5 060 ha (CIDP 2013-2017). Expansion of land under crop cultivation is mainly hindered by water scarcity and pastoralists' lack of passion for cultivation of land as opposed to livestock rearing. In this context, this is sustainable land use practice in the arid lands.

The main ethnic groups in Marsabit who pastoralists are predominantly are Borana, Rendille and Gabra. The Burji community have farming knowledge and practise farming in the Mt. Marsabit and Moyale areas. Protracted droughts and conflicts in northern Kenya, especially in the 1980s and 1970s, led to loss of livestock among different pastoralists. Some of these became destitute pastoralists who then began to settle around newly created agricultural schemes. The Turkana and Elmolo people, who are the minority in Marsabit County, are the only known groups who regularly consume fish as part of their diet. It is important to note that currently more and more people in Marsabit County are increasingly adopting fish as a supplementary food. This is because livestock based protein is decreasing due to increased droughts and increasing demand as a result of population growth. Studies show that fish protein is very important to human nutrition. Sarvenaz & Sabine (2017) noted that fish are considered to be a nutritionally valuable part of human food. They recommend eating of fish at least two times a week. Justification given is the content of long chain polyunsaturated n-3 fatty acids in fish. These fatty acids are said to be very essential in human nutrition and have proven to be involved in many metabolic functions. Other benefits noted are anti-inflammatory effects, decrease platelet aggregation which are essential parts in the cell membranes, cardiovascular system, brain, and nervous tissue.

The county government of Marsabit has in the recent past tried to support fisher folks with a view of producing fish for both domestic and commercial purposes. This intervention, plus the improvement of the Loyangalani road to an all-weather road, has opened the area for traders and thus opened access for fish to new markets. Perhaps, this is why there is a very sharp increase in the sale of fish since July 2017 (Table 1). The county, furthermore, constructed two fish cold storage facilities in Loiyangalani and Ileret. This intervention will enhance the preservation of fish products in readiness for marketing and thus increase the sale of fish. In order to promote sustainable fishing along this development aspiration, the county government has also bought two motor boats that help in monitoring fishing activities and also in eliminating illegal fishing. Prior to this intervention, the

[1] County fact sheet; Commission on Revenue Allocation (CRA) 2013

fishermen were using traditional ways of fishing without attending to conservation, thus threatening the fish population. Inappropriate use of fishing nets and other gears endanger fish populations. There is a recommended fishing net type for use in such environment. They were also using crude methods of gutting and drying fish, thus rendering a significant proportion of the fish unsuitable for human consumption.

The government of Kenya has also set up one Museum at the shore of Lake Turkana. Perhaps this sets a good roadmap for conserving important heritage around the Lake. Scientific studies done in the area produced physical evidence as habitation of flora and fauna of diverse species over millions of years to the present around the Lake and surroundings. The adjacent Mount Kulal Biosphere Reserve serves as a water shed for the Lake Turkana Basin and as a wildlife dispersal area. The museum enjoys legal protection from the government of Kenya. Kenya Wildlife Act cap 376 as well as the Antiquities and Monument Act cap 215 (currently the National Museums and Heritage Act of 2006) under Kenyan legislation has helped in the legal recognition of the area. Sibiloi National Park was legally designated as a national park in 1973 whereas South and Central Islands were legally designated in 1983 and 1985 respectively. These properties are co-managed by Kenya Wildlife Service (KWS) and the National Museums of Kenya (NMK). These interventions are a good sign that the area will receive prominence and increase consumption of fish. The county still needs to do more providing data on fish stocks, catch and traded volumes.

Conclusions

Lake Turkana has great unexploited potential for enhancing food security, not only for the people living in Marsabit County, but the rest of Kenya. It is endowed with a huge fish population that can feed the people. However, the proportion of people who eat fish is very low. Therefore, this article makes the following conclusions;

- Clearly, plenty of fish is available in lake Turkana that can support the growing population but there is low consumption of fish among the communities in Marsabit County.
- Marsabit county has poor infrastructure to support development of fishery in the county for domestic consumption and export. There is a huge need to develop roads in the area and other infrastructure that is needed to support development of the fishery resource.
- Fish harvesting methods are commonly traditional rudimentary fishing methods that limit the potential harvest.
- Unreliable market access and poor access to information on fish. Access to credible information on fish data is very important.

Recommendations and suggestions for further research

Government of Marsabit County should promote eating of fish through rigorous campaigns and cooking demonstrations. A good example is to run “eat more fish” campaigns to change the attitude of pastoralist communities

There is a need for identifying fish marketing opportunities for fisher folks, which will not only create employment for the unemployed youths but also increase the revenue stream for Marsabit County Government.

The government should improve the infrastructure required for fish development, such as cold store facilities and refrigerated trucks, good roads, etc.

The government of Kenya should fund Research on Lake Turkana and come up with how to sustainably manage long term sustainable production of fish.

Thorough training should be introduced for fishermen on how to carry out legal fishing activities.

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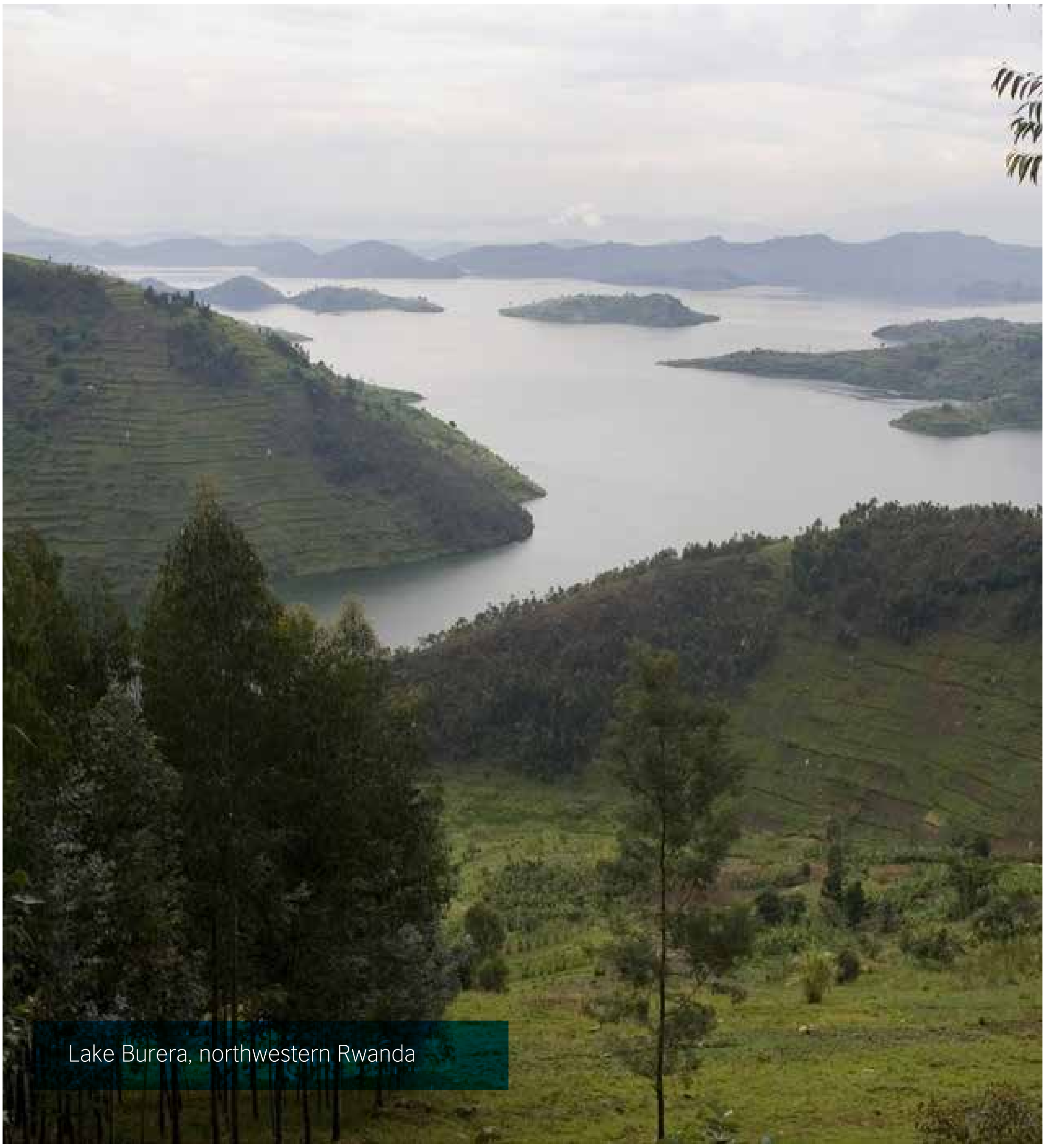

Lake Burera, northwestern Rwanda

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Invasion of the tapeworm *Ligula intestinalis* in the Usipa fishery in Lake Malawi/ Niassa/ Nyasa: implications for food security and nutrition

Nestory Peter Gabagambi[1] and Arne Skorping[2]

Summary

This article reports the invasion of a deleterious parasite infecting an economically important fish species, the Usipa, in Lake Malawi/Niassa/ Nyasa, hereafter Lake Nyasa. Most of the available knowledge on this parasite comes from small lakes in northern Europe, where the parasite has been reported to cause almost complete crashes in fish populations. In Lake Nyasa, however, where ecological conditions are markedly different from these European lakes, our results indicate that the infection level is more stable and that the transmission of the parasite varies at different localities. The research has also indicated the parasite to have an effect of fish behaviour, that makes it more vulnerable to predation by fish-eating birds. The research concludes that to date, there are no indications of population crashes of the Usipa, suggesting that the infection dynamics of the parasite may be markedly different in a large lake in a tropical area, like the Nyasa, as compared to much smaller lakes the earlier studies were based on.

Introduction

Tanzania is well endowed with water resources, having a viable fisheries sector contributing around 2.5% of the national Gross Domestic Product (GDP) and 10% by value of the total national exports (United Republic of Tanzania, 2015a). Fish remains the main source of protein to about one third of the country's population at a per capita fish consumption estimated to be 7.6 kg per annum (United Republic of Tanzania, 2015b). In terms of animal protein availability, fish contributes 30% of the total national animal protein intake (United Republic of Tanzania, 1997). Fish is a highly nutritious food, providing proteins of high quality as well as minerals and micronutrients. Lake Nyasa, also known as Lake Malawi in Malawi and Lago Niassa in Mozambique, is an African Great Lake and the southernmost lake in the East African Rift Valley system, located between Malawi, Mozambique and Tanzania (Fig. 1).

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Fig.1. Map of Malawi showing the location of Lake Malawi/Niassa/Nyasa and the administrative riparian states of Malawi, Mozambique and Tanzania.

(Source: http://www.un.org/Depts/Cartographic/map/profile/malawi.pdf)

In Lake Nyasa, landings of the small pelagic fish species *Engraulicypris sardella*, locally known as Usipa (the name used hereafter, another common name being Lake Malawi sardine), provides >80% of the harvested fish. Due to their nutritive value and affordability, these small fishes are found to be preferred by poor people around the coastline of the lake, and are therefore landed in large quantities.

Usipa is a species in the carp family (a cyprinid) endemic to Lake Nyasa (Rufli and Van Lissa, 1982), which can be found locally abundant in open and inshore waters of the lake (Allison *et al.*, 1996). The fishery of Usipa in Tanzania contributes significantly to the livelihood of local people, by providing employment particularly to women and youth who make up the majority of the people in the post-harvest sector and in the supply of the fish along the value chain. The Kyela District Council records for the northern part of the Lake Nyasa indicate mean annual landings at the Kyela district of 11 574 tonnes.The Tanzanian part of the Lake Nyasa basin is a home to over 1 260 000 people with a growth rate of the population of 2.4% per year (United Republic of Tanzania, 2013). Because of this high population growth rate, the demand for Usipa has increased drastically each year. Currently the consumption of animal protein in the daily diet of people in this part of the basin is about 56 gram of protein per day.

Can a recently established parasite (*L. intestinalis*) threaten the fisheries of Usipa?

In 1996, a milkish white worm was first discovered in the body cavity of Usipa by Mwambungu *et al.,* (1996) during long-line research surveys in Lake Nyasa (Fig.2). The worm was identified to be the tapeworm *Ligula intestinalis* (L.) (Dubinina, 1980). This parasite is believed to be introduced in Lake Nyasa by migrating infected fish-eating birds such as white-breasted cormorant (*Phalacrocorax carbo*) which is one of the final hosts (*i.e.* a host where parasite reproduction takes place) of *L. intestinalis* and therefore an important organism for the completion of the parasite life cycle. White-breasted cormorants are among the most abundant fish-eating birds in Lake Nyasa (Linn and Campbell, 1992).

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Fig.2. Laboratory picture of the tapeworm *Ligula intestinalis* and its host fish Usipa
Source: Courtesy of Nestory Peter Gabagambi (2015)

The parasite attains its maturity in fish-eating birds, and produces eggs which are spread into lakes. Here, the eggs hatch and the parasite larvae develop, first using planktonic copepods as hosts and thereafter cyprinid fish species. The establishment of this parasite in Usipa in Lake Nyasa gives some cause for concern. Earlier studies have shown that the tapeworm suppresses the development of the fish reproductive organs and thereby significantly reduces reproduction, sometimes towards more or less complete castration, rendering the fish host sterile even if they harbour only a single worm (Kennedy *et al.*, 2001; Cowx *et al.*, 2008; Hoole *et al.*, 2010). The studies further suggest that the parasite distresses fish behavior in a way that makes infected hosts more vulnerable to predation (Loot *et al.*, 2001; Loot *et al.*, 2002). These combined effects have been shown to have a major effect on other cyprinid species, sometimes leading to a complete crash in the fish population (Burrough and Kennedy, 1979; Wyatt and Kennedy, 1988) and therefore, the establishment of this parasite in Usipa in Lake Nyasa raises public concern in terms of food security and nutrition. We therefore started a research project in order to find out how this parasite might affect the Usipa population in the northern part of Lake Nyasa.

The tapeworm *Ligula intestinalis* in the Usipa

In our research project, we explored the distribution of the tapeworm *Ligula intestinalis* in its fish intermediate host Usipa in Lake Nyasa, which is the third largest lake in Africa. Despite the global distribution of *L. intestinalis* (Kennedy, 1974), most studies on the species have focused on common cyprinid hosts in small lakes in northern Europe; for example in roach (*Rutilus rutilus*) in England (Wyatt and Kennedy, 1988), in Eurasian minnow (*Phoxinus phoxinus*) in Norway (Museth, 2001) and in silver bream (*Blicca bjoerkna*) in France (Vanacker *et al.*, 2012). However, our study system is markedly different from all of these earlier locations, and we know very little about how a parasite like *L. intestinalis* could affect a fish population in a large ecosystem like the Nyasa. In our recent field study (Gabagambi and Skorping, 2018), we found that the tapeworm *L. intestinalis* is widely distributed throughout the northern part of the lake, but show large differences in infection levels at different lake habitats (i.e. littoral zone (zone close to the coastline) and pelagic zone (the deep water zone)) (Fig. 3). This suggests that transmission differs at different localities, which could result in the parasite becoming persistent, rather than the typical epidemic waves seen in smaller lakes found in northern Europe. In addition, in another experimental study (Gabagambi *et al.,* 2018), we investigated the effects of the tapeworm *L. intestinalis* on behaviour of Usipa and found that this parasite has the ability to make the host sluggish enough for fish-eating birds to catch it more easily. If this parasite tends to become persistent for a long time in Lake Nyasa, we would also expect the fish host to adapt to this situation by changing its life history strategy, for example to become selected towards earlier reproduction. This could reduce the total fish biomass, and therefore have a negative effect on the fisheries.

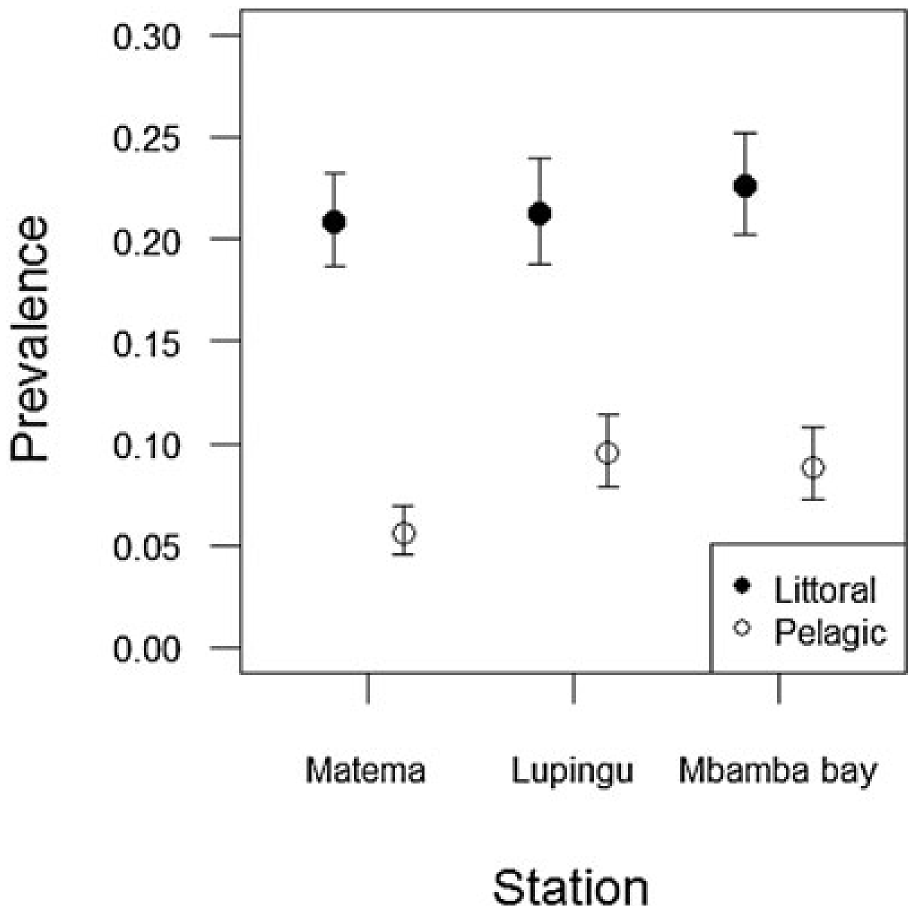

Fig.3. Prevalence (±SE) of *L. intestinalis* in Usipa depending on lake habitat (littoral zone vs pelagic zone) and station (Matema, Lupingu and Mbamba Bay) in Lake Nyasa, 2015.

Source: Gabagambi and Skorping (2018).

Consequences of infection in the Lake Nyasa ecosystem

The effects of *L. intestinalis* on the reproduction capacity of Usipa could have serious implications for the Usipa fishery because infected Usipa may have significantly reduced fecundity. Furthermore, the stock of Usipa in the Lake Nyasa could also be negatively influenced by selective predation by the final host as the parasitized Usipa could be an easy prey for the predators. The invasion of the tapeworm *L. intestinalis* in Lake Nyasa may also affect the lake ecosystem. Usipa forms an important part of the food web of Lake Nyasa. They are primary consumers of zooplankton but they are also an important native prey of the cichlids in the lake (Allison *et al.*, 1996). Therefore, Usipa forms a vital ecological link between top predators and lower trophic levels in this ecosystem (Rusuwa *et al.*, 2014). The lake food web could be disrupted if *L. intestinalis* infestation in Usipa will continue and this may consequently lead to the decline of the fish species that depends on Usipa as a prey.

Discussion and conclusions

The vision 2025 for United Republic of Tanzania, sets one of the development goals as quality livelihood for all (United Republic of Tanzania, 2000) and raising the living standard of any nation including Tanzania is closely related to food security (Godwin and Fellowes, 1999). Achieving food security for the rural poor inhabiting the Lake Nyasa basin in terms of fish food availability cannot be met if the Usipa biomass will decline due to the *L. intestinalis* infestation or other factors like unsustainable fishing levels.

Records of the landed Usipa during the past decade (Fig. 4) suggest that the yields remained very stable at high level up to 2012, then the yields crashed dramatically, especially in the last years, which are also the years when the parasite prevalence were reported by Msafiri *et al.*, (2014) and Rusuwa *et al.*, (2014) to be relatively high of over 30 and 50% respectively. However, other factors that can also be linked to the decline of this fish host in that period could be increased fishing pressure, environmental degradation and/or climate change.

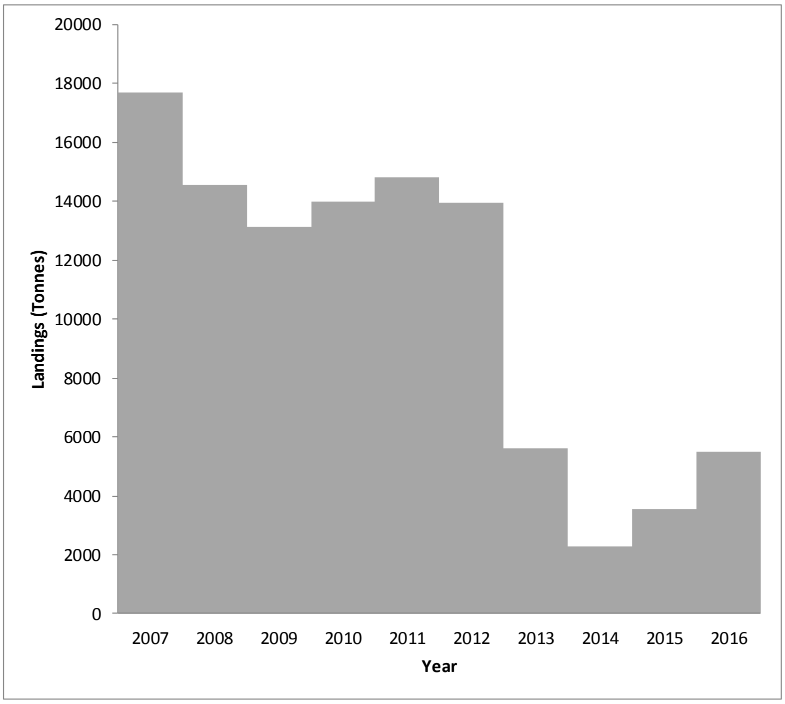

Fig.4. Landings of Usipa from Kyela District (northern part of the Lake Nyasa) from the year 2007 to 2016.
Source: The Kyela District Council Annual Report (2018).

The problem of infestation of *L. intestinalis* in Usipa can be addressed by using biological control strategies. For instance, by increasing populations of native predatory fish, because previous studies (*e.g.* Lafferty and Morris, 1996; Loot *et al.*, 2002) suggest that fish infected with a manipulating parasite like *L. intestinalis* are more vulnerable (i.e. easy prey) to predation. The parasite prevalence will therefore expected to decline if a higher proportional of parasitized Usipa will be removed from the Usipa population by the native predators of Usipa. However, less availability and thus inadequate intake of Usipa could pose a problem with respect to food security and nutrition, especially for women in reproductive age and for young children. Small fishes like Usipa are usually eaten whole without de-boning and this provides different minerals such as calcium and fluorine that are rare in other types of food (Kawarazuka and Béné, 2011). Therefore, increased consumption of the Usipa will consequently enhance the nutritional and the socioeconomic status of the vulnerable groups.

The invasion of the tapeworm *L. intestinalis* in Lake Nyasa could also affect the income of the people who depend on Usipa as their sole source of income. For many decades Usipa has been a valuable source of income that can be used to acquire of other basic household necessities.

Finally, this parasite has not been reported to pose a public health concern when consumed with its fish host. However, we would like to advise people to properly prepare Usipa before consumption because consumption of raw and undercooked fish meat could present a fish-born parasitic zoonoses including ligulosis (Ljubojevic *et al.*, 2015).

Recommendations and suggestion for further research

In a huge natural ecosystem like Lake Nyasa it's unlikely to use anti-parasitic drugs to reduce parasite abundances as can be done in aquaculture. It is therefore important to have more, longer and wide-covering biological control measures that will help us to understand the ecology, dynamics and life-style of this tapeworm and its potential impacts on the productivity of Usipa in Lake Nyasa. One of the biological control strategies that can be taken is by using the native predators of Usipa such as *Copadichromis sp, Diplotaxodom sp, Opsaridium michrolepis*, *O. michrocephalus* and *Raphochromis sp*. to reduce the infection level of the parasite in the host population. These native predators will selectively remove the parasitized Usipa and consequently the infection level in the Lake Nyasa ecosystem will decrease. The number of native predators of Usipa could be increased in the lake by practicing a closing season for these predator fish species.

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Sustainable ecosystem services of Lake Bosumtwi, Ghana – implications for livelihoods and food security

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Summary

Lake Bosumtwi is one of the six meteoritic lakes in the world and enlisted among the World Network of Biosphere Reserves. Current limnologic evidence indicates changing physical and chemical lake conditions that affect ecosystem functions. The cycles of overturn, where anoxic and nutrient rich bottom waters seasonally mix with surface waters, have not occurred since 2008, resulting in lower fish catch and changes to the lake ecology. With heightened effects of a warming climate, coupled with diminishing fish catch, livelihoods of the fishing communities are becoming increasingly vulnerable. This is also stimulating harmful adaptive actions, including the use of agrochemicals for fishing,indiscriminate clearing of vegetation for farming and tourism. These activities are expected to have serious negative feedback on the lake's functionality through increased siltation and pollution. Although there are a number of watershed management programmes in place, the fisheries and associated livelihoods will continue to be threatened by individual and synergistic effects of a changing climate and increasing anthropogenic stressors on the lake's ecosystem services. Based on the synthesis of current evidence, this paper summarizes the current state of knowledge on lake productivity. It asserts that sustainable management requires a far more comprehensive framework for assessing the impacts of multiple stressors on the lake's unique ecology towards supporting livelihoods of the 24 surrounding fishing communities. This can be supported by integrated research models such as that of the ongoing RELAB[7] project which is assessing lake function, fisheries productivity, land use change and livelihood responses to meteorological trends and lake functionality. Scientific data generated will provide better information to inform sustainable management of the lake and maintain its economic, historical and cultural values.

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[7] *RELAB (REsilience of LAke Bosumtwi to climate change)*

Introduction

The Lake Bosumtwi (also spelled *Bosomtwe* in other publications), the only natural lake in Ghana, is one of six major meteoritic lakes in the world. The lake lies within a meteorite impact crater, a circular depression of 11 km diameter formed 1.07 million years ago (Figure 1a), with an area of about 52 km^2 and maximum depth of 81 m. As a hydrologically closed basin, inputs are restricted to rainfall, and consequently lake level fluctuates in response to variations in the balance between the rates of precipitation (80% direct precipitation on the lake surface area) and evaporation (Turner *et al*. 1996). Well-stratified layers of water masses differing in temperature establish the physical structure and basic ecological operating mechanisms of the lake that are important for fish productivity (Turner *et al*. 1996; Otu 2010).

Historically, seasonal increases in fish productivity have been linked to predictable changes in the lake's physical and chemical conditions. Important ecological cycles of overturn, where anoxic and nutrient rich bottom waters seasonally mix with surface waters, were well-known and understood by fishermen and local communities. Seasonal fish kills marked these events due to the anoxic conditions, and the lake became fertilized with accumulated nutrients from the deeper waters which sustained the fisheries throughout the growing season. However, according to the fishermen, this overturn has not occurred during the last decade (2008 – 2018), resulting in no fish kills, nutrient deficiency and disruption to the onset of the fish growing season. These dramatic changes to the lake are strongly believed to be caused by climate warming (e.g. Russell *et al*., 2003), which is affecting the temperature-driven physical structure of the lake that controls other important ecological functions.

A dense human population resides within the catchment, with a total of 24[1] communities comprising about 150 000 people in 2010. Subsistence farming and fishing are the predominant livelihoods. Traditionally, 18 foot wooden planks are used to navigate the waters (Figure 1b) and fish are collected from rudimentary fishing gears such as wire mesh traps, gill nets and cast nets. Typically, fishing is by males, whilst females process and market the produce. Fish catch is currently very low, less than 5 kg per fisherman per net or trap (Dassah & Agbo, undated) (Figure 1c). The lake supports four principal fish species, *Tilapia busumana*, *T. discolour*, *Sarotherodon galilaeus multifasciatus*, and *Hemichromis fasciatus*. There is observable seasonal variation in species dominance. The fishes are generally small in size, between 8.5-12.7 cm in length and 11.9 – 30.8 g in weight (Dassah & Agbo, undated). Since the study of Whyte (1975), who reported nine genera of fish belonging to five families, no other comprehensive studies monitoring fish population have been carried out.

Due to recurring low fish catch, communities are exploring other options to increase fish catch, for example, through the use of non-selective gears and agrochemicals. Observing these unsustainable practices, the Government of Ghana through the Ministry of Fisheries and Aquaculture and the Fisheries Commission, in 2016 planned to restock the lake with fingerlings. However, the gains of such an initiative will not be achieved with continued pressure on fish stocks and use of prohibited fishing practices. In addition, increasing encroachment and farming activities within the core of the lake's basin, expanding tourism facilities and poor sanitation practices are driving sedimentation and pollution of the lake. These have adverse effects on the lake's recovery with negative implications on fish food security and animal protein availability.

[1] Many documents refer to 24 communities in the catchment, however, reference is made to 22 communities by community members during interviews.

Figure 1 – (a)

Figure 1 – (b)

Figure 1 – (c)

Figure 1 – (a) Aerial view of Lake Bosumtwi, (b) Fishing planks used by fishers for navigation, and (c) typical fish landing of a fisherman at Lake Bosumtwi.

Source: Building *REsilience of Lake Bosumtwi to climate change (RELAB) project*

Sustainable management of the lake

As a unique socio-ecological system, maintaining the lake's functionality is critical to the local food security and cultural identity of those living in the lake's catchment. Cultural values have been maintained through various practices of rites, rituals, customs and taboos, although these have declined over the years. Moreover, the lake is globally significant as it contains the vulnerable endemic species *T. discolor* and an archival system of well-preserved historical records of past climate change and ecological change in terrestrial regions of tropical West Africa (Beuning *et al*., 2003; Shanahan *et al*., 2009).

Over the years, local and international[1] institutions have initiated different programmes to change the local attitudes and unsustainable practices within the lake basin. These initiatives cover community environmental education, provision of alternative livelihoods, enhancement the lake's tourism potential, and building local capacity for sustainable management of the natural resource. One noted initiative is the designation of the lake as a Community Resource Management Area (CREMA) which empowers the communities to engage in co-management of the natural resources with the Wildlife Division of the Forestry Commission. The CREMA is legalised by the District Assembly by-law and encourages community decision making structures and processes. Women are also part of the management structure with administrative support from all regulatory and research institutions, and the Water Resources Commission as the coordinating institution.

Despite various successes of these programmes, sustainable management of the watershed and fish resources, however, requires a much more comprehensive understanding of the synergistic effects of climate change and anthropogenic stressors to make informed decisions and develop a long-term plan. For example, as new livelihoods emerge in response to poor fish harvest, altered land use patterns due to clearing of forests and increased pollution within the watershed will have unknown implications for lake health and its ability to recover. There is the need for comprehensive scientific tools of sustainability that rigorously assess ecological, social and economic factors, both individually and in various combinations, over space and time. Models that are able to link meteorological changes with the hydrodynamics of the lake, fish productivity, and land use activities in the watershed can provide managers with accurate information to help understand the resilience of the lake under different scenarios. Such processes can lead to innovative practices developed, even at the community level, that will enhance adaptation and support ongoing management of the lake's natural resources.

[1] In 2016, Lake Bosumtwi was enlisted among the World Network of Biosphere Reserves (WNBR) comprising 669 reserves in 120 countries. In Ghana, it became the third reserve after the Bia Biosphere Reserve in the Western Region and the Songhor Biosphere Reserve at Ada in the Greater Accra Region

Research and way forward

Many research projects and management programmes have assessed individual elements of the lake and its watershed. For example, the NSERC/LBRP project[1] assessed the influence of climate on primary productivity but not on fish production; and baseline studies of fisheries, socio-economics, and land use land cover change, among others, carried out to nominate the lake as a UNESCO Biosphere Reserve, were all evaluated separately. To date, there has been no integrated research to understand the pathways and combined effects of multi-stressors on water quality, fish productivity and influence on livelihoods. The Building REsilience of LAke Bosumtwi to climate change (RELAB) project[2] will, however, contribute towards resolving knowledge gaps on the complex interactions at the ecosystem and watershed scale and linkages to socioecological dynamics. Since early 2018, high frequency data is being obtained by state-of-the-art instruments until the end of the project's five year period (2022). High resolution monitoring of lake physics, biogeochemistry, primary production, fisheries, land use changes, sedimentation and livelihood adaptive mechanisms, all linked to climate projections, will contribute to a comprehensive dataset that will be disseminated to stakeholders in user friendly formats through several mechanisms, such as hands-on workshops[3]. The training of scientists, students and managers will promote sustainable fisheries, livelihoods and watershed management towards building ecosystem resilience and reducing vulnerability of the communities in the Lake Bosumptwe.

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1 Canadian Natural Sciences and Engineering Research Council (NSERC) and Lake Bosumtwi Research Project

2 RELAB is funded by the Ministry of Foreign Affairs of Denmark and involves a collaboration of Danish, German and Ghanaian scientists and students.

3 Up-to-date information will also be disseminated to the wider public through the project's website www.relabproject.uenr.edu.gh

Fish conservation issues in protected areas in the Congo Basin

Jean-Claude Micha[1]

Summary

This review of wetlands in five Protected Areas (PAs) in the Republic of Congo and in the Democratic Republic of Congo indicates that their fishery resources are almost overexploited in and around these PAs and that fishermen enter Parks where fishing is supposedly prohibited to catch fish. These environments must therefore be taken into consideration by carrying out an accurate and rigorous taxonomic inventory, evaluating the exploited resources with the participation of fishermen and leading them to define and respect, by means of co-management, a certain number of rules inspired by the Code of Conduct for Responsible Fishing and provided for in the new fisheries laws to exploit the resources in a sustainable manner. The appropriate approach would be to develop in a participatory way a Sustainable Development and Management Plan for these wetlands that would be integrated into the Global Development Plan for the Protected Area, as was recently the case, particularly in the Lac Télé Community Reserve.

Introduction

Protected Areas (PAs) are, rightly, numerous in Central Africa but their conservation is unfortunately limited to large mammals, landscapes and exceptional flora, which makes them very precarious, particularly because the wetlands they include are too often ignored or even ignored by their managers. These wetlands (WL), which are often the basis for the existence of these PAs, contribute significantly to their biodiversity and ecosystem services (ICCN PNVi, 2015; Van de Voorde *et al*., 2018). During various consultancy and supervision missions of student briefs aimed at assessing the importance of fishermen's interactions with the sustainable management of PAs in the Republic of Congo (RC) and in the Democratic Republic of Congo (DRC), we m*et al*l the stakeholders in these PAs with particular attention to their wetlands and the fishing world within which we reviewed the situation. In almost all cases, we have been struck by the negative and even aggressive attitude of fishermen towards their Protected Areas and Local Authorities that have the attitude to manage them, obviously in an unsustainable way, without the involvement and support of local populations. In the end, it is not poachers but fishermen who, in particular, set fire to the wooded savannah in the dry season (cf. RCLT) to facilitate access to residual ponds. As a result, the activities of fishermen add to the risk which, in the future, may cause the total disappearance of the Status of the Park or Reserve concerned (Pictures 1 and 2 below). For the future of PAs, the fishing world must be taken into account and involved in the development of a management plan for their wetlands (Cochrane, 2005, FAO, 2003) with an emphasis on training in conservation and sustainable use based on a set of biological and socio-economic indicators (yield and income) accepted by all stakeholders (Balole-Bwami and *al*., 2018;

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Bongeba and *al.*, 2013, Kolding and *al.*, 2016; Stamatopoulos, 2003). After a brief inventory of the locations of the WLs in five Parks and Reserves, this article examines the fishery resources, exploitation techniques, fishermen's relations with eco-guards and finally proposals for solutions.

Figure 1: Landscape before bush fires

Figure 2: Landscape of Figure 1 after bush fires

Source: Jean-Claude Micha

Inventory: Ichthyological biodiversity and the fishing world

From the outset, we observed in all the PAs visited in the Democratic Republic of Congo: Virunga National Park (VNP), Yangambi Biosphere Reserve (YBR), Upemba National Park (UNEP), Okapi Forest Reserve (OFR) and the Republic of Congo: Nouabale Ndoki National Park (PNNN), Lac Télé Community Reserve (RCLT), an ignorance or at least a lack of knowledge of the aquatic biodiversity of PA wetlands, most of which do not even have a complete list of fish species inhabiting their waters, although they are very often exploited, overexploited or even extinct (Luhusu and *al.*, 2013). As for the number of fishermen likely to fish, even illegally, in the PA, it is rarely known, but it is estimated that it would be much higher than the number of poachers regularly inventoried [example in PNU: 180 families of known poachers and 73 210 fishermen in the Kikondja area (Upemba and Kisale lakes) according to the 2012 exceptional framework survey carried out thanks to the Katanga Artisanal Fisheries and Aquaculture Development Project (PRODEPAAK), pers. comm. A. Mahunina]. How can we effectively manage the biodiversity and ecosystem services of a protected area without knowing the aquatic species and their interactions with terrestrial flora and fauna and without knowing the populations (fishermen, processors) who exploit them? Finally, poor fishing practices (including mosquito nets) prevent good natural recruitment of exploited fish stocks, which inevitably leads to a decrease in their biomass, the yield of fishing units and therefore the standard of living of fishermen. The consequences are therefore negative both from the point of view of fishing and from the social and economic point of view, following the reduction in the profitability of the fishing effort and the development of illegal and irresponsible fishing. Additional negative factors include administrative and police harassment, distance from markets, inadequate means of transport and lack of adequate cold storage facilities. The consequences for parks and reserves are and will be increasingly damaging as local populations, mainly fishermen, come to exploit (wood, game, minerals, etc.) in protected areas or even develop subsistence agriculture (PNVI, PNU), jeopardizing their long-term maintenance.

However, the inventories differ significantly from one site to another. In PNVi, there is a fairly good basic knowledge of Lake Edward (ICNN PNVi, 2015), its fishery resources (except for small Cichlidae of the genus *Haplochromis*) which include 9 families and 44 species including 6 commercial species. However, for the Yangambi Biosphere Reserve (YBR), the buffer, the peripheral and the conservation zones' boundaries are not even clearly demarcated, nor the number of shoreline fishermen, mainly Lokele. Furthermore, they are not at all aware of their overexploitation of the fish resources with decreases being attributed to a temporary divine curse. Decreases include a decrease in catches per unit of effort from ± 25 to ± 5 kg/day/canoe between 2010 and 2015 and a decrease in the average size of large commercial species below the length of first maturity (LM50). In contrast the fishermen of the Kamalondo depression (PNU annex) are fully aware of their overexploitation and have organized themselves strongly and spontaneously, without PNU support, into associations constituting a Territorial Federation with a well-structured committee that organizes workshops with all stakeholders on the protection of fisheries resources, tries to develop co-management and organizes monitoring patrols on the various water bodies. This approach should be the driving force behind an approach to bring about a change in mentality and strategy everwhere, but the will and means to do so are mostly lacking. It should be noted, however, that given the soaring demography of the fishing population, their numbers have increased sharply, leading them to develop subsistence agriculture on the shores of the lake in order to survive, thus demanding more and more hectares to be cultivated at the expense of PNU. In the Okapi Forest Reserve (OFR), ongoing research (pers. comm. A. Walanga and MRAC) in the rivers of the OFR reports 64 fish species belonging to 13 families, including about ten commercial species. There are probably new species to discover and describe, not only in the OFR, but also and especially in the Ituri-Epulu-Aru landscape where 130 species have been identified so far on 40% of its hydrographic network. However, the field observation indicates that most of the species caught are smaller in number, have a smaller size than the first maturity size and the Catch Per Unit of Effort (CPUE) is barely 2 kg/d/fisherman, which is much lower than what older fishermen reported fishing a few years ago (± 5 years : ± 10 kg/d/p).

In the Republic of Congo, in the Nouabale Ndoki National Park (PNNN), the survey conducted as part of a former WCS Congo project supported by UNESCO, the Central Africa World Heritage Forest Initiative (CAWHFI) and the French Global Environment Facility (FFEM) from 2006 to 2011 on the Sangha River, indicates the presence of 160 fish species (including species that do not exist in this watershed!) and without any specimen in collection, which makes taxonomic verification impossible and demonstrates the authors' poor rigour. It would be desirable to correct, update and continue this inventory and extend it to the other rivers of the NNNP (Ndoki and Motaba) and even eventually to the Trinational Sangha Landscape, but by constituting a reference collection. According to our interviews (10 focus groups of 9 fishermen and 1 fisherwoman), fish catches in recent years in the periphery of/and in the NNNP, where fishing is theoretically prohibited, are in general decline. The number of fishermen, on the other hand, is constantly increasing, as is the number of huts in the villages of Ndoki 1 and 2. In the Lac Télé Community Reserve (RCLT), an inventory carried out by Mamonekene during the 2004 flood but without a reference collection indicates 52 fish species belonging to 15 families. The dominant family is that of Mormyridae (20%) for which some determinations seem erroneous (*Marcusenius spp.*) followed by that of Alestidae (12%), followed by Distichodontidae and Cichlidae (9%). At first glance, there are about twenty commercial species. On the other hand, if we take into account the Lac Télé landscape which extends as far as the Oubangui, the ichthyological diversity is much greater since Gosse in 1968 listed 274 fish species in the Oubangui basin alone. As for the 17 890 inhabitants registered in the 27 villages of the RCLT (Botakowa, Mokomba and Foulungu basins) in 2007, they all consider themselves as subsistence fishers (men and women) from the very early age of 6 to 7 years. It is therefore not surprising that the fish resources of the Likouala aux Herbes are seriously decreasing, as indicated by the link fishermen of the 3 fishing basins and the survey fishermen in charge of sampling fishing statistics by village.

Ichthyological resources

In general, the potential fish yields of wetlands in all these Parks and Reserves, with the exception of Lake Edward in the VNPi (Balole and *al*, 2018), are neither assessed (no application of morpho-edaphic indices or other models) nor estimated (no statistical data on catch efforts, number of fishermen unknown). Nevertheless, according to the fishermen interviewed in each place (focus group and individual questionnaire), their catches per unit of fishing effort are decreasing in all sites and some perceive that they are becoming poorer. It could be expected that recruitment will increase again naturally (Kolding and *al,* 2016) following heavy flooding at least in large floodplain floodplains (LTRC) sites, but this does not compensate for the increase in fishing pressure. Indeed, the number of fishermen is increasing in an intrinsic way (average of 6 children/CTLR fishermen who only see fishing as an activity) but also by the arrival of new foreign fishermen (in the case of the RFO) while the resource is already under very strong pressure since catches Per Unit of Effort are decreasing significantly everywhere, which translates into a decrease in everyone's income. There is therefore a need to regulate, raise awareness and also diversify the livelihoods of local populations, including fishermen, for sustainable and responsible fishing (FAO, 1995).

Operating techniques

Harvesting techniques are quite similar in all sites: surface and depth gillnet fishing, beach-seine fishing in particular and unfortunately with mosquito nets (Figures 3 and 4), longline and trap fishing and RCLT and RFO fishing, harpoon and fish toxicity fishing and all this with free access to the resource, with the more theoretical than real exception of Lake Edouard (PNVi).

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Figure 3 : Beach seine nets

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Figure 4 : Larvae and fry

Source: Jean-Claude Micha

In addition, in all cases, existing regulations (Fisheries and Aquaculture Codes in RD of 2010 and DRC of 2013) are not respected, leading to overexploitation and the risk of collapse of exploited stocks. As for the management of this exploitation, it is deficient, confused and contentious given the large number of actors and their lack of coordination, the multiplicity of state services, the conflicts of competence between different services and institutions. Finally, the quality of the preserved fish is poor: the dried salted fish is non-compliant (too little salt, no brine, poor hygiene), the smoked fish is charred and contains carcinogenic Polycyclic Aromatic Hydrocarbons (PAHs).

Eco-guard relations and fishing populations

The strategy of repression by armed eco-guards is rejected by the fishing population, which may eventually no longer recognize and voluntarily accept this authority. This repressive strategy should be transformed into a positive approach to conservation awareness and training, accompanied by efforts to create alternative means of survival that would lead fishermen, especially young people, to other income-generating activities in agriculture, livestock, integrated fish farming, etc. These efforts to raise awareness and provide conservation training (community conservation) could even extend to schools as early as primary school.

Proposals for stakeholder solutions

During numerous participatory workshops of all stakeholders, we have tried to develop a Sustainable Development and

Management Plan (SDMP) for Wetlands (HZs) as part of the Global Protected Area Development Plan where it exists, which is far from being the general case. The most sustained and consistent efforts have resulted in a PAGD ZH that takes into account the Code of Conduct for Responsible Fisheries (FAO, 1995) and is based on the ecosystem approach to fisheries (FAO, 2003). This PAGD of the PA HZs is then officially validated by all stakeholders. In each case, stakeholders defined their general and specific objectives and developed a four-point action plan:

- return to sustainable exploitation through the application of appropriate measures, by setting biological (minimum sizes of the main commercial species), economic (fishermen's income) and social (number of fishermen) indicators accepted by all stakeholders,
- strengthen the operational capacities of co-management bodies,
- enhance the value of fish products through better conservation, processing and marketing, and finally
- diversify the livelihoods of small-scale fishermen by promoting alternative activities such as agro-fish farming.

This bottom-up participatory strategy better integrates these grassroots actors into sustainable use and aims to better strengthen the maintenance of these Protected Areas for present and future generations. But these PAGDs for the Wetlands of Parks and Reserves imply a substantial budget that well-meaning fishermen's associations or even federations have great difficulty in obtaining. However, in the cases mentioned above, the Agence Congolaise de la Faune et des Aires Protégées (ACFAP) and the Wildlife Conservation Society (WCS) effectively funded and organized the development of the GAPZH of the PNNN and the RCLT. In addition, the European Development Fund XI (FED XI) plans to support the Institut Congolais de Conservation de la Nature (ICCN) and to support a number of actions aimed at improving the situation of fishermen in PNVi, RBY and probably PNUD. It should be noted that a Development and Management Plan (DMP) is being prepared for Lake Edward, but it would be beneficial to implement it for the entire lake in collaboration with Uganda's neighbours.

We can therefore see that the future of PA wetlands is becoming somewhat clearer, particularly in the DRC, Burundi and RC because the Royal Museum of Central Africa (RMCA), with the collaboration of 6 African Universities and Institutions, has been leading the Mbisa-Congo project since 2013, which aims to study fish from ten Protected Areas (1 in the Republic of Congo, 2 in Burundi and 7 in DR Congo) whose rivers are all part of the Congo Basin. But this initiative does not come from Protected Area managers who should think about following this approach in all other PAs in continental Africa.

Conclusion

In conclusion, for the true sustainable conservation of PAs, it is essential that Local and National Authorities, Regional Bodies (COMIFAC, etc.) and Technical and Financial Partners make it possible to really and concretely increase the participation of riparian rural populations and in particular fishermen in the planning and sustainable management of the wetlands they use for all, including park and reserve managers who must finally open their eyes to this reality, so that this contributes to their well-being, while making progress towards achieving the Sustainable Development Goals. But this implies targeted resources that are still very difficult to attribute to this cause.

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Smoked fish ready to be taken to the local market

Factors undermining inland river freshwater quality and supply to estuaries for food production in Sierra Leone

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Summary

Sierra Leone's coastal communities depend on water supply from river networks from upstream for food production. The continuity of these inland rivers to supply water to coastal communities is increasingly challenged by various human activities along and within these river systems that undermine water quality and flow into estuarine systems. While there may be an increasing bulk of literature on the value of inland water bodies to food security, information on how anthropogenic activities influence the river water quality and supply to coastal estuaries is scarce.

This review reveals that current anthropogenic activities along or within river systems in this country might be undermining riverine water quality and flow to estuaries because of poor legislative frameworks. This outcome is the result of poorly enforced rules, coupled with weak governance systems. We suggest legislative reforms that will strengthen the enforcement of existing rules for food production in coastal estuaries in Sierra Leone.

Introduction

Inland aquatic ecosystems are diverse and are part of 42 wetland types recognized by the Ramsar Convention Annex B[2], including lakes, oases, swamps and marshes, wet grasslands, peatlands, estuaries, deltas and tidal flats, nearshore marine areas, mangroves and coral reefs, and human-made sites such as fish ponds, rice paddies, reservoirs, and salt pans. Our focus is on the interactions between rivers and coastal marine ecosystems, with a special emphasis on estuaries. For this article, an estuary is a partially enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open sea. According to the Free Encyclopedia, estuaries form a transition zone between river environments and marine environments. They are subject both to marine influences—such as tidal waves, and the influx of saline water—and to riverine influences—such as flows of fresh water and sediment. The mixing of sea water and fresh water provides important levels of nutrients both in the water column and in the sediment, making estuaries among the most productive natural habitats in the world (NOAA. 2018).

Water is a critical element for the development of ecosystems and human life, because it is needed in many aspects of life and the environment (GWP, 2012). Over 50% of the world's population today live less than 3 km from a surface freshwater body (Small and Nicholls, 2003., Kummu, *et al.*, 2011). Most flowing freshwater bodies originate from inland, upstream and flow to discharge downstream at the coast through estuaries. As the

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2 http://archive.ramsar.org/cda/en/ramsar-documents-guidelines-strategic-framework-and/main/ramsar/1-31-105%5E20823_4000_0__#B

rivers flow downstream to the estuaries, they bring along important nutrients and fresh water, essential for the survival and development of coastal and marine organisms. Moreover, estuaries can arguably be termed the "nurseries of the sea" as many marine animals reproduce and spend the early part of their lives in this habitat (Nagelkerken *et al*., 2008). Consequently, estuaries contribute to about 80% of the world's fish catch (Schultz and Ludwig, 2005). But information on the contribution of African Estuaries to fisheries production is scarce (Lamberth and Turpie, 2003).

An ecological balance between inland aquatic and coastal systems is needed to ensure maintenance of adequate levels of nutrient and water flow to estuaries (GWP, 2012 and Lopoukhine *et al.,* 2012). The challenge, however, is that as rivers meander from upstream to the coast, various human activities take advantage of the ecosystem services of both the rivers and their surrounding environment (Oyebande, 2001; GWP, 2016). Increasing demands to meet human needs for consumption and industry from inland river systems is affecting net water quality and availability for supply to coastal systems (NOAA, 2018). These shifts in resource use patterns and consequent pressures on inland river systems have led to significant transformations in the availability and quality of West Africa's water systems. Damming for irrigation and power generation, pollution, urbanization and intensification of resource use patterns are examples of factors that favor economic development, but ultimately cut off the connectivity of the river with its associated coastal ecosystems, especially when exacerbated by climate change and deforestation in the catchment areas. While development interventions such as dams can have adverse impacts on river systems and estuaries, they also bring along various socio-economic opportunities such as energy production, water for irrigation, fresh fish production and tourism development opportunities. A trade-off is therefore often required to make the right decision that better supports overall development needs.

Regardless, it is clear that human interferences on inland fresh water systems are harming the health of estuaries, and hence undermine food security in the estuaries. Further, the ability of estuaries to continue providing vital ecosystem services is undermined by the combined effects of water pollution from industry, abstraction and diversion of water and reduction of flow to the estuaries. Addressing the challenges that undermine the supply and quality of water for fish and agricultural production in coastal estuaries or adjacent environments, will require cross cutting interventions. Various authorities recognize these challenges and advocate for the sustainable management of waters systems to ensure continuous supply of ecosystem services as a reasonable course of action from upstream to downstream (GWP, 2012;2016). However, for varying economic and political reasons some policy makers continue to take decisions that undermine the ability of these freshwater systems to flourish.

This paper analyses the effect of industry and other human activities on the quality and quantity of fresh water flow from upstream to the coast in Sierra Leone. A companion paper in this issue of Nature & Faune (Feka *et al*., in press), proposes solutions to enhance and sustain food security for coastal communities. We (1) examine drivers undermining the quality of fresh water and flow volume from upstream to the estuaries in Sierra Leone and (2) review available literature and policy considerations to understand what is done by the government of Sierra Leone to address these issues. This paper will be useful for political authorities, the extractive industry and researchers, to emphasize how human actions on inland riverine systems disrupt contribution to food security for coastal communities in Sierra Leone.

The Sierra Leone, coastal and riverine context

Sierra Leone's coastline stretches for about 402 km from its border with Guinea to the North West to its border with Liberia to the South East. The population is estimated as seven million people, 60% of whom live within or close to the coast (Feka and Morrison, 2017). This coastline is characterized by a variety of coastal habitats, from which various stakeholders derive their socio-economic and developmental needs. Sierra Leoneans are primarily dependent on rice (cultivated around estuaries or along river sources), and fish from inland water bodies, estuaries and the marine environment.

Sierra Leone is bordered to the West by the Atlantic Ocean that forms the drainage basin of the numerous rivers. Many of these rivers originate in upstream neighboring countries, namely Guinea to the North and Liberia to the South East (Figure 1), and cross Sierra Leone to discharge downstream into the Atlantic Ocean (Table 1). On their transition to the Atlantic Ocean, these rivers form four major estuaries: Scarcies, Sierra Leone, Yawri Bay and Sherbro. These estuaries are tidal mouths resulting from the deposition of silt and clay-where the river meets the sea. The rivers enable the existence and flourishing of the estuarine systems that form major coastal wetland. These estuaries are the repository of mangrove habitants, mudflats, and swampy grass land that support some of the largest numbers of coastal and marine life in West Africa, including migratory birds, aquatic mammals, reptiles, amphibians, and fish (EPA, 2015). These coastal wetlands are vital for maintaining healthy and functioning coastal/marine ecosystems, in addition to the socio-economic and cultural values they have to the local populations and the economy of this country (Kassam *et al.*, 2017). However, the ability of these estuarine systems to function properly is highly dependent on the supply of fresh nutrients and water from the country's river systems (NOAA, 2018).

Table 1: Water catchments, links to estuaries and connection to countries of origin

Estuaries	Rivers connecting inland to coast	Where rivers originate from/sources	Catchment area in Sierra Leone (in Square Kilometers)	Catchment area outside Sierra Leone (Km^2)
Scarcies Estuary	Little Scarcies	Originates in Guinea	13 383	5572
	Great Scarcies	Takes its rise in Guinea where it is known as the Kolenté. Over a long distance forms the border between Guinea and Sierra Leone.	2 979	5323
Sierra Leone Estuary	Bankasoka River and Kumrabai Creek	Combines with the Rokel River to the south to form the Sierra Leone River	No data	
	Rokel	The Rokel rises from the plateau of the Loma Mountains, in the Guinea Highlands	8 236	No data
Yawri Bay	The Ribi, Kukuli and Kargboro rivers in Moyamba District empty into this Bay	Originate respectively from… Kafuta and Ngagboli	3 670	0
Sherbro Estuary	Waanje	Takes its rise from Kenema, Eastern Sierra Leone	610	0
	Taia or Jong	It originates from a confluence of the Pampana and Teye River at Sedden	8 288	0
	Sewa	Originates in the Northeastern part of Sierra Leone near the border with Guinea	No verifiable data	0

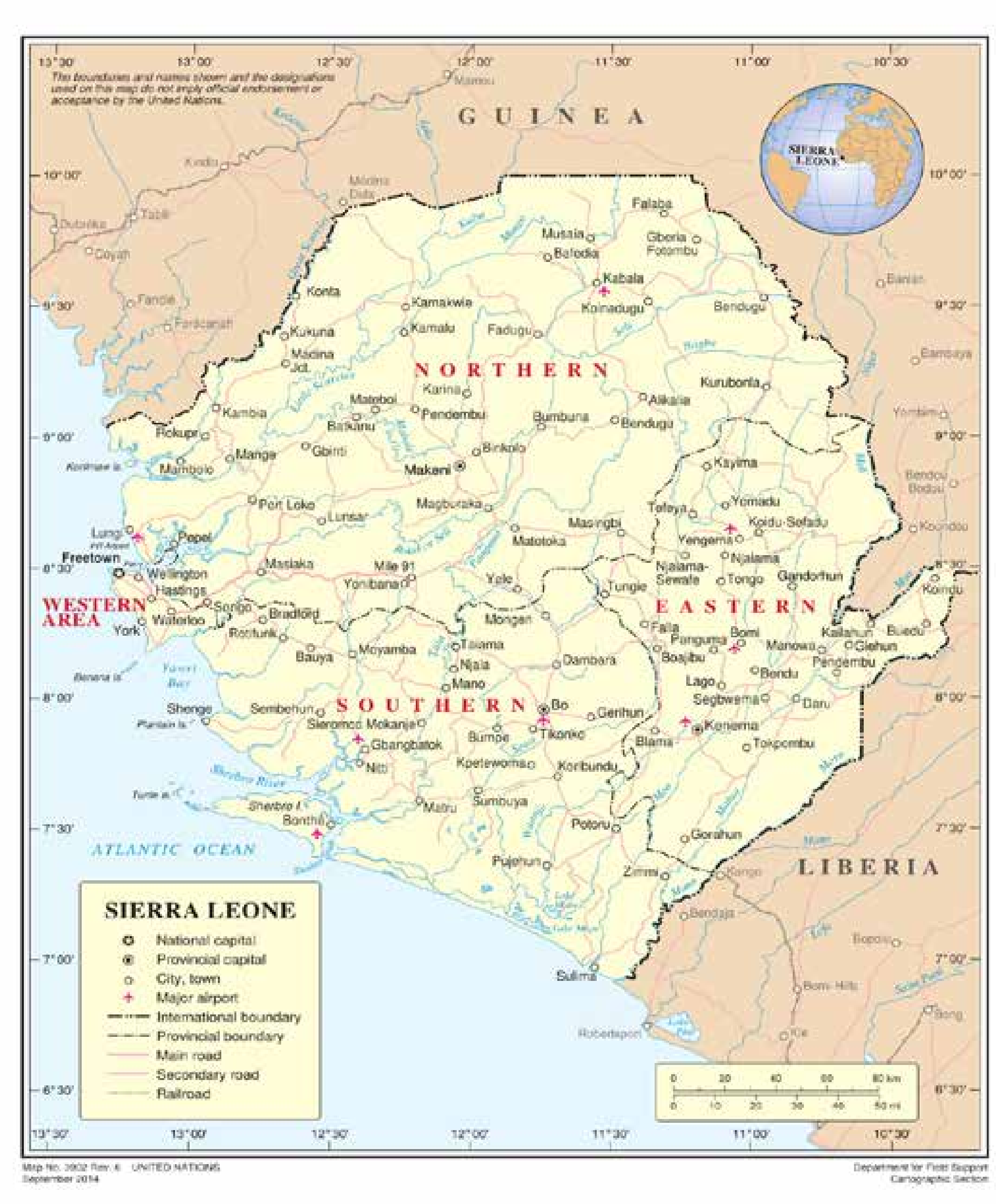


Figure 1: Map of Sierra Leone, showing political boundaries and rivers
Source: Sierra Leone (http://www.un.org/Depts/Cartographic/map/profile/sierrale.pdf)

Rice production

Rice is an important staple food in Sierra Leone, with an annual per capita consumption estimated at 104 kg. Rice is grown mainly by small scale farmers from upland to lowland (Table 2), and accounts for 42% of agricultural Gross Domestic Product (GDP) (Neiland *et al*.,2016). The production of rice is dependent on the river systems for irrigation and increasingly on rainfall. The production of rice has increased from 1960, with a significant decrease during the civil war during the 1991–2002. However, this increase was through expansion of rice growing area and not due to increased yields per hectare. At the community levels, rice farming efforts have increased while yields per unit land cultivated seem to have declined[1]. While farmers point to lack of land and poor

1 personal observation from the field because communities continue to clear mangroves to plant rice, but their harvest is barely enough to feed their families.

variety of planting materials as the principal challenges for the declining yields, aspects of water quality and availability are typified by the strong reliance on the rainy season for cultivation in both coastal and upland areas. Today Sierra Leone is complementing its shortfall by importing about 70% of rice from elsewhere (GOSL, 2009).

Table 2: Major categories of land use for Rice production in Sierra Leone

Ecotype	Arable area (ha)	Cultivated area under rice (ha)*	Percent of total area under rice
Upland	4 300 000	363 894	55
Inland valley Swamp	630 000	170 000	26
Mangrove Swamp	540 000	70 000	11
Riverine Grassland	110 000	5 593	1
Boliland[1]	120 000	50 000	8
Totals	5 700.000	659 487	100

Source: Adapted from GOSL, 2009

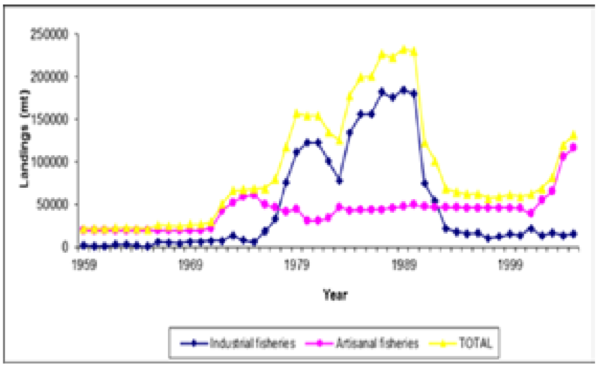
**Rice area in 2007*

Fisheries production

The fisheries industry in Sierra Leone is derived from both riverine and marine water bodies. Fishing is carried out by numerous small-scale artisanal fishers and a plethora of industrial fleets using complex fishing technology. About 90% of fish production in Sierra Leone is derived from the marine or coastal environment (Jalloh, 2010). Fisheries represent around 10% of Sierra Leone's gross domestic product and directly employ over 40 000 fisherfolk with a total of 500 000 of people employed either directly or indirectly in the fisheries-related sector. Fish is also the most affordable and widely available protein source and constitutes 75% of the animal protein consumed in the country (Neiland *et al.* 2016).

Over the years however, fish production has been varying because of various levels of industrial and artisanal fishing efforts (Figure 2 a and b). A series of studies have highlighted that the variation in fisheries production in Sierra Leone is mostly linked to both illegal industrial and artisanal harvesting (Arnason, 1993; Neiland *et al*., 2016; Kassam *et al*., 2017). According to officials of the Ministry of Fisheries and Marine Resources (MFMR), the sharp decline of fish production in 2010 as per figure 2b was probably due to drastic withdrawal of fishing effort and under-reporting by the foreign industrial fleets because of enhanced enforcement of fishing regulations when the World Bank funded West African Regional Fisheries Project (WARFP) started in Sierra Leone. None of the studies seem to explicitly link changed river water quality and flow to this variation as a key element that could undermine fish production.

[1] Boliland is a Temne (tribe in Sierra Leone) word for those lands that are flooded in the rainy season



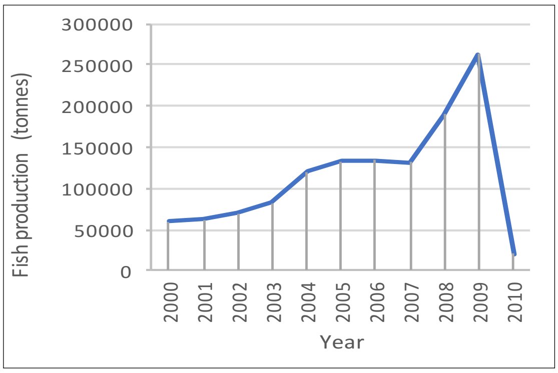


Figure 2 (a): Trends of Fisheries production in Sierra Leone.
Source Unpublished Data from Professor Percival A.T. Showers Professor, Inst. of Marine Biol. & Ocean-FBC, Univ. of Sierra Leone

Figure 2 (b): Trends of Total fishery production in metric 2000-2010
Source MFMR, 2013

Factors affecting river system quality and flow

In Sierra Leone, the production of fish and rice at the coastal realm depends on a network of inland water systems that supply fresh water to coastal estuaries (Blinker, 2006). The country is richly endowed with water resources and is one of the most humid countries of Africa with a mean annual rainfall of 2 526 mm/year (Irish Aid, 2017; Fileccia *et al.*, 2017).

Despite these water resources and their contribution to the country's food security, their collective quality and flow from upstream to the estuaries is threatened by a variety of human drivers (Table 3). Many factors influence fresh water systems, and hence the production of rice and fish in Sierra Leone, but we will narrow down on the extractive activities and policy development/ enforcement that influence quality and volume of water flow from upstream to the estuaries.

To the suite of challenges outlined in Table 3, climate variability is anticipated to affect both availability and quality of water. Because of seasonal variability, variations in the flow of rivers are significant, with minimal discharges occurring during the dry season, thus affecting water availability for food production (Irish Aid, 2017).Furthermore, uncontrolled deforestation will exacerbate the effects of climate change by enhancing evaporation of water during the dry season, while flash floods and increased intensity of rainfall events during the rainy seasons will increase runoff and sediment loads into rivers (Döll and Zhang, 2010). Consequently, water quality in rivers will be affected all the way down to the estuaries.

The extractive industry (Table 4), including massive deforestation of river banks, and related human activities, are also threatening the ability of these rivers to continue providing vital ecosystem services to humans and other ecosystems.

Table 3: Direct threat to Sierra Leone's water systems from upstream to the estuaries and sea

Water system categories	Some threats undermining the ability of water systems to continue providing essential ecosystem services in Sierra Leone
Rivers	Pollution of water sources and courses by e.g. effluent from mining operations, agriculture, dumping of industrial and municipal solid and liquid waste in watersheds and in sources Conversion of wetlands/swamps for rice production Over-exploitation of inland water resources Climate change Invasive species (e.g. water hyacinth proliferation)
Coastal estuaries and mangroves of Sierra Leone	Infrastructure development, e.g. building of roads, houses and tourism infrastructure Pollution, e.g. dumping of untreated sewage and other liquid and solid waste by hotels and households Climate change, especially due to increased evaporation from water bodies Impacts of mining industry that impacts flows and flushes of fresh water into the estuaries Over-exploitation of mangrove resources, e.g. harvesting of mangrove wood for firewood, construction and over-fishing using unconventional harvesting methods Beach sand mining, e.g. extraction of sand for the building industry around Freetown, Lungi and Waterloo
Marine environment	Over fishing by international fishing fleets Unmanaged and poor enforcement of existing policies and regulations- poor governance Off-shore oil and gas exploration Illegal fishing methods by local community members, e.g. use of mono filament nets, use of chemicals etc Pollution from poor up-stream fishing and agricultural practices

Souce: Adapted from DAI, 2013

Table 4: Extractive industries and how they match with the four estuaries of Sierra Leone

Name of Wetland	Type of extractive industries
Scarcies River Estuary	Sand, mangrove logging, agricultural expansion
Sierra Leone Estuary	Sand, mangrove logging and agricultural expansion
Yawri Bay	Zircon (gemstone/ nesosilicates mineral), mangrove logging and agricultural expansion
Sherbro Estuary	Rutile, zircon, mangrove logging and agricultural expansion
Rokel River and tributaries	Gold and sand
Sewa River and tributaries	Gold, diamond, sand
Jong or Taia River	Gold and sand

Impacts of human activities on the quality and flow of rivers to estuaries

In addition to the factors listed above Sierra Leone's inland water systems are also threatened by deforestation from unplanned agricultural development (DAI, 2013). Blinker (2006) estimated that up to 2006, Sierra Leone had lost about 70% of its original forest cover. In addition, over a 26-year period (1990-2016) the country also lost 26% of its mangrove forest cover to wood extraction and the conversion to rice farms (Mondal *et al*.,2017). Forests are usually lost along with the vital ecosystem services that sustain river systems' ability to reduce surface water evaporation from the soil, favor infiltration and regulate the water in the air through transpiration.

On the other hand, anticipated benefits from climate change such as increases in carbon dioxide, may enhance primary productivity. (Explanatory note: The low carbon dioxide concentration in the atmosphere is the biggest limiting factor to crop production but this anticipated benefit could be cancelled by widespread agricultural expansion (rubber and palm oil) and food crops across the country (USAID, 2012). Hence, given the irregularity of freshwater flushes into estuaries caused by deforestation, and the projected sea level rise, increased sea surface temperature and acidification of the ocean at the coastal interface, will alter fish production at the coastal and marine interface with implications for food security and nutrition. Diminishing riverine volumes will also reduce water for irrigation, mangrove swamp[1] rice cultivation at the coast and biodiversity (Niasse *et al*., 2004).

Studies on the direct impact of the extractive industry on river systems, and consequent impacts on estuaries, for Sierra Leone are scarce (Akiwumi and Butler, 2008; SLEITI, 2016). However, aspects of soil contamination and water pollution from extractives is a problem that is already affecting biodiversity and water systems in coastal Sierra Leone. For instance, rutile (titanium mineral), mining operations adjacent to the Sherbro Estuary directly impacted over 66 km^2 of forested land from 1967 to1995 (Akiwumi and Butler, 2008). A recent study reveals that mangrove habitat lost to mining activities is currently estimated to be 1.25 km^2 or 0.18% of the mangrove forest area in the Sherbro Estuary, and this is anticipated to increase with planned additional mining operations (Clark *et al.,* 2018). These very conservative values do not consider the broader impacts on the landscape such as biodiversity loss, flooding of alluvial lowlands, and the creation of tailings and stockpiles over mined-out portions and pollution of the estuary. Mining activities in this region are causing rapid sedimentation of the estuary, with prospects for heavy metal accumulation in fish and other costal agricultural produce.

A recent study reveals that the concentrations of three trace metals, i.e. arsenic (As), chromium (Cr) and nickel (Ni) in sub-tidal sediment samples from this estuary exceed the level where toxicity may begin to be observed in sensitive fauna and flora species (Clark *et al*., 2018). The bioaccumulation of heavy metals, e.g. zinc and copper in samples of oyster flesh exceeds the median recommended levels for human consumption in at least one sampling station (SLEITI, 2016)

Efforts to improve riverine management by the government of Sierra Leone

The government of Sierra Leone has taken various steps to improve the management of water and wetland systems in general. These efforts have focused on developing policies, legislation and institutions to support and regulate the activities of extractive industries (Table 5). Despite the existence of these provisions, there are still implementation challenges due to overlapping mandates and conflict of interest among relevant Ministries Departments and Agencies (MDAs). There are some challenges that exacerbate the proper management of the impact of extractive activities on the environment and water systems (Table 6). The legislative provisions and policy guidance tend to focus more on creating an enabling environment for business development, with little or no stringent measures to incentivize effective corporate

[1] The cultivation of rice in mangrove swamps depends significantly on the salinity of the water system. Communities in across coastal Sierra Leone usually wait for the raining season to ensure that salinity levels are low before planting. However, when there is adequate supply of enough fresh water from inland mangrove swamp rice cultivation can be done more than once a year.

social responsibility (CSR) vis-à-vis the environment- in this case water management. For example, the mining legislation in the 1994 Act does not sufficiently detail environmental, social development, health, safety and community issues. Some effort has been invested into developing different mining legislation in Sierra Leone, unlike the other sectors like forestry and water resources, and soil or river remediation for instance, where efforts have been very scant (SLEITI, 2016). The challenges of managing the exemplified sectors under an environment context are further complicated by the "non-disclosure" clause in the mining companies' contracts (SLEITI, 2016). In addition, there is no provision for water and soil pollution prevention and control, although legislation states that this must be considered to the extent possible during the environmental impact assessment as per the Environmental Protection Agency Act Sierra Leone (FAO,2010). Follow up and monitoring and evaluation of the mitigation or off-set actions as promised in environmental impact assessment reports are often lacking. Most of the MDAs justify this lack of monitoring and enforcement of legislation to inadequate funding and qualified personnel (field observation).

Furthermore, some of the legislative and policy frameworks for environmental and water resources management in Sierra Leone are outdated and revised formats have not been promulgated into law. Attempts to review and update these tools are constrained by lack of financial resources and political instability. Hence, there is a need to review and reform existing provisions conform them to contemporary extractive and water management issues.

Table 5: Legislative and policy efforts by the government of Sierra Leone to manage wetlands

Legislation/policy/strategy	**Remarks**
The Forestry Act (2011)	These are the main instruments for the forestry sector in Sierra Leone and both are alleged to be under review. The Conservation and Wildlife Policy and Act, of 1972 was reviewed into the draft 2011 act-still a draft.
Draft Conservation and Wildlife Policy and Act, 2011	
The 1994 Mines and Minerals Decree, which was enacted as law in 1996 (1994 Act)	The Minerals Act 1927 was amended and revised into the Minerals Act in 1960 and later replaced by the 1994 act
Mines and Minerals (Fees) Regulations 2008.	The 1994 Act was amended in 1999 and 2004 and supplemented by the Mines and Minerals Regulations in 2008
Mineral and Mines Act (2009 Act)	This replaced the 1994 Act.
National Biodiversity Strategy and Action Plan, 2003	This is an international convention signed by Sierra Leone to enhance the management of biodiversity.
A Wetlands Strategy	Developed in 2015 but still a draft document
Environment Protection Agency Act 2008 (EPA Act)	Environment Protection Agency was established under this act
The National Minerals Agency Act 2012	The National Minerals Agency was established under the mineral act
Wetlands Act- Draft	Draft

Source: Assembled by authors from FAO (2010), EPA, (2015)

Table 6: Governance issues and how they threaten water quality and ecosystem integrity in Sierra Leone

Poor governance drivers	Direct links to threats that undermine ecosystems integrity
Lack of information for decision making on services provided by healthy ecosystems to policy makers, corruption and lack of incentives for corporate social responsibility	Poor valuation of ecosystems services favors extractive industry over conservation (Land use conversion), degradation and loss of species, pollution and contamination of firewater, unsustainable harvesting Mining Infrastructure development
Insufficient resources for natural resource and biodiversity conservation	Not Known
Inadequate coordination to protect high-conservation-value habitats	Conversion, degradation, loss
Ineffective integrated planning for climate change and biodiversity management (forests/mangroves, watersheds, estuaries and biodiversity) in national and sub-regional development plans	Over exploitation and degradation of habitats loss because of infrastructure development, indiscriminate expansion of the extractive industry and climate change
Poor governance in the practice of corporate social responsibility as most industries do not often practice promises carried in their EIAs	Pollution, environmental degradation, loss of water quality and disrespect for environmental and social safeguards
Inadequate coordination and corporation between agencies and countries to sustainably manage critical fresh water habitats	Transboundary pollution, possible conflict between Guinea and Sierra Leone on water resources, degradation and loss of fresh water resources

Source: Assembled by authors from FAO (2010), EPA, (2015)

Conclusion

Guaranteeing appropriate river flow and quality to ensure food security in the estuaries of Sierra Leone is an increasingly daunting challenge under unsustainable human practices and climate change. Ongoing extractive industry, forest exploitation and agricultural activities within and around river systems flowing into the four estuaries of Sierra Leone bring in a lot of pollutants and the receiving estuaries are widely opened to sea. The combined action of unsustainable human actions in and within river systems inland, coupled with the effects of climate change results in reduced flow of water in the rivers that regularly combine with rainwater-run-off to form a mixture of contaminants that discharge downstream in the estuaries. If left unmanaged, these will irreversibly harm the heath of these estuaries and disrupt their ability to provide food security services to coastal communities and ultimately jeopardize the health of the dependent populace as reported elsewhere (Parineeta-Dandekar, 2012). The eventual impacts of inland activities on these estuaries will therefore bear far reaching environmental and societal challenges to biodiversity, food insecurity and community health at the coastal interface due to decline in fish production and increased contaminants respectively (Feka and Morrison, 2017). In addition, lack of water in river systems flowing to the estuaries will increase dependency on already variable rainfall patterns for rice farming in this country. To overcome some of these challenges, we suggest reforming existing legislation that will promote improved food production in coastal estuaries in Sierra Leone, and strengthen the enforcement of existing rules in Sierra Leone.

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1995, Ghana - Fish is sun-dried prior to sale in the local market.

What does the future hold for fish farming in Cameroon?

Junie Albine Atangana Kenfack[1], Christian Ducarme[2], and Jean-Claude Micha[3]

Summary

Introduced in Cameroon in 1948, fish farming was somewhat successful and then collapsed after the 1960s. One of the causes of this failure was the implementation of inappropriate policies. More recently, in 2003, the development of the national aquaculture strategy, followed in 2009 by an action plan, was not enough to revive the aquaculture sub-sector. The lack of land tenure, limited access to credit and inputs, often poorly constructed fish ponds, and proposals for unprofitable production techniques all continue to hamper the development of the activity. However, the country has many assets and significant investments are being made in the sub-sector. The conditions for the development of aquaculture activity could not yet be guaranteed, but there is hope and concrete recommendations are made for the sector to produce sustainably.

Introduction

World fish production (fish, shellfish) reached 170 million tons in 2016 (90.9 MT for fishing and nearly 80 MT for aquaculture) (FAO, 2018). Aquaculture is thus the fastest growing livestock production in the world (EESC, 2017).

In Cameroon, national fisheries production is 180 000 tons/year with less than 1 000 tons/year from aquaculture. This remains low for an estimated annual demand of 400 000 tons (ACP Fish, 2011; MINEPIA, 2013). To fill this gap, 212 000 tons of fish products were imported in 2012 (Isolina *et al*., 2013). However, the country has a dense hydrographic network that offers a much diversified potential of fish species, with 542 fish species over more than 40 000 km^2 of freshwater surface area (MINEPAT, 2013). Unlike China, where fish farming is an activity that dates back nearly 3 millennia (Micha, 2013), fish farming was introduced in Cameroon in 1948 by the French colonial administration (Satia, 1992; Tangou, 2009), as a food subsistence activity with some success. After independence in 1960, most of the ponds built were abandoned. Among the reasons given was an inappropriate development policy. Since then, the fish farming sub-sector has developed little, although the country has had a national aquaculture strategy since 2003 with an action plan since 2009 (MINEPIA, 2009). It therefore appears that all the elements are in place to develop sustainable and profitable aquaculture, but the difficulties persist and development does not follow.

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Status of fish farming in Cameroon

Decades of unsuccessful attempts between 1960 and 1994

Between 1948 and 1954, the French colonial administration tried to promote the cultivation of Tilapia in dam ponds and fresh water in the south-central and western regions of the country (Satia, 1992). From 1954 to 1960, twenty-two (22) aquaculture stations and an extension service were created. After a period of withdrawal of support, the Cameroonian government subscribed to several multifaceted interventions: international organizations such as UNDP/FAO (1960 to 1968), the Peace Corps (1969) and USAID (1980 to 1984); and national organizations such as the *Société d'expansion et de modernisation de la riziculture (SEMRY) in 1987*. The multiplicity of these actions has not been sufficient to stimulate a dynamic development of fish farming. The objectives have rarely been achieved (Tangou, 2009). The lack of basic infrastructure, limited access to inputs and the proposal of inefficient policies or inefficient technical routes have led the sector to a situation of stagnation or even regression.

A reorientation of the role of the administration in aquaculture development after the 1987 economic crisis

The economic crisis that affected the country from 1987 onwards reduced the capacity of public authorities to intervene in the economic and social sectors, thus contributing to the modification of the landscape of local development actors. In the rural sector, there has been a decline in agricultural production, which has been exacerbated by the disappearance of farmers' management structures. In 1996, poverty had increased sharply in Cameroon and affected more than 50.5% of the population (ADB, 2009). In this context, the approach developed in aquaculture policy *(Coopération française:* 1995-1998; *World Fish Center:* 2000-2005) took greater account of the profitability and autonomy of production systems and enshrined the principle of the participation of promoters at the various stages of projects (Tangou, 2009; MINEPIA, 2009). Profitability was still not there, activities stopped as soon as the projects were completed.

Since 2003: an aquaculture activity that has stagnated despite promises of new initiatives

The implementation of the Poverty Reduction Strategy Paper (PRSP) in 2003 did not significantly reduce poverty in Cameroon. The economy remained fragile and constrained by structural deficiencies related to the low competitiveness of the productive sector (Mikolasek *et al.*, 2009). As a result, the Cameroonian government undertook to prepare in 2009 the Strategy Document for Growth and Employment (DSCE), which integrates the plan for the sustainable development of aquaculture. However, the results of the implementation of this plan are not conclusive. Fish consumption (9 kg/inhabitant/year) remains below the expected value of 11.57 kg/inhabitant/year (MINEPIA, 2013). The supply of inputs remains difficult. Access to land and credit is still not guaranteed. The lowlands, privileged areas for aquaculture, are in the public domain. The majority of sustainable fish farming systems that have shown some profitability are of the extensive or semi-intensive type in ponds (Efolé and *al*., 2017; Bogne and *al*., 2013; Brummett and *al*., 2004). The Ministry of Livestock, Fisheries and Animal Industries (MINEPIA) supports projects aimed at promoting intensive fish farming systems in above-ground basins (IFAD, 2016 - http://www.ppea-cameroun.org) with varying degrees of success because they are not always profitable. Vocational training is provided by two Universities (Dschang, Douala) and a national zoo technical and veterinary training Centre (Foumban). Despite these investments in training and projects, management structures are insufficient and staff are poorly qualified. The results of the aquaculture policy are still not forthcoming and the activity is stalled. Many constraints persist and concerned institutions, financing, site development and management techniques, have little impact on production.

Challenges and perspectives

Aquaculture remains subject to administrative, financial, technical, socio-economic and marketing constraints that hinder the sustainable development of the sub-sector. The performance of aquaculture policy would not be sufficient to boost the sustainable development of the activity. Domestic aquaculture production is stagnating at around 1000 tons/year while the demand for fish continues to grow. Fish ponds located in isolated areas are often still small in size, partially drained and often far from markets (Kriesemer, 2009). The socio-economic feasibility of fish farming projects is not sufficiently considered.

The increase in aquaculture production will depend on:

- Coherence between public policies: a clear, concerted and shared aquaculture policy, in harmony with policies on finance, land registries, public works, agriculture, water management, etc., would improve the effectiveness and efficiency of interventions for aquaculture development. Incentives such as land security, reducing the tax rate, setting up funds for aquaculture, raising awareness among banking institutions of the profitability of fish farming, reframing aquaculture development in the context of ongoing competition from all meat products, including frozen fish, beef, pork and poultry (Lacroix and Paquotte, 1999) would promote the indispensable and inevitable development of the activity ;

- The adoption of a global and integrated approach at the strategic and local levels. Indeed, the measures to be designed to develop aquaculture must consider the social, environmental and economic implications of the proposed changes in the conduct of the activity. The selection of appropriate sites should take into account proximity to markets, environmental and socio-economic conditions (IUCN, 2009). Thus, integrated production systems (Efolé *et al*., 2017; Oswald *et al*., 2013), agriculture (rice, fish farming, market gardening, fish farming, etc.) or livestock (poultry, fish, pork and fish), as is the case in Asia (FAO, 2000), are to be preferred, while respecting the environment.

- Quality of fish feed: the high price of granulated fish feed in Cameroon (1200 to 1500 CFA/kg) is currently incompatible with the economic profitability of Tilapia breeding in an intensive above-ground system (floating cages). In the case of Clarias, in view of its higher selling price (2000 to 2500 CFA/kg compared to 1500 to 1800 CFA/kg for Tilapia) and low conversion rates (0.8 to 1 for the best fish farms), profitable production is possible (FAO, 2017).

- The organization of the profession, which should facilitate the transfer of good technical practices and also contribute to better marketing of fish products (IUCN, 2009).

- In the longer term, research should offer species with high added value: snakehead fish (Parachanna), river sole (Schilbe), freshwater giant shrimp (Macrobrachium), (Micha, 2006) and food of good nutritional quality.

  In China, the introduction of high-value species has stimulated the development of large food production Companies (FAO, 2000).

In conclusion, far from being an easy equation, the development of fish farming requires a unique combination of social, economic, political, environmental and cultural conditions to ensure that it is integrated into the local economy and that, sites are selected and managed in a concerted, cost-effective and in an environmentally appropriate manner.

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Fishponds with outlets

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Gender in community management of mangrove ecosystems in Cameroon: some lessons to ensure that no one is left behind

Fidèle L. N. Tchinda[1], Gordon N. Ajonina[2] and Jean-Claude Nguinguiri[3]

Gender mainstreaming in development projects is a concern shared by all development support organizations. Practical guides are developed and direct action aimed towards inclusive and gender sensitive approaches. Observations made in a community management project of mangrove ecosystems in Cameroon have shown that the implications of the gender approach depend partly on the level of participation observed for each social category. As far as women are concerned, this level of participation has been determined mainly through the perceptions they had of the expected benefits for each technical or organizational project proposal. In other words, women did not participate effectively in the project until they were convinced that the action being promoted was likely to be beneficial and help improve their well-being.

Introduction

In Cameroon, mangroves cover an area of 2700 km², or 1.5% of the forests, distributed between Rio Del Rey (1600 km²) and the Cameroon Estuary (1100 km²). These mangrove ecosystems have lost about 30% of their surface area over the past 25 years (Moudingo & al. 2015). The causes of this deforestation are mainly linked to human activities (Ajonina & Usongo 2001; Din & al. 2008). In addition to anthropogenic threats, mangrove ecosystems are not immune to climate change (Mbevo Fendoung & al. 2017).

The government, with the support of its development partners, is implementing projects to reverse the trend. Nearly one million people in Cameroon depend on mangrove ecosystems for their livelihood. In addition to the non-timber forest products collected therein for food, medicinal use and sale, local/indigenous/resident populations also depend on mangroves for agricultural and fishing activities. They are equally considered as sacred sites for traditional ceremonies, recreation and tourism (Ndjebet, 2017).

The project "Conservation and Community Management of Mangrove Ecosystems in Cameroon[4]", funded by the Global Environment Facility has been one of the most important actions undertaken by the government over the past five years. This project was implemented by the Ministry of Environment and some national NGOs (CamEco, OPED and CWCS) with technical support from FAO. The gender dimension was therefore taken into account according to the guidelines of the FAO, the implementing agency that ensured the technical quality control of the support mechanism.

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4 Project GCP/CMR/030/GFF " Sustainable Community Based Management and Conservation of Mangrove Ecosystems in Cameroon "

The analysis of the gender dimension in this project has shown that participation cannot be decreed, as Olivier (2011) or Buttoud and Nguinguiri (2016) have already pointed out. After recalling the methodology used and the level of gender participation as reflected in the statistical analysis results, we will try to understand the logic underlying women's participation in the project.

Women's participation in the project: methodology and first results

The exercise was conducted at the end of the project, the ideal time to review the achievements. Three inputs were explored: participation, capacity building and institutions born from the project's action. An approach, partly based on the indicators proposed by FAO (2017) for gender mainstreaming in forestry projects was therefore used.

The methodology here consisted of the use of primary and secondary data; a pre-established questionnaire was submitted to the technical partners implementing the project's activities and the gender-disintegrated data, classified into seven activity areas figuring in the three entries mentioned above, were manually analyzed. The encoding was done in Microsoft Excel software. Inferential statistical analyses using SPSS V. 20.0 software (Pearson and Chi-square test) showed the degree of correlation between gender and the different activities carried out by the project. The conclusions of this analysis are as follows:

- The project implementation strategy is participatory and inclusive. Women, like men and other social groups, are stakeholders in the community-based management process of mangrove ecosystems. As such, the project has endeavoured to guarantee the same benefits to women and men while avoiding that its action generates inequalities between the two categories of stakeholders.

- It appeared that the level of participation of women and men was variable throughout the process. Women, for example, were not very active in the collection of biophysical data needed to develop the simple management plans for community forest. . They were almost absent during the carrying out of inventories and the installation of ecological monitoring plots.

- The number of women participating in project activities increased rapidly during the subsequent phases, which were dedicated to strengthening the technical and organizational capacities of local communities. Men, although more numerous during sessions devoted to the identification of income-generating activities (IGAs) and planning, were outnumbered by women during trainings on appropriate local production and processing techniques and organizational capacity building.

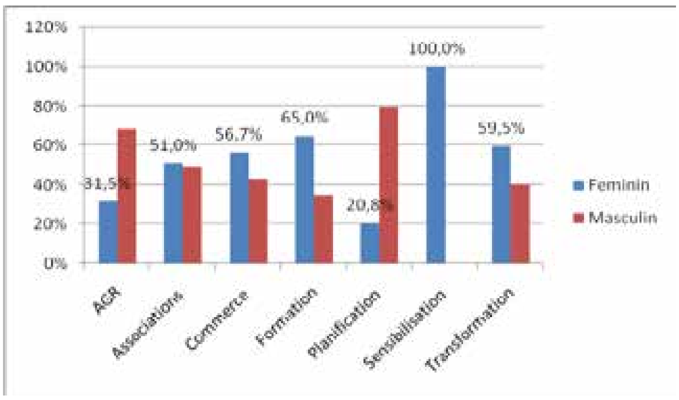

Figure 1: Distribution of participants in project activities by gender
Source: Fidèle L. N. Tchinda

It is clear from Figure 1 that women were more or less undecided during the planning phase but later developed more motivation during the technical and entrepreneurial capacity building support phase. Generally, men were involved at 60% and women at 40%. But women's participation seems to have a greater impact on income-generating activities.

Strategies that underlie women's participation

The division of labour between women and men in the project area has also been described (Ajonina *et al*. 2015). In the fishing sector for example, men control the production segment, while women are more active in processing and marketing, a practice fairly common to all West African coastal Countries (Benett, 2005). The project never intended to challenge these standards through capacity building activities for women and men. Despite efforts to make the support system inclusive, the level of participation of women was not constant. The low participation of women observed during the preparation of simple management plans for the community forest is more likened to an avoidance strategy than a real lack of interest in the project. It has been characterized most often by passivity, or even evasion; behaviours that have often been justified by pointing to customs and its rules for the distribution of tasks and responsibilities between the sexes. In this logic, it was normal to see men carrying out, for example, inventory works in mangrove ecosystems, a tedious and unhealthy task. Beside these avoidance strategies, women also deployed strategies to control resources of all kinds offered by the project. The massive participation of women in the trainings on income-generating activities and organizational capacity building is part of this "hidden agenda". In the absence of an exhaustive description, two examples will illustrate these remarks.

The first refers to innovation in the fisheries sector. The women were very interested in the campaign to popularize the floating cage for the growth of crayfish. With the support of the project, they tested and contributed to giving this tool a more adapted form to the local context. By investing in the growth of crayfish, women are positioning themselves in a new segment of the sector that could well be part of the extension of fishing; an activity traditionally reserved for men. Women's appropriation of this innovation gives a new dimension to processing: its scope is no longer limited to smoking, but also covers this particular aquaculture system. Women also conducted tests of improved smoking rooms aimed at reducing the workload, difficulty, processing time and wood energy consumption rate (40% to 60% less firewood than in regular smoking rooms). Instead of limiting themselves to the tool and techniques popularized by the project, they have shown ingenuity by drawing from local knowledge to integrate another fuel into the technical package, namely fish scales, which gives an exceptional colour to the finished product.

The second example concerns organizational aspects. Women did not remain on the sidelines during the establishment or setting up of community forest management committees created with the support of the project or grassroots/base communities (economic interest groups, cooperatives and associations), as shown in Table 1. Several of them were elected in the offices of community forest management entities or grassroots communities. Some economic interest groups have only women as members; this is the case, for example, of the women's savings and credit cooperative called "ndokohi progress".

Table 1: Gender distribution of members of community management organizations

Organisations	Year of establishment	Absolute frequency		Total of members	Relative frequency (%)	
		Women	Men		Women	Men
Mangrove platform						
Rio Ntem	2014	12	13	25	48	52
Cameroon Estuary	2013	15	17	32	47	53
Rio Del Rey	2014	10	16	26	38	62
Londji Cooperative	2014	18	12	30	60	40
« La mangrove » Association of Manoka	2015	11	13	24	46	54
« Mintin N'Zangwa » Association	2015	8	11	19	42	58
GIC PAFCAM	2007	9	7	16	56	44
GIC the Progress of Ndokohi	2010	14	0	14	100	0
GIC PPRM	2012	9	8	17	53	47

The choice of a strategy (avoidance or adhesion/control of the resources offered by the project) cannot be justified solely on the basis of cultural considerations. On the contrary, the decision to participate or not in a project activity was made taking into account the expected benefits/outcomes. In the first example mentioned above, the innovations to which the women adhered responds to current needs. The growth of crayfish in floating cages allows women to sell the product at all seasons and thus obtain a more attractive gain. The same goes for improved smoking rooms, which make it possible to reduce charges, particularly for fuelwood, improve product quality and increase profit margins. Women also attached more importance to activities that enabled them to be integrated into the decision-making sphere. By participating in office of the management entities, they are now among those who decide on the future of the community and its natural resources. This positioning in community organizations is also explained by the concern to secure their economic activities.

Conclusion

In this experiment, the effects of the project are more marked in the economic role of women than in the questioning of possible discrimination. The good performances observed here are due to the mobilization of women. The level of adherence to one activity or another was influenced by the discovery of the resources of all kinds offered by the project. Women and men are above all social actors with resources and behaviours that are not always controllable by external actors. From this perspective, the effectiveness of the "Gender Approach" does not only depend on the technical aspects related to the integration of the gender dimension into the project's action; it also results from the way in which it is appropriate and renegotiated by the beneficiaries through forms of hidden participation, if we want to use the terms of Lavigne Delville (2011). The identification of the causes underlying the gender division of labour in fisheries or forestry research is an entry that remains unexplored, as recalled by Béné *et al.* (2016) and Mai *et al.* (2011) respectively. This lesson learned in Cameroon therefore deserves to be further documented and taken into account in project management and the facilitation of participatory processes so that no one is left behind.

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Panoramic view of Burera Lake in northwestern Rwanda

Inland waters biodiversity – What is it?

Water itself, as a physical resource, is not "biodiversity." Biodiversity is the life associated with it. Human impacts upon water (whether through pollution or the use of water directly to meet human needs) have impacts on inland water biodiversity – and biodiversity underpins the ecosystem services water provides to humans. "Water" and "inland water biodiversity" issues cannot be separated.

Read more: ***https://www.cbd.int/waters/inland-waters/default.shtml***

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Global overview of inland aquatic ecosystems

Inland aquatic ecosystems include a variety of natural (streams, rivers, floodplains, lakes, swamps, etc.) and manmade (reservoirs, rice fields, irrigation canals, etc.) inland water bodies. In spite of only covering about one percent of the total land surface inland waters are home to around 100 000 aquatic species, including for instance 10 000, or 40 percent, of all fish species.

Production cycles in inland aquatic ecosystems closely track seasonal changes in temperature and precipitation in the surrounding terrestrial environment which create a dynamic environment, where the availability of aquatic habitats are constantly changing and where nutrients are released in pulses; for aquatic organisms this divides the year into a period of intense production and a time of high mortality. The close linkages with the terrestrial ecosystems also imply that inland aquatic ecosystems are strongly affected by land use practices and are vulnerable to human activities. Since water is needed for a range of purposes, human settlements have always been located near inland water bodies.

These water bodies have, however, provided much more than just water, for example food, medicine and building materials are easily available because of the ubiquitous presence of living aquatic resources. But water is increasingly needed for a range of competing purposes and because people comprise an integral part of these ecosystems, many human activities have a direct or indirect impact on inland aquatic ecosystems which are under much more pressure from these activities than their marine counterparts. Fish and other living aquatic resources from inland waters nevertheless continue to constitute an essential role in people's livelihoods on rural areas in many parts of the world, especially in developing countries.

However, human activities have also created new aquatic habitats such as irrigation canals, rice fields and reservoirs, which to varying degrees supplement the services provided from the natural ecosystems.

Linkages between inland and marine ecosystems

Marine and inland aquatic ecosystems are interconnected. Some inland aquatic ecosystems are linked to the ocean ecosystems which they affect for example through nutrient inflows that causes the high productivity in many coastal fisheries, but also negatively by pollutants carried by the water. In addition, a number of marine fishery resources (anadromous and catadromous species, salmons, eels, sturgeons and shrimps) need inland water ecosystems including estuaries and lagoons to complete their life cycles.

Status

In developed countries, industrialization has led to increased pressure on inland waters and aquatic habitats degraded with negative consequences for the associated ecosystems. Many developing countries are now following the same path. Drainage, flood protection and extraction of water have led to the disappearance and fragmentation of aquatic habitats. It is likely that around 50 percent of the inland water area (excluding large lakes) has been lost globally. The reduction in area, combined with pollution and eutrophication, have caused the disappearance of species and changed the species composition in many places. The biodiversity of inland waters now appears to be in a worse condition than that of any other ecosystem. Land-based sources of pollution and degradation are also among the main sources of negative changes in the coastal zone. Excess fertilizers and livestock wastes in the runoff from farmland have caused eutrophication and harmful algal blooms. Deforestation in coastal mountains is a major source of excess sedimentation in the coastal areas, affecting coral reefs and seagrass beds.

However, the situation is gradually changing and many developed countries are trying to reverse the long standing adverse impacts and the international community and FAO with the Code of Conduct for Responsible Fisheries have acknowledged the value of understanding ecosystem processes, the bio-physical-chemical qualities of aquatic habitats, nutrient cycling and the interactions of non-target species in maintaining the productivity of fisheries.

Fisheries and Aquaculture topics. Inland aquatic ecosystems. Topics Fact Sheets. Text by Peter Manning. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 2006 15 09. [Cited 24 March 2019]. http://www.fao.org/fishery/

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Inland water ecosystem, complex of living organisms in free water on continental landmasses.

Inland waters represent parts of the biosphere within which marked biological diversity, complex biogeochemical pathways, and an array of energetic processes occur. Although from a geographic perspective inland waters represent only a small fraction of the biosphere, when appreciated from an ecological viewpoint, they are seen to be major contributors to biospheric diversity, structure, and function.

The Origin of Inland Waters

Only a relatively small fraction of the total amount of water in the biosphere is found as free water on continental landmasses. The oceans contain about 97.6 percent of the biosphere's water, and polar ice, groundwater, and water vapour take up another 2.4 percent. Thus, less than 1 percent exists as continental free water, which is generally referred to as inland water. In spite of this small percentage, inland water is an essential element of the biosphere. It occurs in a wide variety of forms and is inhabited by a diverse set of biological communities, quite distinct from the communities of marine and terrestrial ecosystems.

All inland waters originate from the ocean, principally through evaporation, and ultimately return to this source. This process is part of the global hydrologic cycle. A major feature of this cycle is that more water evaporates from the ocean than is directly precipitated back into it. The balance of water vapour is precipitated as rain, snow, or hail over continental landmasses whence it either evaporates into the atmosphere (about 70 percent) or drains into the sea.

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Lisa Rebelo and Matthew McCartney assure that Earth observation data offers hope for Africa's wetlands

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Botswana's Okavango Delta

Wetlands support millions of people around Africa. They include all areas that are permanently or frequently covered by water, and could be at the edge of a lake or the mouth of a river.

Wetlands offer a source of freshwater, fisheries, moist soil for farming and wild plants for food, construction and medicinal uses. They also help to control floods, maintain rivers in dry seasons, recharge groundwater and purify water.

But despite their importance, they remain among the most threatened ecosystems in the world. Between 1970 and 2015, inland and coastal wetlands both declined by about 35% globally. That's three times the rate of global forest loss. This is a huge loss to important flora and fauna and a critical loss to the many people who relied on them for their livelihoods.

In Africa, three things contribute to the decline of wetlands: growing populations, economic development and climate change.

For example, Lake Chad and Lake Victoria have both undergone significant change in recent years because of human activity. Lake Chad has shrunk by 90% partly because its water is being used for irrigation. Lake Victoria has experienced dramatic changes because of the introduction of Nile perch, sewage inflows and more sedimentation and nutrients from increased agriculture in the basin.

Part of the solution to protecting wetlands is through the creation of accurate inventories. Inventories provide essential information – like the type of wetland, exact geographic location and area –

needed for effective wetland management. But despite their importance, less than 35% of African nations have a national wetland inventory.

Gathering data from satellite based sensors, called Earth observation data, could offer a solution. These could feed into national inventories by providing valuable information on the status and physical characteristics of the Earth's wetlands.

Wetland inventories

Wetlands cover about 4.7% (1.15million km²) of Africa's continental area – about the same size as Ethiopia.

Covering 692 631km², freshwater marshes are the most extensive wetland type within the region. And about 65% of wetland area is located within the four largest river basins on the continent — the Chad, Congo, Niger and Nile river basins.

But there is considerable uncertainty in these figures. This is because countries either don't have them, or because they classify and create wetland inventories in different ways.

Comprehensive and up-to-date national wetland inventories are vital. A wetland inventory typically involves the collection and presentation of data on wetlands within a certain area. It covers attributes like; location, type, area, uses, ownership, physical characteristics, the organisms that live in it and the challenges it faces.

This information is essential for policy-making and management. It can also be used to establish baselines against which the effectiveness of policies can be assessed.

Developing a comprehensive inventory has its challenges, but increasingly available Earth observation data can help. By collecting data from satellites, we can describe many types of wetland over huge areas. The data are also more efficient and reliable as consistent methodologies can be applied nationally for a particular wetland type. They are also more affordable as many wetland areas are difficult to access on the ground.

Aside from flagging challenges to wetlands, this sophisticated data can be used to identify where things can be improved.

For example, the first global study to map mangroves consistently across time using Earth Observation data showed that 20% of the world's mangroves are found along African coastlines. Further assessment showed that over the past 20 years, about 6% in East and Southern Africa have become degraded, and about 2% in West and Central Africa. However, the majority of these – over 90% – have the potential to be restored.

Based on the global mangrove maps and associated tool, decision-makers are given the information they needed to determine where restoration can be attempted by identifying locations where mangroves once thrived, and where conditions are still suitable for restoration.

With this information policymakers can support communities so that they can then use local knowledge to manage the wetlands themselves.

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Source: The Conversation

http://theconversation.com/earth-observation-data-offers-hope-for-africas-wetlands-111123

How one gene in a tiny fish may alter an aquatic ecosystem.

Variations in a single gene in a tiny fish alter how they interact with their environment. The study represents a strategy for uncovering, and perhaps even predicting, the ecological implications of evolutionary change.


©Seth Rudmani

Threespine stickleback, which occupy lakes across the northern latitudes, are a tiny fish with an outsize impact on evolutionary research. A University of Pennsylvania (USA) biologist has found that a single gene affects the way they interact with their environment.

Credit: Seth Rudman

In a remote area of British Columbia's Vancouver Island, Kennedy Lake's deep blue waters stretch over 25 square miles. The lake is home to the threespine stickleback, a diminutive fish species that has provided rich fodder for evolutionary study.

These sticklebacks thrive in both marine and freshwater habitats and exist in most of the inland waters that dot the northern coasts of North America, Europe, and Asia. Significant to scientists, the species has a conspicuously variable trait governed by a single gene: the amount of bony plating, or "armoring," on their bodies.

Variations in this gene in this tiny fish species have the potential to alter the broader aquatic ecosystem, according to new research led by University of Pennsylvania postdoctoral researcher Seth Rudman. Fish with more armoring released more phosphorus into the water around them, the researchers found. Because phosphorus is such a key element in aquatic ecosystems, such a difference may have trickle-down effects on microbes, plants, and algae in freshwater or marine area.

"Genomics has played such a large role in advancing biological research in many, many disciplines and subdisciplines," says Rudman, the lead author on the work, who completed the investigations with colleagues during his doctoral studies at the University of British Columbia (UBC). "But the thing that I think about most and is the motivation for this study is how do we apply genomics to help us better understand ecosystems? In a way I view this work as a proof-of-concept that there are scenarios in which changes in individual genes can have effects on ecology."

Read more: https://www.sciencedaily.com/releases/2019/02/190206123751.htm

Journal Reference: Seth M. Rudman, Jared M. Goos, Joseph B. Burant, Kevin V. Brix, Taylor C. Gibbons, Colin J. Brauner, Punidan D. Jeyasingh. Ionome and elemental transport kinetics shaped by parallel evolution in threespine stickleback. *Ecology Letters*, 2019; DOI: 10.1111/ele.13225

Source: University of Pennsylvania. "How one gene in a tiny fish may alter an aquatic ecosystem." ScienceDaily. ScienceDaily, 6 February 2019 Copyright 2019 ScienceDaily

https://www.sciencedaily.com/releases/2019/02/190206123751.htm

2019 People & the Sea Conference. 24 – 28 June 2019 at the University of Amsterdam, the Netherlands

People & the Sea X: learning from the past, imagining the future
The Conference will take place from the 24th until the 28th of June 2019
Location: Roeterseiland complex, University of Amsterdam, the Netherlands

MARE People and the Sea Conference X:

The Centre for Maritime Research (MARE) is preparing its 10th international People and the Sea Conference that will take place in Amsterdam, The Netherlands, on June 25-28, 2019. This jubilee conference, which is preceded by a policy day (June 24, 2019) and flanked by other events, takes time as its theme. In full awareness of the major ongoing changes in the knowledge industry and how people interact with coasts and seas, we first delve into the past: what have we learned, and to what extent are we making the most of these learning opportunities? From whom should we be learning, and how do we engage in the learning process? To what extent are the insights of earlier generations of social scientists studying maritime affairs and coastal life still relevant to us? We then look forward and ask ourselves what social scientists can contribute to understanding and dealing with coastal and maritime challenges of the future. Topics range from the increasing intensity of storms and their implications for navigators and coastal inhabitants, to plastic pollution and conservation measures, the travails of travelers and the expansion of coastal cities, the fate of long-time inhabitants such as fishers and indigenous people, trends of coastal and ocean grabbing, the regulatory pursuits of planners, officials and scientists, and the ethics of technology. What perspectives and skills do we have to offer to science and the world; what are our strengths and where do our limitations lie?

Under the broad theme LEARNING FROM THE PAST, IMAGINING THE FUTURE, we investigate a myriad of matters in the context of six streams, each of which highlights a particular aspect of coastal and oceanic affairs.

Stream topics

1: *Making a living from coasts and oceans:*

From time immemorial, people around the globe have lived beside and upon the coasts and ocean, subsisting and earning their livelihoods. What are the ways in which they subsist and live? How do such livelihoods impact their culture, social organization, technology and innovations, management and governance structures, way of life, and worldviews? This stream will reflect upon how people in the past, now and in future live and interact with oceans and coasts. This stream is concerned with fishers, navigators, oil platform workers, tourism operators, wind farm mechanics and the whole range of other professions that engage with coasts and seas and with the communities that they belong to.

2: *Framing, knowing and dreaming coasts and oceans:*

How do we know the ocean and how has this changed over time? What are the knowledge-producing entities, routines and practices through which people study, reflect on and make sense of the ocean? What are the different types of knowledge that guide human interaction with the marine environment? How are they produced and communicated and why are some more influential than others in guiding people's behaviour? This stream will reflect on how we frame, dream and know oceans and coasts. It thus focuses on marine epistemologies ranging from scientific to everyday forms of knowledge production.

3: *Governing, steering and managing coasts and oceans:*

The world-wide domestication of coasts and oceans has led to a flurry of managerial activity at various scale levels and in multiple venues. Politicians, planners, legislators, environmentalists, business (wo-)men and scientists consider options to initiate blue growth, save fisheries, reduce pollution and protect the environment, and create a proper and legitimate regulatory environment. 'Stakeholders' sit on the other side of the table, participating, protesting, negotiating and undergoing. This stream is about ocean and coastal governance in all its manifestations and human faces, paying special attention to how it has changed and might change yet again.

4: Navigating, touring and experiencing coasts and oceans:

Oceans and coasts play important roles for the transportation of goods and people and provide attractive landscapes and experiences for tourists and recreationists alike. How do we navigate the ocean, and how do present trends differ from the past? What can we expect in future? This stream will reflect on how we use oceans and coasts for transport purposes and tourism experiences, and how these activities have an impact on environments, economies and societies. It thus focuses on a range of maritime mobilities and assesses the sustainability challenges and opportunities of their development at different scale levels and from other angles.

5: Appropriating, contesting and criminalizing coasts and oceans:

Oceans and coasts are subject to ever-rising conflicts over the distribution of space and resources. What is the nature of the ensuing contestations? How are the games played, who are the winners and losers? Oil spills, pollution, ocean and coastal grabbing and man-made disasters suggest disparities between those causing harm and those vulnerable to the consequences. In addition, oceans are a welcome host for illicit activities: smuggling and trafficking of goods and people, brazen acts of piracy, and illegal resource extractions. Securitization is a common response. This stream reflects the rough and dirty side of life along coasts and oceans and related trends of grand and petty politics.

6: Innovating, technologizing and tracking uses of coasts and oceans:

This stream focuses on the changing role of innovations and technology in the transformation of oceans and coastal areas, highlighting the role of business. Discourses of blue economy and blue growth are facilitated by development in fields such as robotics, monitoring and surveillance systems, energy systems and communication technology. We are interested in studies that address how material innovations and technological progress shift the balance between humans and their marine and coastal environments, and the implications this has for people in different stations of life. Contributions that re-examine the position of the marine social sciences in the paradigm of blue growth are also very welcome.

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Theme and deadline for next issue

The central role of biodiversity, protected areas and wildlife in sustainable development of Africa

Africa is immensely rich in biodiversity. Its living organisms comprise around a quarter of global biodiversity and it supports the earth's largest intact assemblages of large mammals that roam freely in many countries. Africa's biomes extend from mangroves to dryland forests and deserts, from the Mediterranean coast to the tropical rain forests and woodlands. Africa enjoys a highly varied weather conditions, from ice-capped mountains through temperate conditions in elevated landscapes to humid and sub-humid and dry lowlands and deserts.

Africa's biodiversity is crucial for the production of enough and nutritious food in the face of challenges such as climate change, emerging diseases, pressures on feed and water supplies and shifting market demands of the growing human population. Further, biodiversity contributes to maintaining forest ecological services and ecosystem health, addressing climate challenges and preventing and combatting land degradation and desertification, and is a key for the tourism development sector, recreation, cultural life and knowledge of societies throughout Africa.

For the purpose of this special issue of our journal, we focus on the current roles and potential of African biodiversity in food security and nutrition, livelihood enhancement, resilience building and socio-economic development. The emphasis is on protected areas, wildlife and sustainable development, but other contributions from initiatives and projects enhancing biodiversity and focusing on the role of biodiversity in sustainable development will be welcome. Included in the benefits of biodiversity conservation and sustainable use is the crucial role of wildlife and protected areas on which millions of people depend for their subsistence. In some cases, they benefit directly, through the consumption of food obtained from wildlife (plant and animal) resources or produced in or around protected areas. Others benefit from tourism and other income generating activities in/near protected areas, or benefit from grants associated with their roles in supporting the development and conservation of protected areas. Access to infrastructure and health care associated with supporting the protected area development is a noteworthy example.

For several decades, conservation and sustainable use of biodiversity have been the focus of considerable international attention and efforts, as demonstrated by the fact that it has been included in many Sustainable Development Goals (SDGs) and the Aichi Biodiversity Targets. There is growing international recognition that safeguarding biodiversity and managing natural resources sustainably must be priorities in national plans if we are to deliver nutritious food for present and future generations and achieve the African Union Agenda 2063.

To that end, the November 2018 UN Biodiversity Conference held in Sharm El-Sheikh, Egypt adopted, several novel decisions related to biodiversity, inter alia, on sustainable wildlife management[1], and on protected areas and other effective area-based conservation measures(OECM)[2]. The conference theme was, "Investing in biodiversity for people and planet." In addition, the key issues related to the sustainable wildlife management were also the major focus of the second Wildlife Forum that was organized by the Collaborative Partnership on Sustainable Wildlife Management[3] (CPW) and the African Union Commission[4] (AUC) on the margins of that Conference.

"Agenda 2063: The Africa We Want", a remarkable plan of

1 https://www.cbd.int/doc/c/3107/c146/7eace696d136253889d2e4e0/cop-14-l-11-en.pdf

2 https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-08-en.pdf

3 http://www.fao.org/forestry/wildlife-partnership/en/

4 https://au.int/

action to consolidate and position Africa's priorities and concerns in the SDGs, underscores the interconnectivity between people, the planet and the economy as it aims for prosperity and well-being, for unity and integration, with freedom from conflict and improved human security. The Agenda 2063 is aspirational in outlook, requires country-specific actions some of which are hinged on biodiversity, encouraging their integration and mainstreaming into core policy areas.

The next edition of Nature & Faune journal due in June 2019 will focus on the central role of biodiversity, protected areas and wildlife in the sustainable development of Africa. It invites authors to submit original contributions to the following overarching areas:

- Realising the genetic resource gains for food and agriculture from natural biodiversity conservation
- Sustainable use of wildlife resources (including nutritious food : fruits, bush meat, etc.), and medicinal plants)
- Protected areas management and development and livelihoods challenges (legal, social and economic considerations, prevention and mitigation of human wildlife conflicts, community-based engagements, gender aspects)
- Protected areas management and other effective area-based conservation measures: challenges and opportunities
- Roles of local, national, regional and international stakeholders in the management of protected areas and of biodiversity: challenges and opportunities
- The impact on biodiversity of REDD and REDD+ and other carbon sequestration and climate change adaptation and mitigation measures (Where indigenous forest cover is encouraged and biodiversity is enhanced)
- The impact of increased commercialisation and research on traditional fruits, vegetables and trees on the management of protected areas
- The impact of agricultural practices on biodiversity and in particular on their impacts on protected areas and wildlife
- Illegal trade in products from protected species
- Improving Africa's share of income from globally-marketed nature-based tourism
- The contribution and inclusion of products and services from protected areas in local and national accounting systems

This issue of the journal will offer a dedicated platform to concerned stakeholders in the broad society as well as institutional and individual specialists to share their thoughts and information about various projects and programmes and other initiatives related to sustainable use and conservation of biodiversity in Africa, from local to national, transboundary or regional level. Africa has a large number of projects with substantial outcomes and the overview of these projects and lessons learned from them will probably encourage interested people elsewhere in the world to connect with kindred efforts in the region. Case studies of the projects are especially encouraged.

Please send your manuscript(s) by email to the following addresses:

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Deadline for submitting manuscripts for the next issue is 25 April 2019.

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