THE INFLUENCE OF FLOODING ON FISH SPECIES DIVERSITY AND FISHERIES PATTERNS IN THE FLOODPLAIN LAKES OF LOWER TANA RIVER, KENYA

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DECLARATION

I declare that this thesis is my original work and has not been submitted elsewhere for award of any other degree. Where work authored by other people has been used, full acknowledgement has been given and referenced accordingly.

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DEDICATION

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	–	Analysis of Variance
BMU	–	Beach Management Unit
CGTR	–	County Government of Tana River
CIDP	–	County Integrated Development Plan
KENWEB	–	Kenya Wetlands Biodiversity Research Team
KeFS	–	Kenya Fisheries Service
KWS	–	Kenya Wildlife Service
NMDS	–	Non-metric Multidimensional Scaling
NMK	–	National Museums of Kenya
RGS	–	River Gauging Station
WIO	–	Western Indian Ocean
WIODER	–	Western Indian Ocean Deltas Exchange and Research Network
WRA	–	Water Resources Authority

ABSTRACT

Floodplain fisheries resources are under frequent disturbances due to seasonal variation in flood peaks and intensity. This study investigated the influence of flooding on fish biodiversity and fisheries patterns in the floodplain lakes of lower Tana river, Kenya. Fish diversity and abundance in the floodplain lakes were assessed in relation to changes in space and flooding period. Influence of patterns of hydrological connectivity and water quality on fish assemblages were determined. The impacts of seasonal flooding on annual fishing pattern and governance in the Tana River delta lakes was also investigated. Fish was sampled by using monofilament gillnets, and six water quality parameters (pH, temperature, dissolved oxygen, electrical conductivity, salinity and water clarity (turbidity)) recorded using multi-metre probe (YSI Model 85/50) and turbidity tube at three sampling points in each lake in pre-flood, during flood and post-flood period. Thirty-two fisher-folk were interviewed across the entire study area using semi-structured questions. A total of 2982 fish comprising 15 species in 9 families, were captured. The predominant species in the floodplain lakes were Zanzibar barb (*Enteromius zanzibaricus,* 41%), Gregori's labeo (*Labeo gregorii,* 11%), Red-fin robber (*Brycinus affinis,* 8%) and Sabaki tilapia (*Oreochromis spirulus,* 7%).Lake Gumba and Kongolola had the highest Margalef's richness index (2.06 and 2.07) respectively. Shannon Weiner diversity index was highest at Lake Dalu (2.16) while fish found at Lake Shakababo was least diverse (1.67). Two-way ANOVA on transformed data showed a statistically significant effect of sampling period on fish species abundance ($p<0.01$). Non-metric multidimensional scaling (nMDS) plots showed a high similarity of fish assemblages during floods in the floodplain lakes. Pearson's correlation matrix showed fish abundance was positively correlated with increasing dissolved oxygen ($p<0.01$), and water depth ($p<0.05$). The length-weight regression lines suggested normal fish growth patterns and the calculated relative condition factors indicated fish in the floodplain lakes were generally in good body condition. Although hydrological connectivity showed inconsistent association with fish species composition and abundance, findings of this study suggested that preservation of river-floodplain connectivity was important in maintaining fish species diversity in the floodplain lakes. Fisheries patterns indicated that communities did not entirely depend on fishing. Fisheries governance structures existed; however, they essentially were non-functional due to seasonality of floodplain lakes.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Tana River arising from the Aberdares and Mount Kenya forests has a catchment area of 130,000 km², which is approximately 23% of Kenya's land area. It flows for approximately 1000km from the mountains of central Kenya to the Indian Ocean. Itis Kenya's longest watercourse with an extensive basin and a wetland-rich flood plain (MEMR, 2012). The river periodically overflows its banks at the Delta providing water and important nutrients to floodplain and estuarine ecosystems (RAMSAR, 2012; Leauthaud *et al*., 2013) and is among the major estuaries and deltas of the Western Indian Ocean (WIO) region (Diop *et al*., 2016). The delta is of national, regional, and global importance for biodiversity conservation (Mireri, 2010); a second most important deltaic ecosystem in East Africa (RAMSAR, 2012).

It is widely acknowledged that rivers, their estuaries and deltas are biologically diverse and complex systems that support many livelihoods through provision of important goods and services, such as food and transport (Darwall & Vie, 2005; Welcomme, 2008; Leauthaud *et al*., 2013; Diop *et al*., 2016; Duvail *et al*., 2017). Studies have shown the occurrence of diverse habitats within the Tana River delta (Njuguna & Mburugu, 1992; Hamerlynck *et al*., 2010a; Samoilys *et al*, 2011; Diop *et al*., 2016). Indeed, the delta's mangrove forest ecosystem are important habitat and nursery ground for juvenile fish and shrimps and is important in sustaining the productivity of Ungwana Bay, described as Kenya's most productive coastal fishing ground (Diop *et al*., 2016). Like any other floodplain ecosystem, Tana deltas' high productivity is maintained through a dynamic balance revolving around frequency, extent, and duration of flooding (Mireri, 2010).

Seasonal and inter-annual variation in flooding has intense effects on fisheries and livelihoods of the deltaic communities (Duvail *et al*., 2017a). Seasonality affects abundance and distribution of floodplain fisheries. Furthermore, seasonal changes in hydrological connectivity contribute to spatial heterogeneity in floodplains resulting in high alpha, beta, and gamma diversity (Amoros & Bornette, 2002). This intermittent connectivity between the rivers main course and floodplain water bodies is critical in providing the diverse habitats required by floodplain fish for spawning and foraging and directly impacts fisheries production and utilization (Hamerlynck *et al*., 2011).

Nevertheless, floodplain fish community assemblage is a result of interaction between regional (rivers main course dispersed through flooding) and local (both biotic and abiotic) forces. At the floodplain landscape, water temperature, turbidity, nutrient content, and substrata composition are major habitat components influencing these biodiversity patterns (Amoros & Bornette, 2002), together they induce fish movement between floodplain wetlands (Winemiller & Jepsen, 1998a). These movements combined with the patchiness of floodplain enforce a meta-community framework, a concept that explains dispersal and interaction of multiple species in an ecosystem. Welcomme (1979) noted that fish are inherently diverse and variations in fish biomass are strongly affected by flood duration and volume. Similarly, Hamerlynck *et al.*, (2011) showed that fish production peaks when floods recede, and catchability improves. It can therefore be concluded that fisheries utilization in floodplains is affected by flooding regimes.

Floodplain fishes are an important source of animal protein, an alternative to livestock products, that is easily accessed by deltaic communities, thereby forming an important source of livelihood (Terer *et al*., 2004; Hamerlynck *et al*., 2011, 2017; Duvail *et al*., 2017a). The aim of this study was to determine to identify the patterns of hydrological connectivity and water quality characteristics in the floodplain wetlands and their influence on fish diversity and abundance, in relation to changes in space and season and establish the annual fishing pattern and the effect of prevailing regulatory regime and seasonal flooding in the River Tana delta.

1.2 Problem statement

Lateral connectivity of the main course of rivers and the floodplain wetlands has been shown to be critical in maintaining important habitats for fish species**,** such as sites for spawning, rearing young (nursery) and for foraging (Bunn & Arthington, 2002; Hurd *et al*., 2016; Duvail *et al*., 2017b). The great diversity of freshwater and brackish water fishes maintains a vibrant fishery for local communities and supports a diverse food-web in the flood plains (Seegers *et al*., 2003). Despite this several gaps of knowledge exist in ecology and behaviour of floodplain fish. Furthermore, many floodplain species are still listed as data deficient under the IUCN Red List of Threatened Species, while others continue to bear uncertain taxonomic status (Nyingi, 2013).

In the Tana River delta, fishing is a traditional form of livelihood, which ranks highly among the deltaic communities, only second to shifting cultivation (Terer *et al*., 2004). Fishing in the delta has attracted both local communities including Pokomo, Orma, Wardei and immigrant fishing communities, such as Luo and Luhya who practise small-scale fishing for domestic consumption and commercial purposes (Duvail *et al*., 2012a). The prevailing point of view is that fish in the river and floodplain water bodies is a common resource available for exploitation by all. According to Duvail *et al.*,(2012), fishing among other major economic activities in Tana River delta is dependent on the flood regimes which occur twice a year. The dwindling fish and fisheries resources have been mainly attributed to reduced magnitude, duration and extent of flooding, growing demand due to local population growth, use of inappropriate fishing gear, poorly regulated fishing leading to overfishing and siltation of oxbow lakes (Mireri, 2010). Prolonged dry seasons and insufficient flood water to inundate the floodplain lakes reduce the critical spawning areas for fish. Despite fish being an important food resource to all deltaic communities, fishery variation in wet and dry season is still not well understood. No studies have been carried out on the role of flooding in sustaining Tana Delta floodplain fish biodiversity and fisheries.

1.3 Justification

Tana River is the longest river in Kenya and the second longest in East Africa, after the Rufiji River in Tanzania. The delta is an important socio-ecological landscape (KENWEB, 2011) where ecosystem services are directly linked with biodiversity functions (composition, structure, and function) and human wellbeing (Hamerlynck *et al*., 2010b). Due to its great importance and unique diversity of fauna and flora, the Tana Delta was listed as a Wetland of International Importance under the Ramsar Convention in 2012 (RAMSAR, 2012).

Studies on equally important floodplains in Africa such as lower Gambia River floodplains in West Africa (Louca *et al*., 2009), the Okavango delta in Botswana (Mosepele *et al*., 2009; Mosepele *et al*., 2012a;) and lower Rufiji floodplain lakes (Hamerlynck *et al*., 2011) have shown that floods affect fish biodiversity and distribution in the floodplains. However, there has been no similar studies carried out to establish the links between floods and fisheries in the Tana Delta. Fish biodiversity studies in the delta, have been limited to taxonomic identification and diversity (Seegers *et al*., 2003).

Some research studies in the floodplains have suggested that a reduction in its fishery productivity is primarily linked to the loss of lateral hydrological connectivity with the river. Further it has been suggested that floodplain fishes may have evolved life history strategies, behaviour, and physiology that enable them to benefit from access to floodplain wetlands (Junk, *et al*., 1989).Wetlands in river floodplains act as nursery and foraging areas for young fish, and refuge for many aquatic vertebrates, including amphibians, reptiles and fish.

Furthermore, the aquatic vertebrates tend to migrate onto the floodplain to exploit newly available habitats and food resources. Fish species assemblages in the floodplain wetlands can be expected to change with flooding regime and seasonal variation (Araújo *et al*., 2009a). In addition, the seasonality of floodplain habitats and fisheries resources are a key factor affecting many aspects of life of the people living in the delta (McConnell, 1987). These seasonal impacts are further compounded by changing abiotic conditions in floodplain wetlands (Winemiller & Jepsen, 1998b).

1.4 Overall objectives

To assess the impact of river flooding on fish biodiversity and abundance, and the patterns of utilization of fisheries resources by local communities in the River Tana Delta. The specific objectives were;

i. To identify the patterns of hydrological connectivity and water quality characteristics in the floodplain wetlands

ii. To determine fish diversity and abundance in the floodplain wetlands in relation to changes in space and season.

iii. To establish the annual fishing pattern and the effect of prevailing regulatory regime and seasonal flooding in the Tana River delta.

1.5 Research hypothesis

i. Fish community assemblages are unlikely to change with water quality characteristics of different flood plain lakes.

ii. Seasonal variation in flooding and hydrological connectivity has no effect on fish diversity, abundance, and distribution in the floodplain lakes of the Tana River Delta.

iii. Fishing activities are not influenced by flooding regime and are not regulated by fisheries laws.

1.6 Research questions

i. How does the hydrological connectivity of the floodplain wetlands affect fish diversity and abundance?

ii. How does fish diversity in floodplain wetlands of Lower Tana vary with space and season?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Significance of African Deltas and Floodplains

Floodplains have been defined as areas periodically inundated by lateral overflow of rivers or lakes but also direct precipitation and groundwater (Junk *et al*., 1989). Conversely, the resulting physico-chemical environment causes the biota to respond by morphological, phenological, anatomical, physiological and or ethological adaptations and produce characteristic community structures. To contrast earlier definitions that characterized floodplains as permanent lentic and lotic habitats, Junk *et al*. (1989) further termed floodplains as “aquatic/terrestrial transition zone (ATTZ)” to explain the alternation between aquatic and terrestrial environments. Bayley, (1989) supported this argument noting that a floodplain is part of the river ecosystem that is regularly flooded and dried, representing a type of wetland. Welcomme, (2008) added that floodplains in their natural state are usually covered with flood resistant macrophytes or by woodlands or forests even though man has systematically adapted them for various forms of agriculture and livestock keeping.

Regular flooding characterizes all floodplain ecosystems. Moving littoral, an inshore zone from the water's edge to a few meters’ depth, is recognized as the most active in floodplains (Junk *et al*. 1989 cited in Bayley, 1989) as the water traverses during flooding. This activity provides excellent nursery grounds for fish and optimal environment for growth of macrophytes, resulting in high primary productivity. Junk *et al*. (1989) contended that while detritivores, herbivores and or omnivores support large fish in the main river channel, high yields are supplemented by the floodplain ecosystem where production is high. Furthermore, river-floodplain biota seems to be r-strategists, with high annual growth and mortality rates, a life history strategy that enables them to quickly colonize large areas. On the other hand, the work by Bayley (1989) observed that as the water level recedes, decomposition processes increase relative to production, a phenomenon that generally reduces dissolved oxygen.

Despite the reported flood-related fatalities in Africa (Di Baldassarre *et al*., 2010), floods are ecosystem engineers that support many ecosystem functions and human wellbeing. This is well documented in early research; Junk *et al*., (1989) explained that indeed the flood pulse was not a disturbance and instead, conventional mechanisms adopted by man to control floods were themselves a disturbance. For example, the extensive floodplains of Sub-Saharan Africa (Table 1) add up to close to 30 million hectares of land that have huge agricultural potential (Spate Irrigation Network Foundation, 2016). Alongside adapted crop agronomy and pastoralism, fishery is another major use of floodplains. The importance of floodplains in sustaining fisheries cannot be emphasized further, for example the production potential of African floodplains has been estimated between 40-60 kg/ha/6 months (Welcomme, 1975 cited in Welcomme, 1976).

Turpie (2000), discussed how communities in the floodplains of Rufiji almost entirely derived their livelihood from flood associated ecosystem goods and services. More recently, (Duvail & Hamerlynck, 2007)) supported this in their study in Rufiji delta. Here, communities perceived floods as a blessing, necessary for the sustenance of floodplain fertility. As a determinant to floodplain productivity, floods support vital floodplain livelihoods through farming systems such as forestry, fisheries, wildlife and, livestock keeping. While it is true that floods and floodplains offer invaluable ecosystem services that directly contribute to human wellbeing, governments and associated development partners are always in constant efforts to exploit them for commercial purposes (Maingi & Marsh, 2002; Duvail & Hamerlynck, 2007; Duvail *et al*., 2012b).

Table 1: Distribution of major drainage systems and respective floodplains in Africa

Drainage system / geographical area	Area km^2	Major floodplains /comment /reference
Nile system	93,000	Sudd, Kagera basin, delta in Alexandria
Democratic Republic of Congo basin	70,000	Middle Congo depression, Kamulondo, Malagarasi
Lake Chad system	63,000	Chari and Logone River system
Niger/Benue system	38,900	Niger central delta, Benue River
Zambezi system	19,000	Kafue flats, Barotse plain, Liuwa plain
Western system	19,000	Floodplains along the Senegal (excluding delta), Volta and Ouémé
Eastern systems	9,270	Kilombero, Rufiji, Tana
Southern system	7,500	Okavango, Pongolo, Limpopo
Gash river	3000	Inner delta in Sudan

Source: Spate Irrigation Network Foundation: Flood based farming systems in Africa

2.2 Fish growth and biomass relationships in tropical floodplains

Floodplain inundation avails food resources that benefit many river-floodplain fish assemblages (Bayley, 1988). The predictable annual flood pulse drives massive fish production in some of the world's most productive freshwater fisheries. Timing for sexual maturity and reproduction in floodplain fish communities is therefore linked to food availability, habitat diversity and accumulation of energy reserves because of flooding (Welcomme, 2008). The production of floodplain fisheries is thus determined by the reproduction and growth rates of individuals within the population and by their mortality rate. These are further important in shaping the population dynamics over time, such as biomass, density, and size-frequency distribution (Balcombe *et al*., 2007). As a result, growth studies are an integral part in sustainable fisheries resource management since they explain estimates of production, stock size, recruitment, and mortality of fish populations. Several dimensions exist for measuring fish growth. However, measurement of length and conversion to weight is considered the easiest (Bagenal, 1978). In fish biology the length – weight relationship is represented by;

$w = al^b$ …………………………… equation (i)

Where *w* is weight, *l* is total length and *b* is an exponent between 2 and 4 related with the form of individual fish growth (Bagenal, 1978).

A logarithmic transformation of equation (i) gives a straight line with the equation;

$\log w = \log a + b \log l$ …………equation (ii)

Log weight is first plotted against log length and regression coefficients *a* and *b* determined. Bagenal (1978) explained that these coefficients differ not only between species but also between stocks of the same species. Moreover, there may also be differences in the relationship due to season, maturity, and sex of the fish.

The index of wellbeing calculated as the condition factor, *Kn*, is a quantitative indicator of physiological state of fish in relation to its welfare. It reflects the recent feeding conditions of fish and provides information when comparing different populations (Muchlisin *et al*., 2010). Therefore, it assumes that the heavier fish of a given length are in a better condition. Thus, when a fish is growing isometrically its weight (*w*) will increase in relation to its cubic length (l^3), theoretically represented by;

$Kn = \frac{100w}{l^3}$ ………………………………equation (iii)

Equation (iii) denotes Fulton's Condition factor and is appropriate when fish lengths are the same or the range is very small. On the contrary, if the length range is large, equation (iv) should be used;

$$Kn = \frac{100w}{l^b} \text{ ……………………………… equation (iv)}$$

When b is equal or close to 3 fish growth is said to be isometric where fish becomes more robust with increasing length. Values of b lower or greater than 3 indicates an allometric fish growth. Allometric fish are said to become thinner with increase in length. The expected range for most tropical fish species is $2.5 < b < 3.5$ (Froese, 2006).

2.3 Hydrological connectivity in floodplains

Not only do floods influence fish diversity and distribution in floodplain wetlands through recruitment, and ecosystem productivity but also physico-chemical parameters. It has been shown that floods may impact at floodplain landscape level while at local scale, abiotic factors associated with the origin of flood and *in-situ* activities impact on fish assemblages (Louca *et al*., 2009). Conversely, floods have been shown to increase similarity within and between floodplain habitats (Thomaz *et al*., 2007), and therefore correlation of biotic and abiotic factors to fish species diversity during flood peaks may not be significant for different floodplain wetlands.

Water quality characteristics easily determined in the field are dissolved oxygen (mg/L), temperature (°C), electrical conductivity (µS/m), pH, salinity, and water clarity (cm). Dissolved oxygen is an essential requirement for aquatic organisms and has been termed a barometer for river health (Kannel *et al*., 2007). Many organisms can only survive in a specific range of pH. Temperature affects availability of oxygen concentration in the water besides its effects in rates of biochemical processes.

Equally, it has been discussed that electrical conductivity, a useful indicator of water quality, increases with increased organic matter degradation and dissolved ions (Araújo *et al*, 2009b). It is therefore an important variable in understanding habitat characteristics in floodplains. Water depth and volume along with turbidity, both determined by incoming flood water, may indirectly influence EC, or directly impact on fish community assemblages by increasing predation risks and genetic diversity of isolated fish populations.

2.4 Fish species diversity and fisheries of the Tana River Delta

Tana River Delta, its oxbow lakes, and wetlands, provide unique habitats and spawning area for fishery resources. The delta sustains commercial and subsistence fisheries that are key to survival of many deltaic communities as source of food, income, and employment. Fisheries in the delta is majorly from capture fisheries and its availability and importance can further be explained by the existence of immigrant fishers, Luhya, and Luo, who are traditionally fishing communities from western part of Kenya (Terer *et al*., 2004). Fish communities of the delta are subjected to large seasonal fluctuations depending on the amount of water carried to the Indian Ocean from the Tana River catchment (Seegers *et al*., 2003), normally after the flood peaks in May and November. A checklist by Seegers *et al.*, (2003) lists the following fish nine families in Lower Tana Mochokidae, Protopteridae, Claroteidae, Schilbeidae, Cichlidae, Alestidae, Clariidae, Mormyridae and Cyprinidae.

Earlier studies recorded 30 species in lower Tana (Seegers *et al*., 2003) and currently 44 species have been recorded by the National Museums of Kenya (NMK) Ichthyology collection. Most of these species have been recorded or sampled from the main river channels, oxbow lakes, and other wetland types in the floodplain. In addition, these studies point to possibility of endemism of some species and the need to conduct further studies to answer the uncertainty on the taxonomic status. However, poorly regulated fishing and use of inappropriate fishing gear, population growth and siltation of oxbow lakes are among the major threats attributed to the dwindling fisheries of the delta (Terer *et al*., 2004; Mireri, 2010). Against this backdrop, compounded by the reduction in flood peaks, many livelihoods are currently threatened (Leauthaud *et al*., 2013b).

2.5 Tana River Delta - a Wetland of International Importance

Tana River Delta, a mosaic of coastal deltaic and floodplain ecosystem, is a flood dependent ecosystem rich in biodiversity and supports many livelihoods. Among the traditional livelihoods supported include recession agriculture, forest users, fisheries and livestock keeping. Covering approximately 163,600 hectares, the delta is also home to Tana River Primate Reserve, managed by Kenya Wildlife Service (KWS), that is habitat to the two endemic primates; Tana River red colobus (*Procolobus rufomitratus rufomitratus*) and the Tana River mangabey (*Cercocebus galeritus*) (Hamerlynck *et al*., 2012). Over 650plant species have been identified including the endangered species of legume *Cynometra lukei* and *Gonatopus marattioides* in the family Fabaceae and Araceae, respectively. (Luke, 2011 cited in Duvail *et al*., 2012b). The patches of riverine forest that grow along the smaller river tributaries are also characterized by the presence of numerous endemic plant species (Luke *et al*., 2011 cited in Duvail *et al*., 2012). The delta is also an Important Bird Area (IBA), habitat to more than 345 species of birds including the threatened Basra reed warbler and Tana River cisticola (*Cisticola restrictus*) that is endemic to lower Tana River (BirdLife International 2018). Consequently, the delta supports one of the very few breeding sites for colonial water birds in Kenya.

Towards the shoreline, the delta extends into the nutrient rich Ungwana Bay that supports the most valuable offshore fisheries in Kenya (Samoilys *et al.*, 2011) and one of the largest stands of mangrove forests in East Africa (Diop *et al.*, 2016). Despite its importance in biodiversity conservation and uniqueness as a socio-ecological landscape (KENWEB, 2011), the delta has continued to experience dramatic changes in its hydrology. Like any other deltaic ecosystem, Tana Deltas lifeline is dependent on the frequent flooding regimes. One major notable impact has been the heavy damming of the Tana River on its upper basin (Maingi & Marsh, 2002), five hydropower dams built in the 1970s and 1980s to provide electricity to Kenyans halved average flooded surface area in the floodplain. The effects have been well documented (Maingi & Marsh, 2002; Lebrun *et al.*, 2010; Leauthaud *et al.*, 2013b). In the wake of all these challenges, multidisciplinary studies were initiated by multi-institutions and international team of wetland experts for the purpose of providing high quality data on wetlands (KENWEB, 2011). These culminated in Tana River Delta being designated as a Wetland of International Importance in October 2012 (Ramsar, 2012).

2.6 Fisheries resource management and governance in Tana River Delta

Historically, fisheries in Kenya had been managed locally using community user rights. After independence in 1963, the Kenyan government took over the management of fisheries resources, implementing a top-down approach with little input from stakeholders and local custodians of the fishery resource. The Fisheries Act of 1989 was marked by a lack of enforcement capacity as well as overlapping administrative mandates between various authorities for fisheries, wildlife protection, and forestry. Today, all capture fisheries in Kenya are managed by the Kenya Fisheries Service (KeFS). The service is vested with an overall responsibility for fisheries administration, which includes: co-ordination of development of policy, legal, regulatory and institutional framework for the fisheries industry and the blue economy; setting standards and preparing guidelines to ensure fish quality and safety; fishing licensing; and providing technical assistance for fisheries development to various stakeholders in accordance with Fisheries Management and Development Act No. 35 of 2016 (GoK, 2016).

In response to the decline in fish stocks and decreasing aquatic biodiversity, Kenya opted to promote co-management of fisheries resources. Legal Notice no. 402 of the Fisheries Act (Cap 378) contains the Fisheries (Beach Management Units) Regulations 2007.The administrative structure of BMUs consists of assembly members, executive committee, and sub-committees. Membership to BMUs is open to all fisheries stakeholders. The aim of forming BMUs at various fish landing site was to integrate local and national management rules, and optimizing the use of both traditional knowledge and scientific evidence (FAO, 2017).Further, BMUs were expected to help alleviate poverty and improve welfare and livelihoods of members, marketing and development of landing sites in partnership with the government and other development partners. They were also mandated to prevent or arbitrate conflicts in the fisheries sector within their jurisdiction. Each BMU was expected to formulate its own binding by-laws and action plans that govern day to day activities. BMUs were responsible for fisher vetting as well as implementing monitoring, control, and surveillance (MCS).

BMUs were initially registered as Community Based Organizations (CBO) through the State Department for Social Services. However, such registration was social based and could not give BMUs the legal mandate to operate their fisheries co-management functions and hence the issuance of registration certificates by the Director of Fisheries, Ministry of Fisheries (Kanyange *et al*., 2014). Three BMUs at Ozi, Kipini and Moa, were operational in Tana River County at the time of this study.

Many reasons abound the challenges facing fisheries resources sector. However, devolution of certain fisheries management and governance functions to County Governments while leaving BMUs under the relevant national government ministry had further compounded the challenges. The establishment of BMUs and active community participation was in line with Aichi Biodiversity Goal B target 6 to ensure that by 2020 all fish and invertebrate stocks and aquatic plant resources are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species (Convention on Biological Diversity, 2010). This target also aimed to ensure that development of fisheries and its exploitation had no significant adverse impacts on threatened species. Further, it ensures that vulnerable ecosystem and the impacts of fishing on stocks, species and ecosystems are within safe ecological limits. To achieve this, BMUs were enacting by-laws to prevent overfishing and regulating destructive fishing techniques. In addition, BMUs were directly working towards implementing Strategic Goal E through participatory planning, knowledge management and capacity building specifically recognizing the role of women and youth.

2.7 Tana Delta Fisheries in the context of Blue Economy

Fisheries as a component of the renewable natural resources sector play an important role in Kenya's national economy. The fisheries and aquaculture sector contributed about 0.8% to the Gross Domestic Product (GDP), providing direct employment opportunities to over 500,000people and supported over two million people indirectly (KMFRI 2017).The sector supported livelihoods for about 2.3 million Kenyans involved mainly in fishing, fish processing, trade and micro-enterprises in associated industries and other ancillary activities. In addition, fish contributed to food and nutritional security (FAO, 2018), a source of protein consumed directly by small-scale fishers at household level.

The estimated annual economic value of goods and services in the marine and coastal ecosystem contributing to blue economy in the WIO was over US$22 billion, with Kenya's share slightly over US$4.4 billion (20%) and with the tourism sector taking the lion's share of over US$4.1 billion (FAO, 2018). The blue economy in the Tana Delta included several artisanal and commercial scale fishery activities, as well as wildlife tourism, aquaculture, boat, and net making and basketry.

Fishing in the delta was carried out at small-scale business levels, targeting regional and local markets and restaurants. At that time, aquaculture was least developed activity, although with a great potential (FAO, 2017). Tana Deltas freshwater fisheries is therefore an important source of livelihood and an integral part of local and national economy. In 2013 – 2014, Tana River County overall fishery and aquaculture production amounted to over 1073 metric tons of fish harvest valued at approximately USD 117 230 (Table 2).

Table 2: Fishery statistics (2013 – 2014) in Tana River County

	2013	2014*
Number of persons engaged		
Number of fishermen	1,252	1,600
Number of fishing families	1,275	1,578
Number of fishing ponds	975	975
Area of fishponds (m^2)	300	300
Fish catch by species of (Tonnes)		
Tilapia	70	18
Clarias	8	6
Protopterus	8	4
Catfish	48	8
Marine species	882	105
Other fish species	12	9
Fishing effort (hours)	2	2
Number of landing beaches	4	4
Fish gear used		
Fishing nets	965	1030
Hooks/links	6,300	6,147
Traps	12	15
Motorboats	135	150
Dhows	41	48
Canoes	21	25
Marine seine nets	33	35
Fish harvest		
Weight (Kg)	922,193	150,923
Value (KES)	103,621,845	13,608,497

Source: County Statistical Abstract Tana River County, KNBS 2015.

2.8 Summary of research gaps

- No study exists on the effect of lost lateral connectivity of River Tana main course and associated floodplain wetlands to the fish biodiversity and distribution. Connectivity is fundamental in maintaining important habitats for fishes including sites for spawning, nursery, and foraging.
- There is still limited understanding of diversity and abundance of several fish species that inhabit the floodplain wetlands of Tana River. Taxonomic knowledge is also limited with many species being listed as data deficient and of uncertain taxonomic status (Seegers *et al*., 2003; Nyingi, 2013).
- Like other major economic activities in the delta, fishing is dependent on the flood rhythms which occur twice a year. Despite this, fishery variation in wet and dry season is still not well known.
- No studies have been done on the role of flooding in sustaining floodplain fish biodiversity and fisheries.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

This study was carried out in River Tana Delta in Tana Delta Sub-county of Tana River County. The delta lies on 02° 30´S 40° 20´E with its apex north of Garsen at Lake Bilisa and a base of 50 km stretch along the beach at Ungwana Bay on the western shores of the Indian Ocean (Figure 1). At Garsen, the river divided into two major brooks: Oda flows southwards while Matomba flows eastwards. These two brooks split further into tertiary branches forming an extensive network of channels that inundates during flooding.

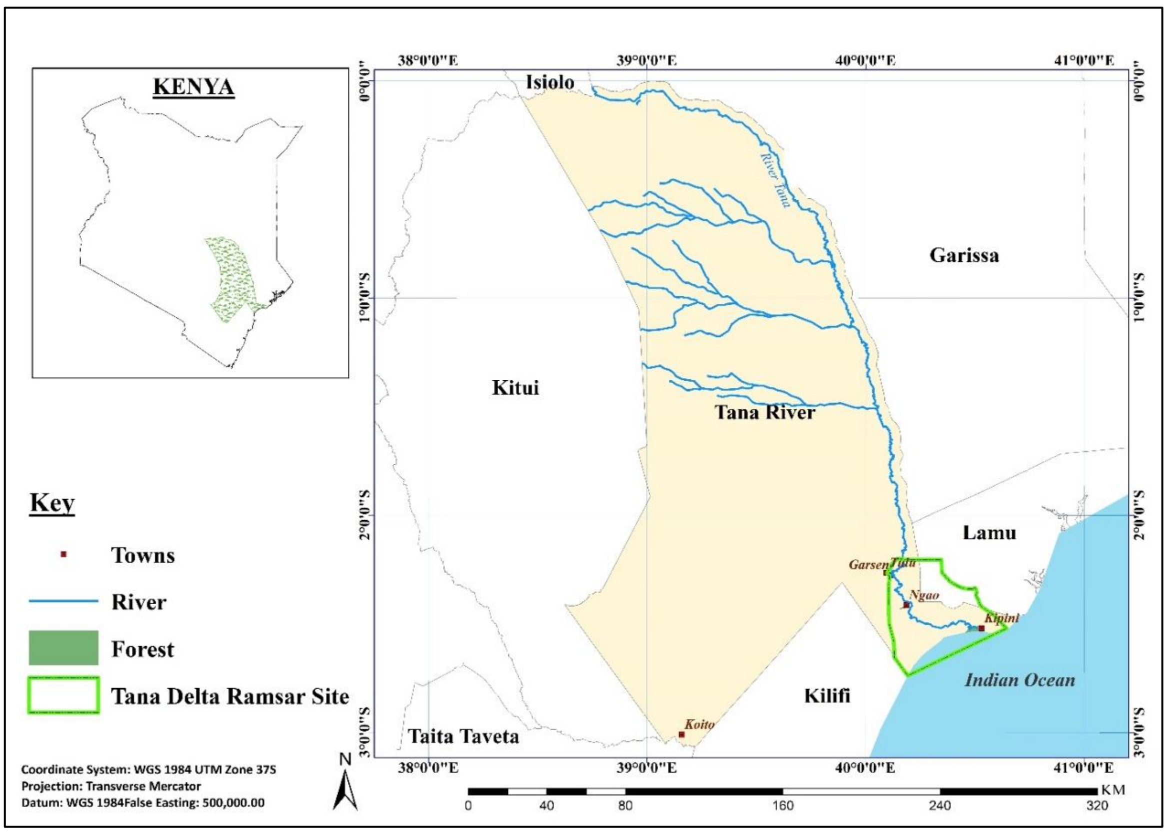

Figure 1: Map of Tana River County showing Tana Delta RAMSAR Site

3.1.1 Physiography

The entire lower floodplain was covered by alluvial sediments, transported, and deposited during the annual flooding of the river (Diop *et al*., 2016). The delta comprises of diverse habitats, including riverine forest, open grasslands, woodland, bushland, shallow lakes, mangrove forests, sand dunes, beaches, estuaries, and coral reefs. Riverbanks are characterized by riverine forests and doum palm (*Hyphaene thebaica*). Tana River estuary at Kipini is covered with mangrove forests containing eight of the nine mangrove species found in the Western Indian Ocean shoreline (Diop *et al*., 2016). The dominant mangrove species in the area include Cannonball mangrove (*Xylocarpus granatum*), Grey mangrove (*Avicennia marina)*, Red mangrove (*Rhizophora mucrunata)* and Spurred mangrove (*Ceriops tagal*).

The floodplain is characterised by shallow oxbow lakes and many wetlands resulting from cut-off meanders of the River Tana. The oxbow lakes and cut-off are recharged through ground water seepage or by the periodic flooding. Major wetlands comprised of basins of oxbow lakes where water remained for most of the year to include lakes Bilisa, Shakababo, Kongolola, Kitumbuini, Dida Warede, Harakisa, Moa and Kenyatta (Mireri, 2010).

3.1.2 Climate and hydrology

Tana River flows through different eco-climatic zones and is supplied with water from streams originating in many sub-catchments along its 1000km stretch to the Indian Ocean. Annual precipitation ranges from 500mm in lower Tana basin to 1600mm in upper parts of the basin. In Tana delta, precipitation is low, bimodal and quite erratic, and fluctuated between 300mm to 500mm annually while temperature averaged 28°C (Leauthaud *et al*., 2013).A dense network of headwater streams originating from different sub-catchments along the River Tana valley drain into the main river channel. The river then flows through several impoundments, the largest of which was Masinga Dam covering an area of 156km^2. The dams were constructed in the 1980s for trapping silt and storing water for recharging the hydropower dams located downstream.

Tana River floods seasonally primarily due to heavy precipitation in its main catchment areas on Mt Kenya and the Aberdare Mountain Ranges. The long-term average discharge of the river at the gauging station (4G02) at Garsen bridge is estimated to be approximately 110 m^3/s (WRA, 2012). Long-term trends indicate that flooding normally peaks during and shortly after the long rains in April and May (Figure 2). However, moderate flooding can extend to June in the lower Tana. A smaller but sharp peak of flooding follows the short rains in November and December (Leauthaud *et al*., 2013). The timing, extent and duration of the flooding varies greatly from year to year. In the previous year, 2017, the peak river discharge at Garsen Bridge was 130 m^3/s and occurred at the end of May. The discharge was generally below the long-term average of 160m^3/sec implying characteristically lower rainfall in that year. A comparatively higher peak of 250 m^3/second occurred in November-December (Leauthaud *et al*., 2013). The water level remains relatively high at Garsen Bridge until mid-December 2017 (Figure 2).

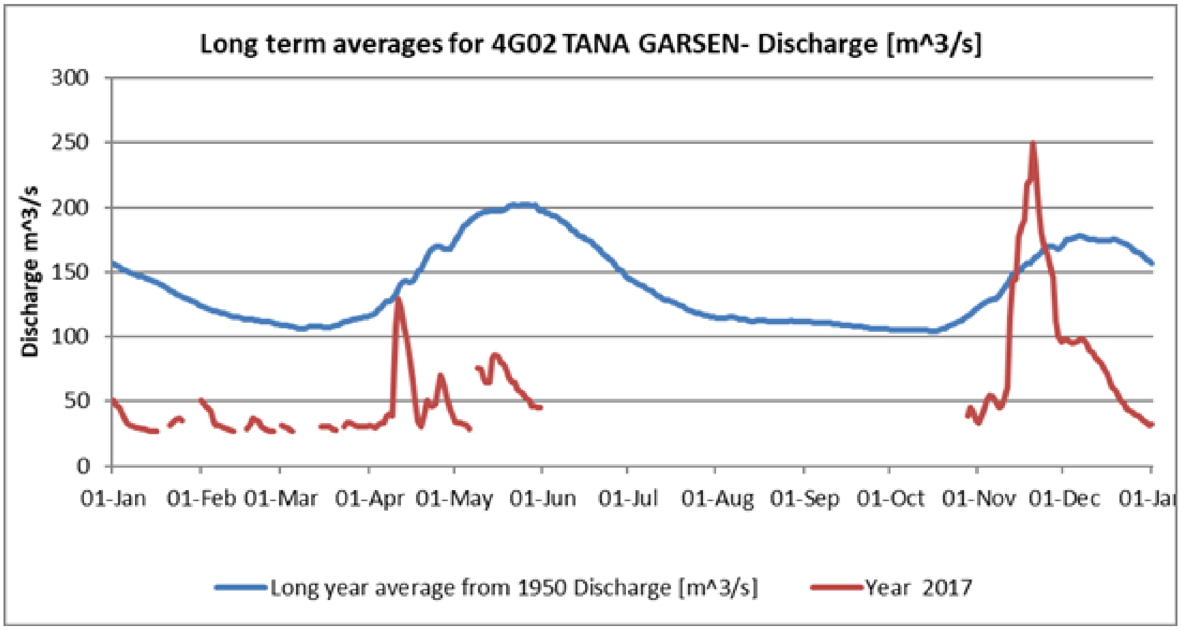

Figure 2: Long term discharge averages for River Tana at Garsen River Gauging Station *(Source: WRA, 2017).*

3.1.3 Human population

Tana Delta sub-county in Tana River County is generally sparsely populated with an average density of six persons/km^2. The total human population for Tana River County reported in 2018 was 349,338, including 126,626 people in Garsen constituency (Tana River County CIDP, 2018). Further, the county integrated development plan indicated that the population growth rate is 2.8% and 62.2% of its population living in absolute poverty. The area has three dominant communities, viz., Pokomo, Orma and Wardei. The other significantly larger ethnic groups were Luhya and Luo people who migrated to Tana River from the western part of Kenya.

3.1.4 Economic activities

There are diverse traditional livelihoods and commercial activities supported by the highly productive Tana River delta, including agricultural farming, livestock keeping, fisheries and forestry. Nevertheless, these livelihoods are continuously changing among the inhabitants as they adopt diversification of livelihoods; fishing communities taking up crop and livestock keeping, while pastoralists are also practicing crop farming and fishing (Mireri, 2010).

3.1.4.1 Agriculture

Farming, mainly recession agriculture, was the dominant and important source of livelihood while tidal and floodplain rice dominated, especially immediately or during the floods. However, a reduction in flood peaks had led to diversification in agriculture with rain-fed maize, mango, and banana cultivation (Maingi & Marsh, 2002). Terer *et al*., (2004) reported that growing of apple mangoes along the river is an important source of family income that is needed to pay school fees and to meet other family needs. Farming was widely practiced by the Pokomo ethnic community who over the time had understood patterns of silt build-up due to floods and flooding patterns.

3.1.4.2 Livestock keeping

The central floodplain grasslands of Tana River Delta are important grazing areas for livestock. The Orma and Wardei, who are traditionally pastoralist communities utilizes these floodplains in the lower reaches of R. Tana mainly during dry season. Whereas livestock products are an important source of protein to the locals, livestock numbers increase during dry season causing overgrazing (Mireri, 2010), and conflict between the farmers and pastoralists.

3.1.4.3 Fisheries

Fishing activities are an important source of livelihood ranking second after agriculture (Terer *et al*., 2004). Fishing is mostly practiced alongside other livelihoods and seasonal variation is observed depending on intensity and duration of floods. Fisher-folk in Tana River Delta exhibit dynamic fishing patterns; fishing along R. Tana main channel during dry season and spilling over to floodplain wetlands and lakes during flooding. The seasonality of flooding enables nutrient regeneration that enriched the floodplain and constitutes vital habitats and nursery grounds for fish. The floodplain also attracts immigrant communities (majorly Luo and Luhyas), from western Kenya whose traditional source of livelihood was fishing. They settled in Moa village around Lake Moa on the northern part of the delta and are responsible for the thriving commercial fishery in the delta (Njuguna & Mburugu, 1992).

3.1.4.4 Other sources of livelihood

Forestry resource utilization is widely practiced by Wataa and Pokomo ethnic groups. Gathering of wild plants and hunting is a popular social and economic activity among the immigrant Luo and Luhya people. Tourism, and small-scale trading are among other livelihood sources.

3.2 Study design

The study was carried out in four floodplain lakes, selected based on intensity and frequency of inundation (Figure 3). Three of these lakes, Gumba, Kongolola and Dalu, were open access fishing sites while Lake Shakababo, an oxbow lake, was a restricted fishing site during the time of this study since it had just been restocked. The restriction of Lake Shakababo was due to the need to allow restocked fingerlings to mature, before allowing fishing. All the four lakes had dried up over a decade and only became flooded and connected to the Tana River main channel in 2018.

After site selection, each lake was characterized to determine whether it was seasonal or permanent, and how long it connected to the River Tana. This was carried out through assessment of habitat stability. Equally important was the distance to main river channel and between each lake. This was used to denote potential for fish mixing and fresh nutrient supply. Fish sampling was conducted during three fishing expeditions each covering pre-flood (January 2019), flooding (June – September 2018) and post-flood (October 2018).

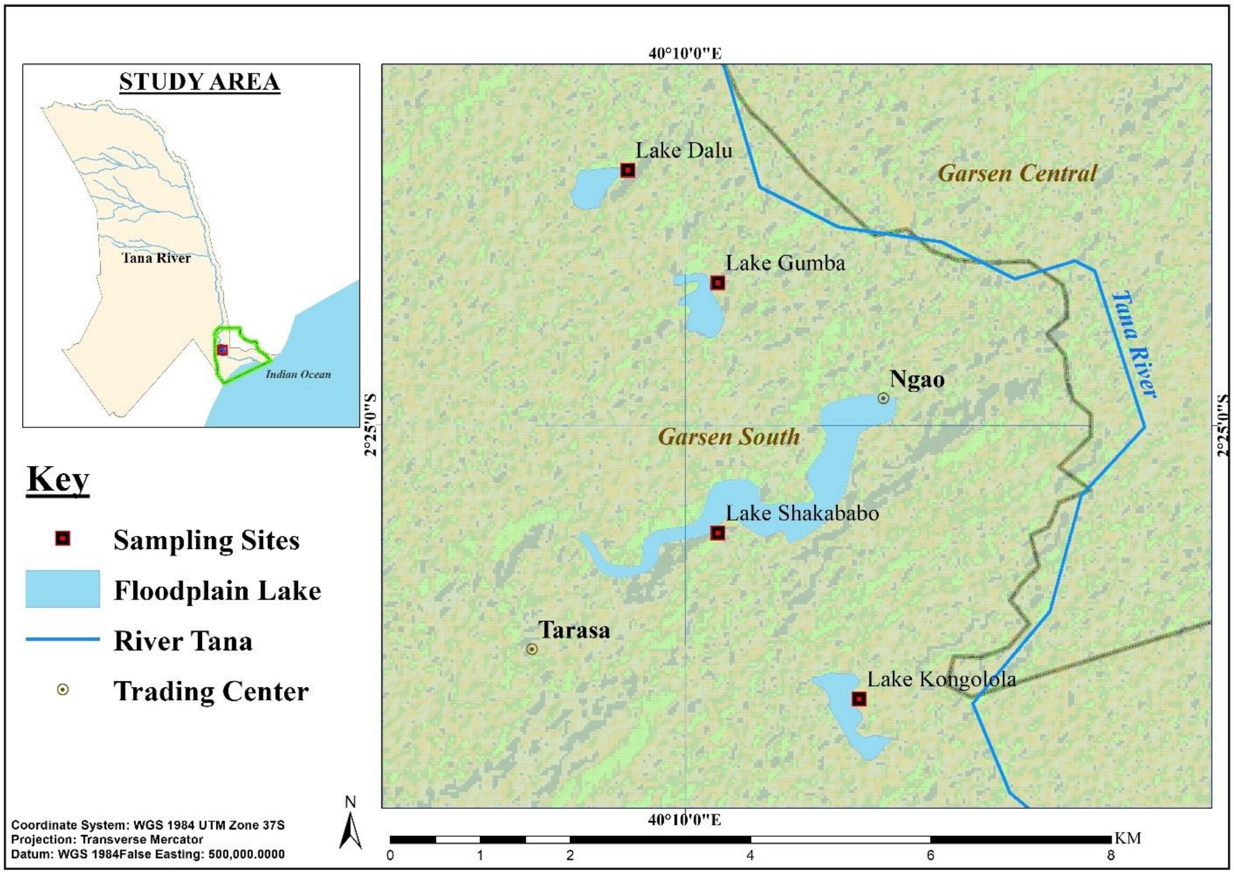

Figure 3: A map of study area showing the distribution and location of selected lakes studied and sampling sites.

3.3 Site characteristics

Apart from varying proximity to the main river channel, areas surrounding these lakes were generally characterized by a mixture of habitats that included invasive “Mathenge” (*Prosopis juliflora*) bushes, doum palms (*Hyphaene thebaica*), *Acacia zanzibarica* among other vegetation types. The spread of *Prosopis* probably indicated longer dry periods and reduced flooding events that had occurred in the delta during the last decade. All these floodplain lakes were open access to the public when inundated except for Lake Shakababo where County Government of Tana River had enforced a closure after introducing Nile Tilapia, *Oreochromis niloticus,* when floods subsided. The characteristics of each sampling site are described in Table 3.

Table 3: Characteristics of selected study sites in the lower Tana delta

Site	Area (ha)	Geographical location	Distance from the main channel (km)	Description and human activities
Lake Gumba	12.5	02°24.142'S 040°10.194'E	0.15	Lake Gumba is located approximately 150m from Oda channel. The river embankment along the channel is high overflowing only at peak floods. The surrounding community practiced recession farming as lake water receded and partly irrigated by drawing water from main river channel. There were also active fisher-folk at the lake. The southern part of the lake has Doum palms, *Prosopis juliflora* bushes among other vegetation types.
Lake Dalu	3.0	02°23.465'S 040°09.654'E	1.8	This is relatively a small lake compared to the other study lakes. It is shallow and highly invaded by *Prosopis juliflora*. No human activities were observed around this lake but cattle grazing.
Lake Shakababo	120.0	02°25.648'S 040°10.196'E	3.6	The lake is considered the largest ox-bow lake in East Africa. It is relatively deep lake compared to the other floodplain lakes studied with an elevation of limited extent rising above the surrounding land. Flood water from Oda channel gets into the lake via Kisichi brook while Kitengela channel on the opposite side brings in water due to local rain. Recession farming is common on the eastern side of the lake. The lake is bordered by Ngao trading centre to the south while to the north are diverse vegetation types.
Lake Kongolola	8.1	02°26.647'S 040°11.042'E	1.3	This is shallow lake with a lot of silt deposits. Receives flood via L. Shakababo and partly directly from Oda channel. The surrounding area is characterized by recession farming activities while *Prosopis juliflora* bushes had invaded the lake area. The lake borders Golbanti village.

3.4 Assessment of patterns of hydrological connectivity in the floodplains

3.4.1 Hydrological connectivity

Patterns of hydrological connectivity were assessed using diverse methods. First, historical information on floods and climatic influences of flooding in Tana River delta was collected from studies undertaken by KENWEB (Leauthaud *et al*., 2013; Duvail *et al*., 2017) and Water Resources Authority publications (WRA, 2013, 2018). Moreover, to understand the frequency of inundation, straight-line distance from each lake to the main channel was determined using a scale on a map (Figure 3). To incorporate local knowledge to this, questions relating to flood dynamics in the delta were included in the semi-structured interviews (Appendix VI). Above all, field observations were conducted to understand physical barriers to fish mixing.

3.4.2 Lake morphometry

Maximum lengths and widths for each lake were estimated using range finder (figure 4). The approximate surface area was calculated using the formula;

$\text{Surface area} = 1/3\ (L1 + L2 + L3) * 1/3\ (W1 + W2 + W3)$……………...Equation (v)

Similarly, lake water depth was estimated by taking an average of three points using a dip stick.

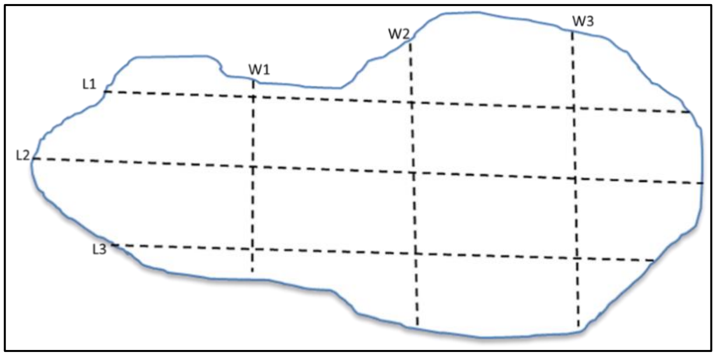

Figure 4: Illustration for estimating lake surface area

3.4.3 Assessment of water characteristics

This study probed the following water quality characteristics insitu: pH using pH meter (Model pH 01), temperature(°C) – T, dissolved oxygen (in mgL^{-1}) – DO and electrical conductivity (µSm-1) – EC were recorded using a multi-meter probe (YSI Model 85/50) and water clarity(cm) using turbidity tube. At each floodplain lake selected for fish sampling, three sampling points for water quality characteristics were established. At every point, the water quality characteristics were recorded at the top and middle water column. Recording was done in pre-flood, during flood and post-flood alongside fish sampling.

3.5 Assessment of fish diversity, abundance, and distribution

Fish sampling was carried out in pre-flood, during flood, and post-flood period. Sampling was carried out using monofilament gillnet 1x30 m long and of 0.5, 1.0- and 2.5-inch mesh sizes. Nets were set out during the early hours of the morning between 7.30 am and 8.30 am for 1.5 hours when fish were presumed to be actively moving either searching for food or migrating (Hart & Reynolds, 2008). During each sampling, details of each sample such as date, site and manner of collection were recorded (Appendix IV). Furthermore, number of each fish species captured was recorded. Assumptions were made regarding variations due to species agility and predation on fish caught in nets that may cause species overestimation (Hoeinghaus *et al*., 2001). Sampling duration and gear were maintained throughout the study lakes and period to standardize on possible effects of seasonality and habitat types such as variation in mean size of individuals and species activity patterns.

3.5.1 Sample treatment

The specimens collected were sorted into different sizes to ease field measurements and identified to species level using established freshwater fish taxonomic keys in Ichthyology Section, National Museums of Kenya (NMK). Similarly, the identified species were compared against the annotated checklist of the freshwater fishes of Kenya (Seegers *et al*., 2003), guide to common freshwater fishes of Kenya (Nyingi, 2013) and fish specimen collection available at NMK. Fish specimens considered unique or not curated at NMK collection at that time, were photographed *in-situ* and samples fixed in 10% formalin (Strauss & Bond, 1990; Coad, 1998). These were transported in separate containers for each sampling site, labelled properly against the physical data sheet of the sampling site and taken to Ichthyology laboratory at NMK. After 7-10 days of preservation, the formalin was thoroughly rinsed out with water, and transferred to 70% Ethanol, which was the state in which, the museum collections were curated. These specimens were catalogued with a unique identification code per species, and added to the NMK Freshwater Fish Database based on species and locality data (Appendices I and III)

3.5.2 Assessment of length-weight relationship

Thirty samples for each identified fish species were measured to the nearest 1 mm for total length (TL) and weighed to the nearest 0.1 mg(W). In instances where less than thirty samples were caught then all were measured. A pair of vernier calliper (Mitutoyo

Ser. No. 08037483) was used for measuring fish<20 cm and a meter rule mounted on wooden board for fish > 20 cm long (Figure 5). Digital weighing scale (brabantia kitchen scales) was used for measuring weight of fish.

Figure 5: a) Length-weight measurements using Vernier caliper, measuring board and weighing scale at L. Shakababo, b) The Tana bulldog (*Marcusenius devosi*)

3.6 Determination of annual fishing patterns and fisheries governance

Information on fishing patterns, flood dynamics and fisheries governance were collected in pre-flood, during flood, and post-flood period from 32 fishermen within the study area. Interview schedules were prepared with structured and semi-structured interviews (Appendix VI) to extract information from fisher-folk. One focused group discussion (FGD) was held on 17th October 2018 at the shoreline of Lake Shakababo. Interviewees were purposively selected on the basis that they fish on a regular basis, regular fish vendors and/or old retired fishermen and comprised both men and women willing to be interviewed. Qualitative and quantitative questions relating to fishing patterns, flood dynamics, fishing gear and fisheries governance were asked.

3.7 Ethical Consideration

Ethical issues were addressed during field data collection using interview schedules including informed consent, access, and acceptance as well as confidentiality and anonymity. The principle of informed consent was given the required attention by explaining the purpose of the study to participants and making them aware that participation and answering of any question was optional. Further, none of the information provided by interviewees was disclosed to other people.

3.8 Data analysis

Data collected on fish species composition, number of species, size (length) and water quality characteristics were entered into excel for analysis. Prior to all analyses, variables for fish and water quality data were tested for normality using Shapiro-Wilk tests in R software.

3.8.1 Assessment of fish diversity, abundance, and distribution

3.8.1.1 Fish species composition and abundance

Relative abundance of fish across different sampling sites was calculated by using the following formula in excel;

$$Relative\ abundance = \frac{Number\ of\ samples\ of\ particular\ species\ X\ 100}{Total\ number\ of\ samples} \ldots\ldots\ldots \text{ Equation (vi)}$$

Two-way analysis of variance (ANOVA) was used to assess the impact of site (floodplain lake) and sampling period on fish species abundance. Floodplain lake and sampling period were treated as two independent variables while fish abundance was the dependent variable.

3.8.1.2 Fish Diversity

The following univariate species diversity measures were calculated in R-software and used to describe patterns of fish distribution in each floodplain lake: total number of individuals(N), total species (s), Margalef's index (d=(s-1)/log(N)) a measure of species richness, Shannon-Wiener diversity index of diversity(H'), and Simpson's Diversity

Index (J). Simpsons index of dominance explained the probability that two species randomly selected from the sample belonged to the same species while Margalef's index compared different ecosystems (sites) taking only species richness into consideration reflecting sensitivity to sample size (Magurran, 2004.).While computing the diversity indices, it was assumed that the probability of each individual fish being caught in the fishing net remained constant throughout the sampling period, and all individuals had the same probability of being captured.

3.8.1.3 Fish species composition and assemblage

Multivariate non-metric multi-dimensional scaling (MDS) technique (Field *et al.*, 1982) was used to visualize the differences in fish assemblage composition among the floodplain lakes and in different sampling periods. This was performed using the function metaMDS in the R package vegan 2.5-3(R Core Team, Vienna, Austria). The analysis involved dimension reduction by taking the original fish data and calculating a dissimilarity (distance) measure based on Bray-Curtis similarity for sampling month and site. NMDS was preferred to other ordination techniques because it assumed any relationship in variables.

3.8.2 Assessment of length-weight relationship and relative condition factor

Log weight was first plotted against log length and regression coefficients *a* and *b* determined using the equation below;

$$\log w = \log a + b \log l \text{............equation (vii)}$$

Consequently, the index of well-being calculated as the relative condition factor, *Kn*, was represented by;

$$Kn = \frac{100w}{l^b} \text{ ....equation (viii)}$$

When *b* was equal or close to 3 fish growth was said to isometric where fish became more robust with increasing length. Values of *b* lower or greater than 3 indicated an allometric fish growth type.

3.8.3 Association among fish assemblage, water quality and lake morphology

Non-parametric Kruskal-Wallis test was used to test for any significant differences in water quality characteristics across the four floodplain lakes. Pearson's correlation coefficient was calculated to test the relationship between fish abundance, floodplain lake morphological and water quality characteristics ($\alpha = 0.05$).

3.8.4 Determination of annual fishing patterns and fisheries governance

To determine annual fishing patterns and governance of the lakes, quantitative data on number of fisher-folk and traders was tabulated in excel and analysed descriptively. Qualitative data was analysed by collating responses into themes relating to fishing patterns, flood dynamics, fishing gear and fisheries governance. Opinions of fisheries stakeholders were documented to inform better fisheries co-management in the seasonal floodplain lakes.

CHAPTER FOUR

4.0 RESULTS

4.1 Water quality and hydrological connectivity of the floodplain lakes

4.1.1 Spatial changes in hydrological connectivity

Water flow at Garsen river gauging station (RGS) peaked in April – June 2018 (Figure 6). This coincided with the long rains in Tana River catchment. Inundation of the floodplain lakes was mainly due to overflow of main river channel at the delta and it peaked in July–August. Thus, local rainfall accounted for only a small proportion of the flood waters in the delta.

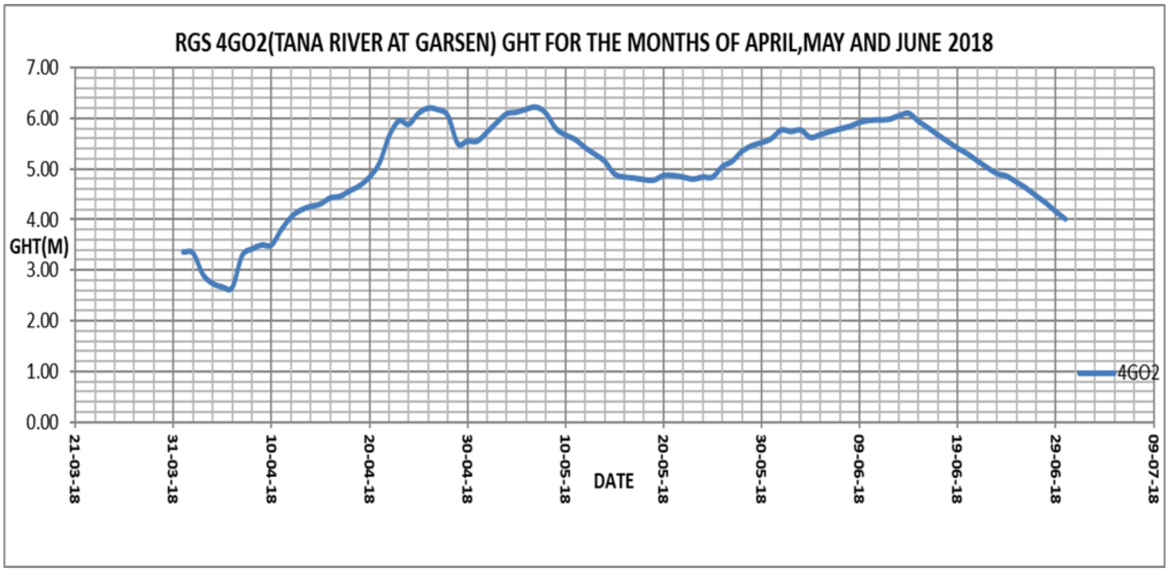

Figure 6: Hydrograph for R. Tana for the period between April – June 2018. (WRA 2018)

During this study connectivity of each floodplain lake was observed to be dependent on the water level in the river and height of the main river channel. It was also observed that the location of the specific floodplain lake relative to river's main channel influenced how long it remained connected. Various hydrological phases of the four floodplain lakes observed during this study are shown in Table 4.

Table 4: Hydrological phases of the floodplain lakes over the study period

Site	Period	Hydrological connectivity	Water surface area $\bar{x}$ (ha)	Water depth $\bar{x}$	Transparency $\bar{x}$ (metres)
Lake Dalu	Pre-flood	Disconnected.	0.0012	0.2	1.60
	During flood	Connected.	3.00	1.0	1.73
	Post-flood	Disconnected.	0.54	0.6	1.58
Lake Gumba	Pre-flood	Disconnected.	6.00	0.8	2.23
	During flood	Connected.	12.50	1.8	2.34
	Post-flood	Intermittent.	10.81	1.2	2.16
Lake Shakababo	Pre-flood	Disconnected.	118.11	4.0	0.42
	During flood	Connected.	120.00	4.0	0.51
	Post-flood	Intermittent.	120.00	4.0	0.36
Lake Kongolola	Pre-flood	Disconnected.	0.00	0.0	5.43
	During flood	Connected.	8.10	1.3	0.81
	Post-flood	Disconnected.	0.06	0.4	2.77

During flooding period, all the four target floodplain lakes were connected to the main river channel. Lake Gumba which is 150m to the main Oda channel was the first to start losing its connectivity. Water started flowing back to the main channel in early October 2018 (post-flood period). This, according to field observations, was due to the deep river channel that quickly lowered river water level as floodwater receded. The neighbouring community however, disconnected the lake by blocking the brook connecting the lake to Oda channel using sandbags. However, the lake was deep enough and sustained floodwater throughout the sampling period.

Lake Shakababo was connected to the main river channel approximately 3.5 km away via Kisichi brook. It had the largest surface area among the four floodplain lakes and its depth remained unchanged during the study period (Table 4). Like lake Gumba, the neighbouring community blocked water from flowing back into the river thus, hastening its disconnectivity. Lake Shakababo also received substantial amount of water from local run-off.

Figure 7: Village scouts in a surveillance fiberglass engine boat at Lake Shakababo

Lake Dalu, surrounded by a mosaic of vegetation and invaded by *Prosopis juliflora* bushes was connected to the main river channel, approximately 1.8 km away. This shallow lake, less than 1m deep, first broke into two smaller lakes before completely drying in January 2019. Its shallow water and high ambient temperature accelerated the recession and ultimately drying of this lake.

Figure 8: Heavily silted Lake Dalu and dead stems of *Prosopis juliflora*

Lake Kongolola was partly connected with the main river channel located approximately 1 km away via lake Shakababo. The shallow lake was also invaded by *Prosopis juliflora* bushes and together with Lake Dalu, they had receded into tiny muddy pools of water in January 2019. Thousands of water birds congregated on the lakebed, feeding on the abundant fish resources in the small pools of water.

Figure 9: Lake Dalu with many Yellow-billed storks and *Prosopis* bushes

4.1.2 Water quality characteristics in the floodplains lakes

The water quality characteristics recorded during this study are shown in Table 5. Electrical conductivity(μSm-1) and Dissolved Oxygen (DO) changed markedly during sampling period from pre-flood to post-flood in all floodplain lakes. Also, water clarity for all floodplain lakes were lowest during pre-flood. Mean pH remained generally stable throughout the study period (30.23±1.57).

Lake Gumba had the highest value of mean DO of 9.41 ± 9.41 followed by Lake Shakababo (8.91 ± 0.30). Dissolved oxygen varied the least at Lake Shakababo. Lake Gumba had the lowest mean temperature (28.87 ± 1.25). Low values of electrical conductivity were recorded at Lake Shakababo, 342.34 ± 13.13. Consequently, Lake Gumba had the lowest salinity level of 0.26 ± 0.09. Lakes Gumba and Shakababo tended to have clearer waters;7.92 ± 2.23 and 13.79 ± 0.88, respectively. Lake Dalu recorded least of DO, 5.86 ± 5.86. Mean electrical conductivity was highest at Lake Dalu 597.56 ±

171µSm. Lakes Dalu and Kongolola were highly turbid throughout the entire study period; values averaged 2.29 ± 1.60 and 2.85 ± 0.81, respectively. Salinity values were high at Lake Dalu, 0.48 ± 0.22.

Kruskal-Wallis test was conducted to examine the differences in water quality characteristics among the four floodplain lakes (Table 6). Statistically significant differences across lakes in electrical conductivity (Chi square = 41.667, $p<0.05$, df = 3), dissolved oxygen (Chi square = 22.66, $p<0.05$, df = 3),water clarity(Chi square = 19.442, p = 0.00022, df = 3), and salinity (Chi square = 32.656, $p<0.05$, df = 3) were observed. On the other hand, temperature (Chi square = 18.424, $p>0.05$, df = 3) and pH (Chi square = 9.9526, $p>0.05$, df = 3) showed no significant variation across the lakes.

Table 5: Summary statistics of water quality in the four study sites
(DO = Dissolved Oxygen; EC = Electrical Conductivity; Temp = Temperature; StdDev = Standard deviation)

Sampling period		Pre-flood	Flood	Post-flood
Lake	Variable	Mean ± StdDev	Mean ± StdDev	Mean ± StdDev
Lake Gumba	EC (µSm-1)	508.12 ± 2.64	346.45 ± 5.18	385.95 ± 6.88
	Water clarity (cm)	4.62 ± 0.04	10.12 ± 0.15	7.92 ± 0.58
	Temp. (°C)	28.58 ± 0.55	27.68 ± 0.66	30.34 ± 0.45
	DO (mgL-1)	5.75 ± 1.51	8.06 ± 0.62	14.46 ± 2.27
	pH	8.26 ± 0.36	8.65 ± 0.28	8.54 ± 0.14
	Salinity	0.20	0.20	0.39
Lake Dalu	EC (µSm-1)	773.92 ± 15.57	426.14 ± 161.61	592.62 ± 23.58
	Water clarity (cm)	0.33 ± 0.06	4.14 ± 0.13	2.37 ± 0.19
	Temp. (°C)	32.62 ± 0.48	29.26 ± 0.6	30.01 ± 0.86
	DO (mgL-1)	2.78 ± 0.15	8.82 ± 1.02	5.97 ± 3.92
	pH	8.33 ± 0.14	8.45 ± 0.26	7.98 ± 0.22
	Salinity	0.70	0.20	0.54 ± 0.12
Lake Shakababo	EC (µSm-1)	355.39 ± 5.56	326.75 ± 6.21	344.87 ± 3.95
	Water clarity (cm)	13.38 ± 0.75	13.6 ± 1	14.4 ± 0.63
	Temp. (°C)	32.39 ± 0.77	29.1 ± 0.94	30.78 ± 0.25
	DO (mgL-1)	9.03 ± 0.40	8.91 ± 0.05	8.78 ±0.34
	pH	8.03 ± 0.08	8.04 ± 0.04	8.10 ± 0.23
	Salinity	0.20	0.35	0.36
Lake Kongolola	EC (µSm-1)	-	462.93 ± 50.3	561.59 ± 1.87
	Water clarity (cm)	-	2.7 ± 1.17	3 ± 0.09
	Temp. (°C)	-	31.12 ± 0.66	30.60 ± 0.55
	DO (mgL-1)	-	4.88 ± 1.22	5.99 ± 1.49
	pH	-	7.97 ± 0.26	8.32 ± 0.13
	Salinity	-	0.20	0.46

Table 6: Results of the Kruskal-Wallis-tests for changes in water quality in the floodplain lakes
(EC = Electrical Conductivity; Temp = Temperature)

Water characteristic	Lake Dalu N = 18	Lake Gumba N =18	Lake Kongolola N =12	Lake Shakababo N = 18	Kruskal-Wallis Chi square test	df	p-value
EC (µSm-1)	597.56 ± 171	413.51 ± 70.98	512.26 ± 61.69	342.34 ± 13.13	41.667	3	S
Water clarity (cm)	2.29 ± 1.60	7.92 ± 2.23	2.85 ± 0.81	13.79 ± 0.88	19.442	3	S
Temp. (°C)	30.63 ± 1.61	28.87 ± 1.25	30.86 ± 0.64	30.76 ± 1.54	18.424	3	NS
DO (mgL-1)	5.86 ± 3.36	9.41 ± 4.09	5.43 ± 1.42	8.91 ± 0.30	22.66	3	S
pH	8.25 ± 0.29	8.48 ± 0.31	8.14 ± 0.27	8.06 ± 0.14	9.9526	3	NS
Salinity	0.48 ± 0.22	0.26 ± 0.09	0.33 ±0.14	0.30 ± 0.08	32.656	3	S

4.1.3 Historical information on flooding in Tana Delta

Historical information (Maingi & Marsh, 2002) indicated that the highest discharge ever recorded of 3568.3 m^3s^{-1}along River Tana was at Garissa on 21 November 1961. However, annual discharges dropped markedly in subsequent years, between 1968 – 1981, when major hydropower dams were built in the river's upper reaches. Maingi & Marsh (2002) reported the last major dam, Masinga, completed in 1981 significantly reduced peak flows and altered hydrological regimes in the delta. Since then no major flooding had been recorded because of main river overflow until the period of 1997-1998 (Figure 10).

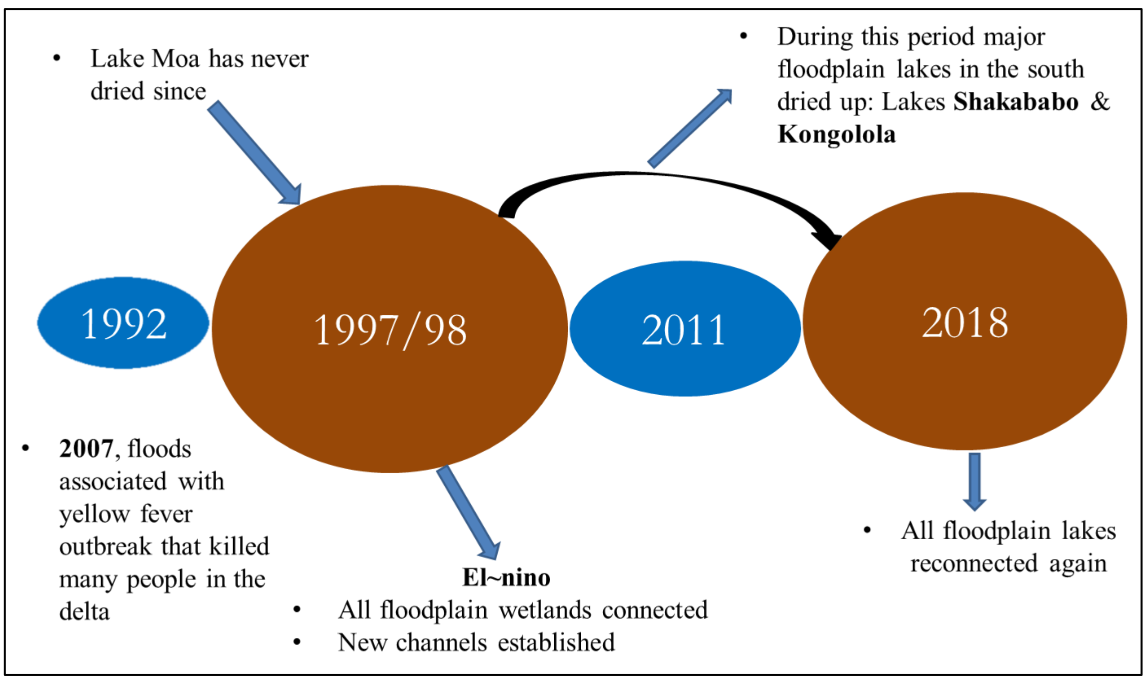

Figure 10: Major flooding events in Tana River Delta in the last 2 decades

The major flooding event of 1997 – 1998 was the most recent in post-dam construction. It had been associated with the warm phase of El Niño–Southern Oscillation (ENSO). The peak flows and subsequent increase in sediment loads during this period led to re-emergence of oxbow-lakes such, as lakes Moa, Shakababo, Bilisa Boka and several other cut-off meanders and channels. Thus, the diversity and productivity of Tana Delta floodplains improved. However, increased water abstraction and irrigation schemes in the river's catchment meant annual flooding peaks could not be sustained anymore. The four target lakes in this study largely received water from Oda channel, when it flooded. Local rains accounted for a very small contribution of water flowing into the lakes. In most years, floods were experienced in the delta towards the end of April and sometimes at the beginning of May. Floods were because of heavy rainfall in Aberdare and Mt. Kenya forests where River Tana's headwaters originate. Floodwater rose for about two months reaching its peak around June. The peak was sustained for a month and a half before it started to subside in August.

Lake Shakababo, the largest among the four sites (Table 4), was connected to the Oda channel via Kisiki brook. Fisher-folk interviewed around this lake stated that it had completely dried in 2010. They cited a diversion in 2008 that diverted water to Matomba channel on the North East of the delta. However, they did not seem to agree on what exactly caused the diversion; siltation was widely mentioned to have caused the river to divert naturally. However, other residents believed commercial farmers intentionally diverted the river water course to pass through Matomba brook. The embankment along Oda brook was high, estimated to be over three meters. Thus, a substantially high amount of water was needed before the surrounding floodplains could be inundated. The reduction in ecosystem services due to reduced flood peaks and altered flow regimes had significant impact on local livelihoods especially for fishers and farmers (Leauthaud *et al.*, 2013).

4.2 Fish abundance, diversity, and distribution patterns in floodplain lakes

4.2.1 Fish species abundance and composition

A total of 2982 fish specimens comprising 15 species in 9 families were sampled (Table 7). The overall species richness calculated as number of species counted per site, ranged from 10 at Lake Dalu to 15 at Lake Gumba. Relative fish abundance per site was generally high for Zanzibar barb (*Enteromius zanzibaricus* Peters, 1868) and Gregori's labeo (*Labeo gregorii* Günther, 1894) (>4) which accounted for >52 % of total numbers and occurred in >47% of the sites. *L. gregorii* exhibited a relative abundance of 6% — 20% over the study period, whereas Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758) was less abundant (0.22 - 29) and more dominated (18%) at Lake Shakababo. Tank goby (*Glossogobius giuris* Hamilton, 1822), Somalia glass catfish(*Paraillia somalensis* Vinciguerra, 1897), Churchill (*Petrocephalus catastoma* Gunther,1866), Tana bulldog (*Marcusenius devosi* Kramer et al, 2007), Wide-headed catfish (*Clarotes laticeps* Ruppell, 1829) were less abundant (<2% relative abundance in all sites), and were not caught at Lake Dalu. Among these species, East coast squeaker (*Synodontis zanzibaricus* Peters, 1868) showed high fluctuating relative abundance of between 1 - 12%. Only fish species sampled in all the four floodplain lakes and with an overall relative abundance of >4.5% were used in subsequent data analyses.

Table 7: Composition of fish assemblage in the floodplain lakes during the study period quantified using the relative abundance for each species

Species	Lake Dalu	Lake Gumba	Lake Kongolola	Lake Shakababo	Overall
CYPRINIDAE					
Labeo gregorii	14	16	20	6	11
Labeo sp.	5	5	7	3	4
Enteromius zanzibaricus	13	31	46	52	41
GOBIIDAE					
Glossogobius giuris	-	2	1	2	2
SCHILBEIDAE					
Schilbe intermedius	17	7	1	1	4
Paraillia somalensis	-	0	-	-	1
MOCHOKIDAE					
Synodontis serpentis	4	1	1	1	1
Synodontis zanzibaricus	12	1	9	3	5
CLARIIDAE					
Clarias gariepinus	14	10	2	1	5
MORMYRIDAE					
Petrocephalus catastoma	-	1	1	1	1
Marcusenius devosi	-	0.89	1	1	1
ALESTIDAE					
Brycinus affinis	4	13	6	5	8
CICHLIDAE					
Oreochromis niloticus	3.0	0.22	2	18	9
Oreochromis spirulus	3	7	3	6	7
BAGRIDAE					
Clarotes laticeps	-	2	-	1	1
Total species	10	15	13	14	15

4.2.2 Variation in fish abundance across the floodplain lakes

Fish species with relative abundance of >4.5% and sampled in all the four floodplain lakes were used to assess variation in fish abundances. The data was transformed to $\log_{10}$ to meet the requirement for normality of distribution before applying ANOVA test. Two-way ANOVA with interaction was then conducted to examine the effect of site and sampling period on fish species abundances (p=0.05) (Table 8). Site included four levels (Lake Gumba, Lake Dalu, Lake Shakababo, and Lake Kongolola) and sampling period included three levels (pre-flood, during flood, and post-flood).

There was no statistically significant interaction between the effects of sampling period and site on fish species abundance ($F(6, 240) = 1.63$, $p = 0.14$). There was also no statistically significant influence of sampling site on fish species abundance ($F(3, 240) = 1.43$, $p = 0.23$). However, there was a statistically significant effect of sampling period on fish species abundance ($F(2, 240) = 6.47$, $p = 0.002$).

Table 8: Differences in fish species abundance between sampling period and site

Source of Variation	n	SS	df	MS	F	P-value	F critical
Sampling site	4	1.309941	3	0.436647	1.429781	0.234694	2.642213
Sampling period	3	3.949718	2	1.974859	6.466587	0.001839	3.033439
Interaction	7	2.978859	6	0.496476	1.62569	0.140639	2.136479
Within		73.29464	240	0.305394	-	-	-
Total	252	81.53315	251	-	-	-	-

4.2.3 Variation in fish species diversity

Margalef's richness index was lower for Lake Dalu (d = 1.593) and high for Lake Gumba (d = 2.058) and Lake Kongolola (d = 2.07) indicating a high number of species per unit sample in these two lakes (Table 9). Shannon Weiner diversity index, H' did not vary greatly among the four lakes and was below H' = 3, the value calculated for most stable ecosystems. Further, Simpson's diversity index was generally similar for L. Dalu ((λ = 0.874) and Lake Gumba ((λ = 0.84) but was lower at Lake Shakababo (λ = 0.69) and Lake Kongolola (λ = 0.727). Pielou's evenness index (J) indicated a similar composition of the fish species in all four lakes. The low evenness value of Lake Shakababo (J = 0.26) indicates low probability of species mixing while its low Simpsons Diversity Index (λ = 0.69, implies that the lake ecosystem was less diverse and was dominated by a few fish species. This could be explained by the high number of the more competitive *E. zanzibaricus* and *O. spirulus* sampled at the lake (Table 7).

Table 9: Univariate diversity indices of fish species in the four floodplain lakes

Site	Abundance, (N)	Total species	Margalef's richness index, (d)	Shannon Weiner Diversity Index, (H')	Simpson's Diversity Index (λ)	Pielou's evenness, (J)
Lake Dalu	284	10	1.593	2.16	0.874	0.38
Lake Gumba	901	15	2.058	2.127	0.84	0.31
Lake Kongolola	329	13	2.07	1.724	0.727	0.283
Lake Shakababo	1468	14	1.783	1.667	0.688	0.261

4.2.4 Fish species assemblage distribution

Results of nMDS ordination by site (Figure 11) revealed a more distinct clustering of fish species at Lake Shakababo and Lake Gumba. The fish assemblages at the two lakes indicate a slightly different fish species composition compared to Lake Dalu and Kongolola. Lake Gumba and Lake Shakababo were connected for the longest period. Fish assemblages that are more similar appear closer together in the diagram.

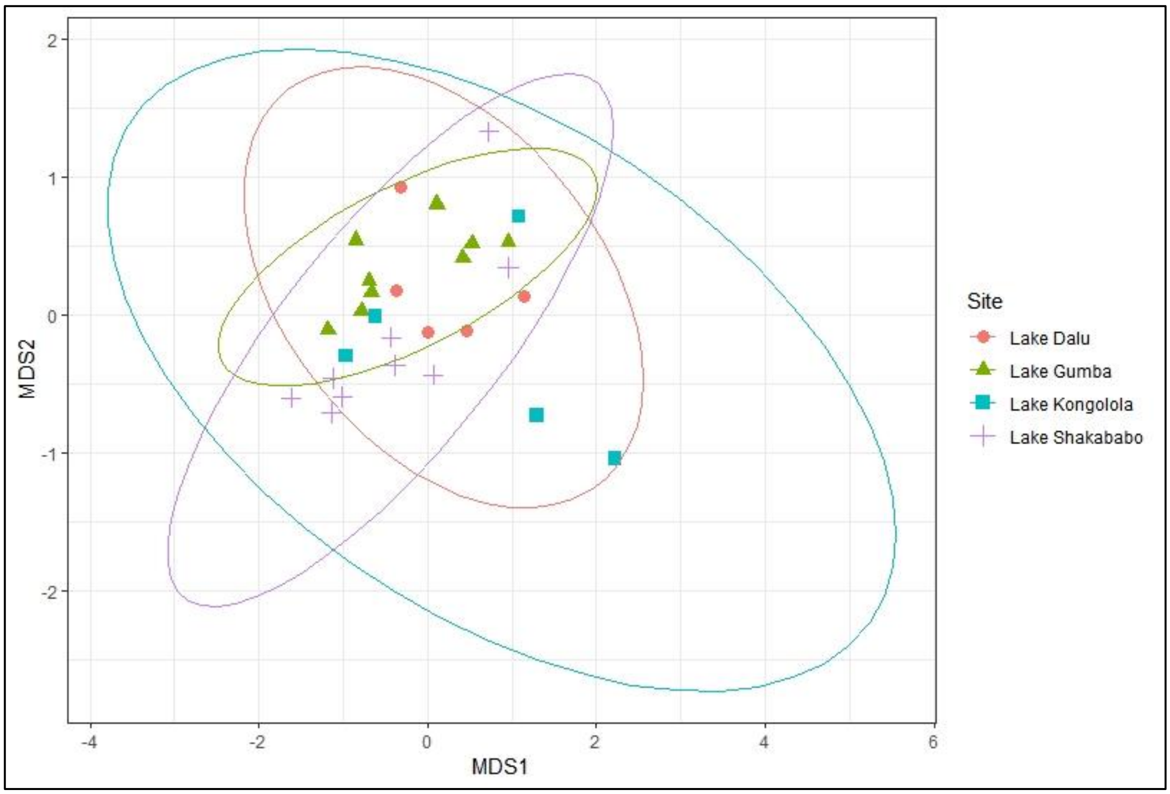

Figure 11: Non-metric multidimensional scaling ordination plot of fish species composition by site

Ordination in relation to sampling period (Figure 12) showed high similarity of fish assemblages during floods in the Tana Delta floodplain lakes as indicated by high clustering in fish species composition. The clustering eased during pre-flood and post-flood period as the connectivity between the floodplain lakes was lost.

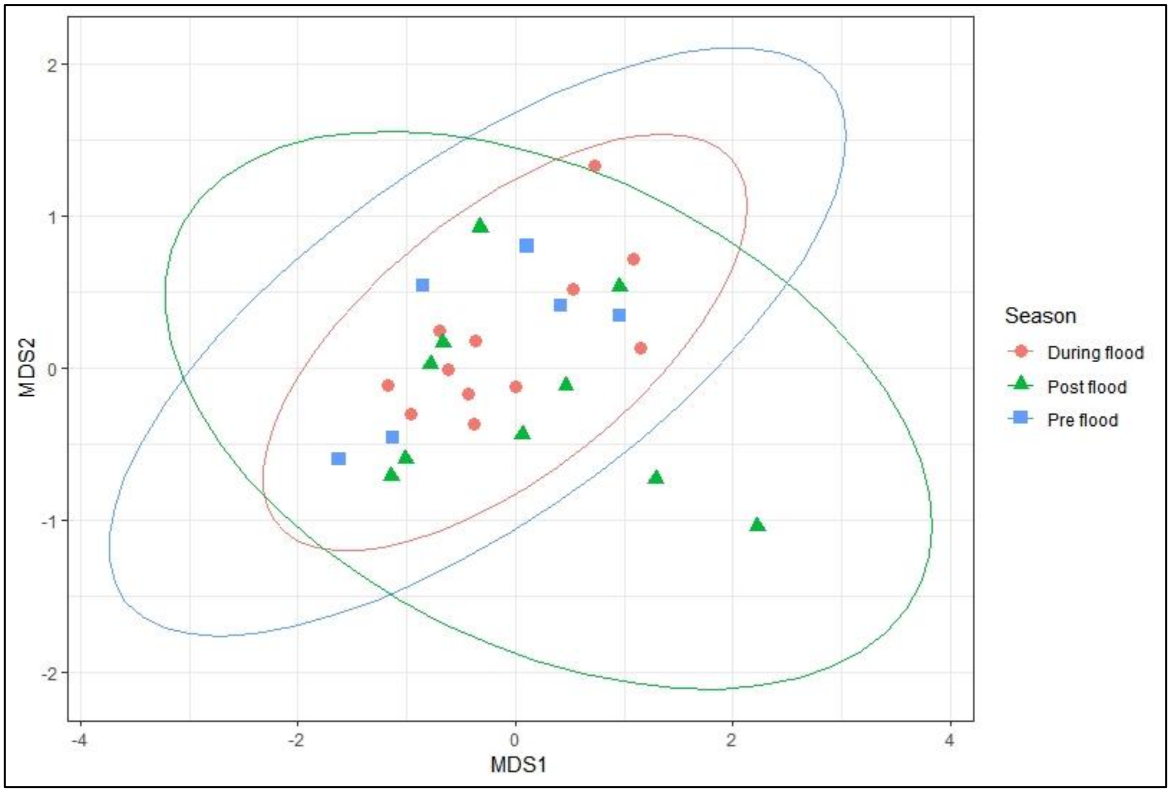

Figure 12: Non-metric multidimensional scaling ordination plot of fish species composition in relation to sampling period

4.2.5 Length-weight relationship and condition factor of selected fish species

4.2.5.1 Length-weight relationship and variation in fish size

A total of 304 *Labeo gregorii* and 279 *Oreochromis niloticus* measured for individual total length (TL) and weight (W) and occurring across all sites during the sampling period were used in this analysis. There was a high positive relationship between length and weight for *L. gregorii* in Lakes Dalu, Gumba, and Shakababo (R^2=0.93, R^2=0.94, and R^2=0.98), respectively (Figure 13). Lake Gumba had a high abundance of *L. gregorii* dominated by small sized individuals, while, Lake Kongolola had few individuals of *L. gregorii*, but the fish size ranges were smaller. Few large sized individuals of *L. gregorii* were sampled at Lakes Dalu and Kongolola.

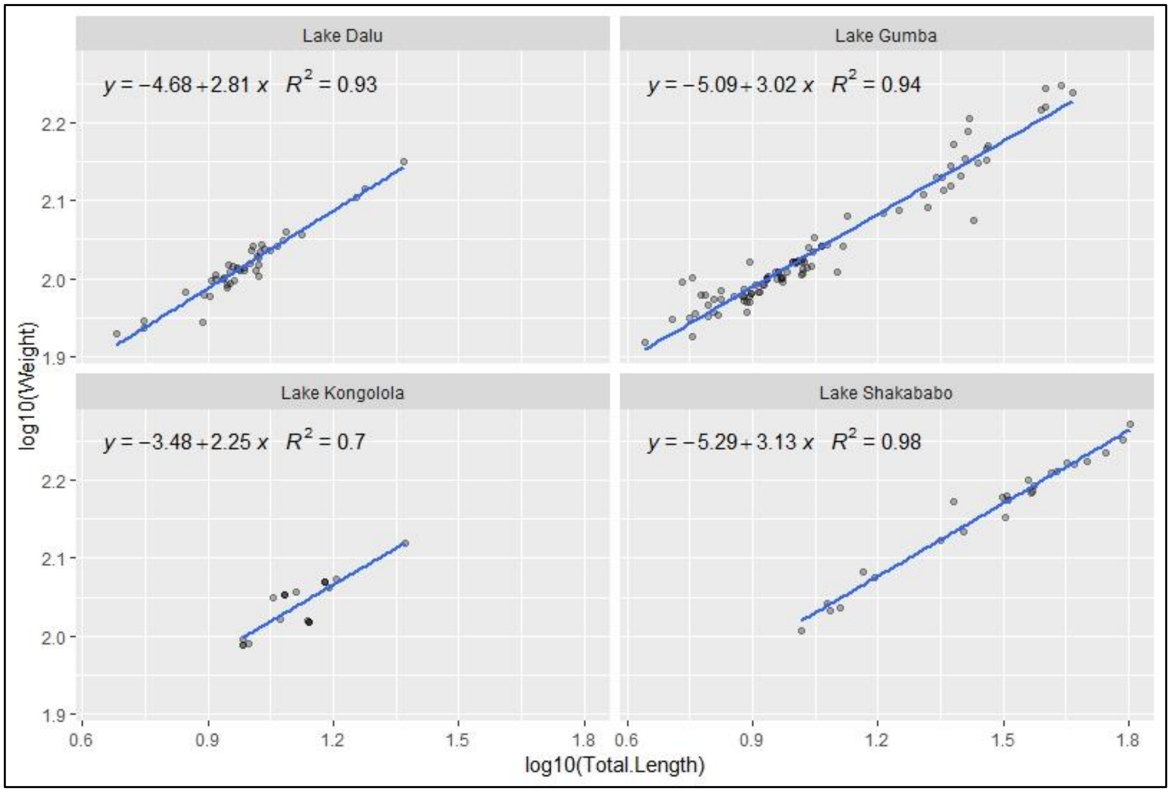

Figure 13: Length-weight relationship for *Labeo gregorii* in studied floodplain lakes

Length-weight relationship for *O. spirulus* was positively correlated at Lake Dalu and Lake Gumba (R^2=0.97 and R^2=0.93), suggesting normal growth pattern (Figure 14). Similarly, there was a positive length-weight relationship at Lake Kongolola and Lake Shakababo, however, this relationship was not highly correlated (R^2=0.69 and R^2=0.62). Individual fish sizes were evenly distributed at Lakes Dalu and Gumba while at Lake Kongolola larger sized individuals were sampled. The length-weight relationship was, however, positively correlated (R^2=0.62).

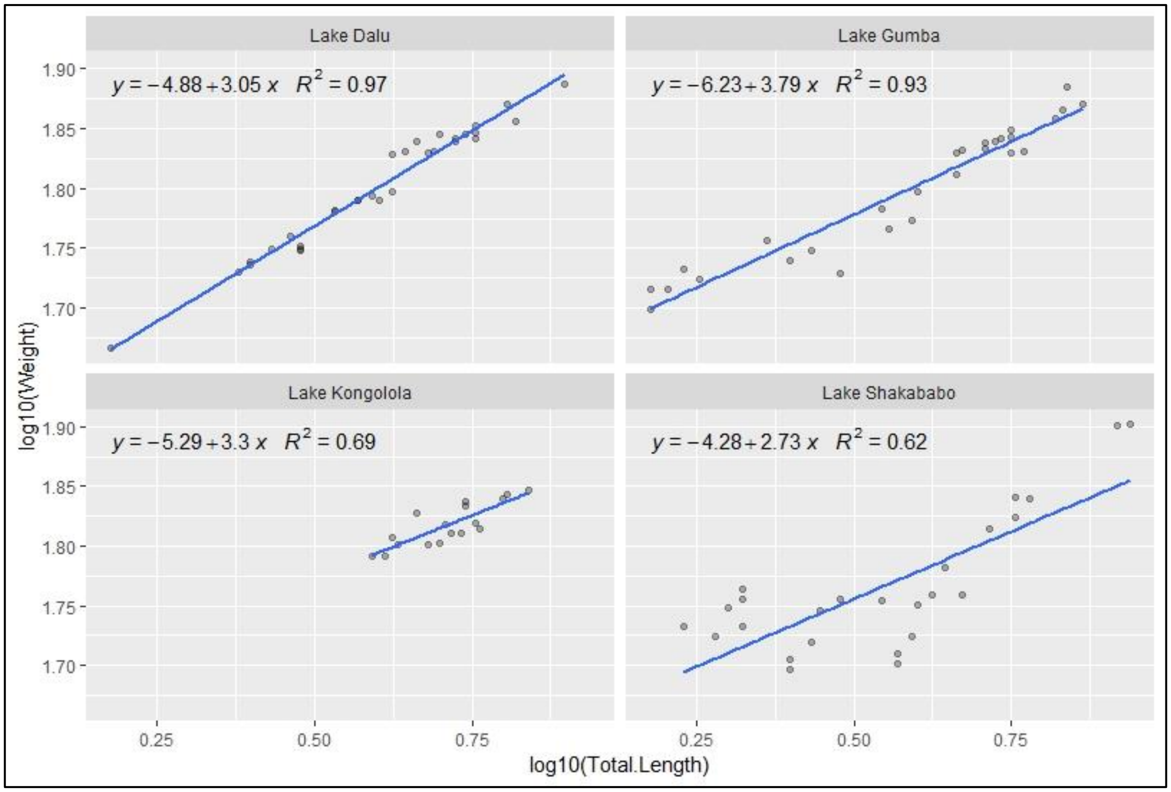

Figure 14: Length-weight relationship for *Oreochromis spirulus* in the four floodplain lakes

The mean TL and W for *L. gregorii* and *O. spirulus* were high at Lake Shakababo followed by lake Gumba (Table 10). Lakes Kongolola and Dalu had lower mean TL and W. Results showed that the correlation coefficient, b, values of *L. gregorii* and *O. spirulus* were significantly different across the sites ($p<0.05$). *L. gregorii* had the lowest b value of 2.25 at Lake Kongolola and the highest value of 3.13 at Lake Shakababo (Table 10). *O. spirulus* b values were highest at Lake Gumba and lower at Lake Shakababo. The calculated b values irrespective of sex were lower than or greater than 3 (b < 3> b), thus both species displayed an allometric growth pattern.

Table 10: Length - weight relationship of *Labeo gregorii* and *Oreochromis spirulus*
b = growth exponent; R2 = correlation coefficient

Species	Site	Mean Total Length	Mean Weight	b	R^2
Labeo gregorii	Lake Dalu	9.60	18.40	2.81	0.93
	Lake Gumba	11.57	31.39	3.02	0.94
	Lake Kongolola	10.44	23.17	2.25	0.70
	Lake Shakababo	11.64	43.61	3.13	0.98
Oreochromis spirulus	Lake Dalu	4.56	3.83	3.05	0.97
	Lake Gumba	6.29	6.96	3.79	0.93
	Lake Kongolola	5.54	4.29	3.30	0.69
	Lake Shakababo	7.52	9.72	2.73	0.62

4.2.5.2 Relative condition factor (Kn)

The mean condition factors (Kn) of *L. gregorii* and *O. spirulus* sampled in each floodplain lake are shown in Table 11. Fish samples were not separated for both sexes. Results indicated that there were significant differences in condition factors for the two fish species in the four floodplain lakes ($p<0.05$).

Table 11: Relative condition factor (Kn) values for *Labeo gregorii* and *Oreochromis spirulus*

Species	Lake Dalu	Lake Gumba	Lake Kongolola	Lake Shakababo
Labeo gregorii	1.46	1.93	1.62	2.01
Oreochromis spirulus	1.79	1.97	1.86	2.32

The two fish species from Lake Shakababo were in best condition (Kn=2.01 and Kn=2.32). Similarly, fish species from Lake Gumba were equally healthy with mean relative condition of 1.93 and 1.97 for *L. gregorii* and *O. spirulus,* respectively. Despite the lowest mean condition factors at Lakes Dalu and Kongolola. The fish were still relatively healthy, suggesting that fish in these floodplain lakes were generally in good body condition.

4.2.6 Correlation of water quality, lake morphology and fish distribution

Pearson's correlation matrix was used to explore the relationships between water quality characteristics, lake morphology and fish distribution (Table 12). All water quality characteristics except temperature had high correlation coefficients. Temperature showed no significant correlation with electrical conductivity (EC), water clarity, dissolved oxygen (DO), lake surface area, water depth, fish abundance, and salinity ($p>0.05$).

EC significantly but negatively correlated with water clarity ($r = -0.946$, $p<0.01$). EC also negatively correlated with DO ($r = -0.853$), however, the relationship was not significant ($p>0.05$). EC however had a significant positive correlation with salinity ($r = 0.841$, $p<0.05$). Similarly, it significantly but negatively correlated to fish abundance ($r = -0.95$, $p<0.05$).

Water clarity had a positive significant relationship with lake surface area ($r = 0.91$, $p<0.05$) and water depth ($r = 0.95$, $p<0.05$). It was also positively correlated to fish abundance ($r = 0.99$), which was highly significant ($p<0.001$).

Fish abundance positively correlated with DO ($r = 0.857$, $p<0.01$), and water depth ($r = 0.94$, $p<0.05$). Of the water quality characteristics, EC had a negative correlation with lake surface area ($r = -0.780$) and water depth ($r = -0.827$) but this relationship was not significant ($p<0.05$)

Table 12: Pearson Correlation matrix between water quality, lake morphology and fish abundance

	EC (µSm-1)	Water clarity (cm)	DO (mgL-1)	Lake surface area (ha)	Water depth(m)	Fish Abundance	Salinity(ppt)	Temperature (°C)
EC (µSm-1)	1.000							
Water clarity (cm)	-0.95**	1.000						
DO (mgL-1)	-0.853	0.837	1.000					
Lake surface area (ha)	-0.780	0.91*	0.460	1.000				
Water depth(m)	-0.827	0.95*	0.630	0.99***	1.000			
Fish Abundance	-0.95*	0.99***	0.857**	0.895	0.94*	1.000		
Salinity(ppt)	0.841*	-0.622	-0.707	-0.347	-0.405	-0.634	1.000	
Temperature (°C)	0.276	-0.138	-0.653	0.279	0.176	-0.174	0.503	1.000

Correlation significance at *0.05, **0.01, and ***0.001 level (2-tailed); EC=Electrical Conductivity; DO=Dissolved Oxygen

4.3 Annual fishing patterns and fisheries governance

4.3.1 Socio-demographic characteristics of the fisher-folk

A total of 32 respondents engaged in fishing or fish marketing were interviewed. Most of the respondents were found in Lake Shakababo (41%), Lake Gumba (28%) and Kongolola (25%) as shown in Table 13. Lake Dalu had been invaded by dense shrubs of Prosopis juliflora, which hindered movement by boats and the fish resources were quickly depleted by large flocks of piscivorous birds. Fishing opportunities were therefore limited.

Table 13: Distribution of fisher folk in the study sites located in the Tana Delta

Variable	**Category**	**Number of respondents**	**% Frequency**
Fishing site	Lake Shakababo	13	41
	Lake Gumba	9	28
	Lake Dalu	2	6
	Lake Kongolola	8	25
	Total	**32**	**100**

Out of all the respondents interviewed within the study sites during the period between June 2018 and February 2019, 81% were men while 19% were women (Table 14). Most of the respondents (79%) were over 24 years with the rest being adolescents working alongside adult men and women. School-going children were actively engaged in fishing alongside adult fishermen during the school holidays.

Although the majority of the respondents (63%) were married, a significant proportion of them (37%), especially women were single either because they had been divorced (24%) by their former husbands or had not decided to get married (Table 14). This situation was replicated in all fish landing beaches in the studied flood plain lakes in the Tana Delta.

Fishing was a full time livelihood activity for 54% of the respondents interviewed in the studied flood plain lakes of the Tana Delta (Table 14). However, 44% of the respondents indicated that they were engaged in fishing on a seasonal basis, especially shortly after the floods when fish were perceived to be abundant in the flood plain lakes. However, small scale fishing continued to meet household protein needs until the flood plain lakes dried out.

Table 14: Social demographic characteristics of the targeted fisher folk in the Tana Delta.

Characteristic	Category	Number of respondents	Relative frequency
Gender	Male	26	81
	Female	6	19
Age	< 24 years	7	79
	> 24 years	25	21
Marital status	Married	20	63
	Divorced	8	24
	Unmarried	4	13
Fishing cycle	All year round	17	54
	Seasonal	15	46

The study revealed that fishing majorly done by men (81%), while women engaged in fish processing and marketing. Engagement in fishing was partly influenced by traditional beliefs as mentioned by one fisherman;

> *"In our custom, women are discouraged to get into water to fish except when it floods in the farmlands. Then we can collect fish for food. Once my husband does*

fishing, I receive the fish at the landing site, assist with processing and selling. I am also a custodian of some of his money."

It was observed during the study period, many women traders buying fish at landing sites. Interview with two women fish vendors at Lake Gumba revealed that majority of them in the area receive fish from their fishing husbands. They also indicated that a larger number of women fish vendors provided income for their families. Women fishers located fishing sites by calling male fishers to inquire about fish availability. Others reluctantly said it depended on one's relationship with the fisherman. In fact, one woman described how most of them were lured into sexual relationships for them to be assured of fish supplies. However, fishermen seemed not to concur, they said due to lack of storage facilities they had to maintain a reliable fish vendor who could collect fish on time. Some fishermen also reported exploitation from women fish vendors; they said women would indirectly coerce them to sell fish at lower prices in exchange for sexual favours.

Nearly half (46%) of fisher-folk interviewed reported that they undertook fishing on a seasonal basis alongside other livelihood activities. Majority took up fishing when it flooded to take advantage of the abundant fish and cover for the other livelihood sources that were untenable at that time.

4.3.2 Fisheries patterns

4.3.2.1 Knowledge on fish behavior in relation to floods

When asked to explain fish behaviour in relation to flooding, majority of fisher-folk members believed that fish breeding season started at the onset of long rains in April - June. They explained that fish spawning and feeding continued as floodwater rose in June - August. Once the river overflowed and inundated the floodplain, juveniles colonized the flooded grasslands for food and shelter. In addition, some fisher-folk said that adult fish tended to forage along the main river. As the flood water receded in August through September 2018, the widely dispersed fish in the floodplain started returning to the main river channel. Majority of fish however, remained confined in isolated pools due to lost connectivity where intensive feeding, faster growth, and higher mortality due to bird predation and degraded water quality ensued.

4.3.2.2 Fishing and fisheries patterns in relation to floods

When asked about fishing patterns in response to flood dynamics, majority of fisher-folk interviewed stated that fishing was more profitable during dry season in January – April. During this period fishing activities were confined along River Tana main channel and permanent floodplain water bodies such as Lake Moa. During the focused group discussion at Lake Shakababo, it was found that floods created diverse habitats in the delta that consequently attracted different fish species (Table 15).

In addition, fisheries activities were said to vary with location and season. Experienced fisher-folk fishing for commercial purposes mentioned they were willing to invest in appropriate fishing gear to supply fish throughout the year. Some mentioned they went as far as Tana estuary and into Indian Ocean to fish until when river water level rose again. A seasoned fisherman at Lake Shakababo indicated that at peak flooding both women and children joined in fishing using a variety of gears, including makeshift forms, such as buckets to scoop fish in isolated pools.

Table 15: Common fish species identified by fisher-folk

Local name	English name	Scientific name
Borode/Chika	Gregori's Labeo	*Labeo gregorii*
Ngogo/Korokoro	East coast/Tana squeaker	*Synodontis sp.*
Pawa	Silver Catfish	*Schilbe intermedius*
Parapara/Ntuku	Sabaki Tilapia	*Oreochromis spirulus*
Tonzi	Sharp-tooth catfish	*Clarias gariepinus*
Mpumi	Wide-headed catfish	*Clarotes laticeps*
Mpumi hwahwa	Somalian giant catfish	*Pardiglanis tarabini*
Mchokole/Njumburi	Tank goby	*Glossogobius giuris*
Kamongo	Lungfish	*Protopterus sp.*
Mbelewele	Tana Bulldog	*Marcusenius devosi*
Kwakwa	Red-fin robber	*Brycinus sp.*

4.3.3 Fishing gear used by local fishermen

When asked which type of gear used in different seasons, fisher-folk indicated that they used active gill netting and drag net fishing (Figure 16) when water levels in the floodplain lakes were low. They explained further that benthic dwelling fish such as *Protopterus sp.*, *Clarotes laticeps* and *Clarias gariepinus* were caught using baited hook and line. Subsistence fisher-folk explained that as the river water spilled laterally into the floodplain, they started using traditional fishing methods more frequently (Table 16).

Figure 15: Fishermen using a drag net at Lake Gumba

Table 16: Summary of various traditional fishing methods in Tana Delta floodplains

Gear type	Mode of operation	Target species	User	Period
Drag net (Fig. 18a)	Active	Gregori's Labeo; Silver Catfish; Tilapia; Red-fin robber	Men	Pre-flood Post-flood
Basket trap 'Mgono' (Fig. 18b)	Passive/Barrier gear when water is moving	Sharp tooth catfish; Lungfish	Men	During flood
Gill net	Passive	All	Men	During flood Post flood
Spear	Active	Sharp tooth catfish; Lungfish; Wide-headed catfish; Somalian giant catfish	Men	Pre-flood
Hook and line	Active; Passive in some occasions	Sharp tooth catfish; Lungfish; Wide-headed catfish; Somalian giant catfish; large Tilapia	Men	All time
Mosquito net	Active	All fish trapped in farmland water pools	Women	During flood
Scoop buckets	Active	Trapped fish	Women & Men	All time

Though not mentioned by fisher-folk interviewed for fear of victimization, mosquito nets were widely used for fishing in June – July period when the entire floodplain and farmlands were inundated. Fisher-folk stated that fishing activities intensified as flood water receded, a period when both women and children actively participated in fishing. Other fisher-folk mentioned that active gill netting became more profitable when flood water increased, however, they said there were higher risks of being washed away by the fast-flowing flood waters. Others said that during flood peaks in May – July period fish catches were low as fish are dispersed and water flow speed is usually high during this time. This is also a period local community identified as “Kusi”, a Southeast monsoon season when fish were said to be actively spawning.

4.3.4 Fish value chain

While discussing the role of women in fisheries at Lake Shakababo it was pointed out that majority of fish traders were women while fishing was almost exclusively done by men. Some women at the focused group discussion indicated that they own fishing nets and contract fishermen to do the fishing for them. In some instances of a fishing couple, the husband did the fishing while his wife processed and took the fish to markets. During field visits it was observed that fish was either sold fresh or dried by smoking before selling. During this study, most fresh fish were being sold at nearby markets such as Garsen and Minjila. Fisher-folk drying their own fish were targeting traders from far markets like Malindi, Takaungu and Kilifi where prices of dried fish were said to be better.

Women fish vendors at the focused group discussion indicated that they travel from village to village sourcing for the dried fish. Some fishermen who doubled as fish vendors would sell their catch at nearby markets. Fish was sold in bunches around the floodplain lakes (Figure 17) and the price of each bunch varied with species, size, and season. For example, at the time of this study, a bunch of fresh *Clarias sp.* was sold at approximately KES 100 (US$1) and a bunch of Tilapia at KES 50 (US$ 0.5) at fish landing site. Very few women fish vendors had cooler boxes to transport the fresh fish to markets. As such, motor bikes were deemed very useful for quick delivery of fresh fish to various markets nearby.

Figure 16: Bunches of *Oreochromis spirulus* and *Clarias gariepinus* sold at Lake Gumba

4.3.5 Fisheries management and governance

4.3.5.1 Existing governance structures

Majority of fisher-folk interviewed reported that access to fishing sites was not restricted during floods. But it appeared this was linked to the inaccessibility of floodplain as indicated by one fisherman;

> *"No one has control over fishing grounds although there are areas restricted by farmers. When the delta floods and fish migrate to floodplain lakes no one stops*

us from fishing. All roads are broken, and we cannot access important fishing zones anymore"

Some respondent fisher-folk, however, explained attempts by some village groups to restrict access to neighbouring lakes. A headman in Gumba village narrated how he mobilized village members to dig up a dyke that released floodwater from the nearby Oda channel into Lake Gumba. He explained that Lake Gumba had lost its connectivity almost a decade ago when Oda brook started receiving less water. Once they dug up the channel, the lake filled with water and became rich in fish. Consequently, only village members had privileged access to fish at the lake, perhaps indicating they owned the lake at that time. The lake therefore seemed to be locally governed and outsider fisher-folk were supposed to seek clearance from Gumba village headman though this was not strictly adhered to. The duration of control was, however, tied to seasonal flooding and specifically to fisheries activities.

At the start of this study in June 2018, County Government of Tana River (CGTR) facilitated digging up of Kisiki brook enabling yet another important and the largest floodplain lake in southern delta, Lake Shakababo, to fill with flood water. The county department of fisheries then restocked the lake with Tilapia fingerlings to enrich its fisheries. CGTR then implemented a closed season around the lake for a period of four months, reopening it to active fishing activities in October later that year. Majority of fisher-folk interviewed around the lake criticized the prolonged closure of the lake saying that should another flooding occur in November as it was expected, the adult fish would have easily migrated back to main channel. Some fishermen interviewed indicated that the village scouts employed to enforce the closure were instead using the motorboat provided to fish at night and selling the fish to far markets. Others said it was an uninformed decision at the time when majority of deltaic community were relying on food aid and fishing being the most immediate source of livelihood at that time. Despite the management intervention by CGTR, local community members were actively exploring possibilities of reviving Lake Shakababo Beach Management Unit which collapsed in 2008 when the lake completely dried. Many agreed that managing the lake as a community resource was better for its sustainability.

The other two floodplain lakes in this study, Kongolola and Dalu were entirely open access. However, they had very limited fishing activities. Local conditions around these lakes appeared to have imposed inadvertent fisheries governance. For example, across the floodplain, the weed species, *Prosopis juliflora*, commonly known as “Mathenge” prevented fishing activities while offering important fish breeding and spawning sites. Around Lake Kongolola, majority of residents were farmers and therefore were less involved in fishing activities. There were no operational Beach Management Units around the study floodplain lakes. This was attributed to lack of major flooding in the delta for over a decade that led to drying of all floodplain lakes in the area before 2018.

4.3.5.2 Role of Kenya Fisheries Service

Formerly the Fisheries Department, the Kenya Fisheries Service (KeFS)was responsible for the conservation, management and development of Kenya's fisheries resources as stipulated in Fisheries Management and Development Act, 2016. The service had some of its functions devolved to County Governments (Constitution of Kenya, 2010), where a county director of fisheries oversaw all fisheries activities within the County.

4.3.5.3 Role of County Government

The Fisheries Management and Development Act, 2016 mandated that county governments be consulted and kept informed of relevant fisheries management measures and processes undertaken by KeFS. Similarly, the counties were expected to collaborate with the Director-General (DG) of KeFS, in the management of fisheries. The counties were to ensure that the DG was informed, by effective means of communication, of relevant developments in relation to the management of fisheries within the county. Furthermore, the counties would develop fisheries management plans and submit them to DG-KeFS for endorsement.

In Tana River Delta, a sub-county fisheries officer represented the Tana River County Director of Fisheries. A fisheries officer based at Minjila trading centre was the lowest representative of KeFS within the study area. The fisheries officer had an overall fisheries management mandate in Tarasa and Garsen wards.

During an interview with the fisheries officer in June 2018, the role of ward fisheries officers in fisheries management and development was elaborated. Overall, it was said they were responsible for monitoring, surveillance, and control (MSC) and fish marketing and distribution. Still, the officers were responsible for compiling reports submitted to the sub-county fisheries officer monthly. The data captured in the report included: fish landings; fish marketing and distribution; events, incidences, and occurrences; staff matters; and challenges and constraints.

However, while discussing the implication of the new Act in fisheries management, the officer revealed that the service employees were yet to clearly understand the new fisheries management structure. Moreover, the county had not put in place appropriate mechanisms to sustainably manage fisheries resources. That is, inadequate and poorly serviced motorbikes and motorboats and inadequate staff hugely limited their capabilities to patrol and collect fisheries data. In addition, there were tendencies by the county government to delay salaries. The officer suggested the need to streamline reporting lines under the new Act. It was observed that while BMUs were the lowest fisheries resource user and conservation group in the county, they were working directly with KeFS at the national level. This was seen to be excluding county fisheries department that was crucial in funding and implementing various fisheries activities at the county level.

When asked the role of floods in sustaining fish resources in the delta, the officer agreed floods are important in replenishing floodplain lakes with fish. However, it was difficult to quantify the amount of fish harvest during that period because many areas became inaccessible during floods. Moreover, locals used diverse methods (Table 16) mostly traditional systems that were not regulated.

4.3.5.4 Traditional mechanisms of fisheries resource governance

When asked to describe existing traditional methods in fisheries governance, many fisher-folk members could not expressly state such methods. A discussion with an elderly fisherman at Lake Shakababo, however, revealed some traditional regulations that existed in the last four decades. There were temporal fishing restrictions to certain areas of the lake around the month of June. It was known that these were fish spawning and breeding areas. Further, there existed a fishing access restriction in some lakes in the larger delta. For example, a fisher-folk from outside Tarasa area would first seek permission from the village headman to be allowed to fish at Lake Shakababo.

In an interview with another fisher-folk at Lake Gumba it was indicated that some gear types were restricted at certain seasons. For instance, drag nets and gillnets of below one-inch mesh size were discouraged in all fishing sites. Also, there were agreements on the number of drag nets that could be drawn at a lake in a day. This, as explained by one fisherman was to reduce overexploitation of the fishery resource. However, these agreements were frequently flouted; the rapidly shrinking lake and presence of thousands of piscivorous birds implied high competition for the readily available fish.

Nevertheless, it seemed that knowledge of traditional fisheries governance methods was dependent on fisher-folk age and tribe. Fisher-folk from the traditionally fishing communities in the delta, Luo, Luhya and Pokomo, were more conversant with these methods. Similarly, the elderly fisher-folk were able to explain these customary methods that had since been abandoned in favour of BMU regulations. Alluding to this, a fisherman at Tamaso area on the Matomba side of the delta mentioned that majority of current fishermen were a young generation that took up fishing after the last El Nino flooding event in 1997-1998. Apparently, many fishers were not aware of the customary methods of regulating fishing activities in the delta.

Figure 17: Interview with a fisherman at a fishing camp in Tarasa area of Tana Delta

4.3.5.5 Fisheries conflict resolution mechanisms

Conflicts relating to access to fishing zones were said to be more intense during dry season. It was reported that some fisheries conflicts were indirectly aimed at protecting boundaries. For instance, a fisherman at Lake Gumba said that they were not comfortable with some pastoralists who had camped next to the lake with large herds of sheep and goat since it refilled with water. This was viewed as an indirect attempt to take over the lake denying them an important fishing site.

Conflicts relating to incursion by experienced non-local fisher-folk were also mentioned. During prolonged drought situation, fisher-folk migrated to various parts of the delta to access important fishing sites. Usually, the migrating fisher-folk possessed better fishing gear and were more versed to fish behaviour. Local fisher-folk were in most cases prepared to protect their fishing sites and occasionally confiscated intruders fishing gears. Interview with a village headman around Lake Shakababo revealed that contrary to other livelihoods in the area, fishers had not experienced much conflicts. Although there were conflicting interests in controlling fishing sites, this had always been kept lower due to the seasonality of floodplain lakes. Furthermore, fisher-folk migrated once the lakes dried leaving farmers and pastoralists to utilize the land.

When asked to explain ways in which conflicts were resolved, majority of fisher-folk said they reported to village headmen. The headmen together with other elders would then arbitrate and solve the issue. In some instances, the cases were reported to local administrators such as sub-chief and chief. Elsewhere, around Lake Moa, the local Beach Management Unit was actively handling all issues relating to fisheries governance and conflict resolution.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Fish biodiversity and abundance in Tana Delta floodplain lakes

The floodplain lakes of the Tana River Delta are diverse socio-ecological systems (Terer *et al*., 2004; Hamerlynck *et al*., 2010; Leauthaud *et al*., 2013; Mukhwana *et al*., 2016) important for biodiversity conservation, provision of ecosystem services and sustainability of socio-economic livelihoods. The delta is characterized with endemism both in plant diversity (Luke *et al*., 2005) and fish (Nyingi, 2013). Furthermore, the entire floodplain depends on frequent river flooding for supply of freshwater, sediments and nutrients that provide important fishing ground and grasslands for livestock production. Despite its recognition as a wetland of international importance (Ramsar, 2012), the delta continues to face numerous threats. Many include development schemes in areas of hydropower generation, water supply and irrigation schemes that have had severe impacts on its hydrology and associated ecosystem services (Maingi & Marsh, 2002).

Temporal variability in hydrological regimes is the major driving force that maintains the functioning of floodplain ecosystems (Welcomme, 2008, Hamerlynck, 2011; Leauthaud *et al.*, 2013). Furthermore, it has been shown that floodplain inundation may cause conditions that are either suitable or intolerable for the survival of individual fish species (Amoros & Bornette, 2002; Arthington & Balcombe, 2011). In the Tana River Delta, however, this study found that the floodplain lakes present a highly suitable ecosystem for some animal species, particularly fish. The relative abundance of major fish species sampled did not vary over the sampling period but rather spatially in the four studied floodplain lakes (Table 8). Diversity of floodplain wetlands and environmental variables has been reported (Araújo *et al.*, 2009) as major drivers of change in tropical floodplain fish community assemblages. Moreover, the diversity of the floodplain lakes is dependent on habitat types, lake morphological and water quality characteristics, distance to the main channel and frequency and duration of flooding (Amoros & Bornette, 2002; Hamerlynck *et al.*, 2011; Karim *et al.*, 2012).

On closer inspection, species richness in the four floodplain lakes was also found to be evenly distributed with 10 out 15 species sampled occurring in all the lakes (Table 9). These results indicated that floodplain inundation provided a major channel for fish movement and mixing between the floodplain habitats and main river channel. A study by Thomaz *et al.* (2007), similarly reported that floods increase homogeneity in floodplain aquatic habitats. Further assessment of fish caught in the four floodplain lakes revealed a pattern of benthopelagic species (Appendix II). Bentho-pelagic fish species inhabit both the bottom and column of a water body. Some of these species are intermediate, reproducing both in lotic and lentic habitats of the river floodplains. The flood pulse model postulates that floods act as cues for the initiation of fish breeding. Junk *et al.* (1989), notes that flooding opens floodplain habitats and resources that are used by the larvae, juveniles and mature stages of many species as feeding and nursery grounds.

Even though this study did not sample fish community in main river channel, floodplain lakes have been found to maintain river channel populations (Junk *et al.*, 1989). This is done when the floodplain is connected through flooding that increases fish migration resulting in increased fish production and diversity in the river systems. Thus, the supplemental function of floodplain lakes to main river fish populations requires sustained connectivity of the river main channel and floodplain lakes.

Studies have shown that floodplain lake distance from the main river could positively correlate with fish diversity and abundance (Louca *et al.*, 2009; Shoup & Wahl, 2009). Floodplain lakes are naturally unstable ecosystems that are frequently disturbed by floods (McConnell & Lowe-McConnell, 1987). It is assumed that those pools further away the main channel are more stable due to lower flood intensity if they are deep enough to retain water for longer periods. However, this study could not out rightly correlate this. Lake Gumba and Lake Shakababo showed no distinct variation in fish species assemblage despite being located 0.15 km and 3.8km, respectively from the main channel. The increase in relative abundance of species and Shannon-Weiner diversity indices at these two floodplain lakes however, indicated they were more stable than Lake Dalu and Kongolola. Lake Shakababo and Gumba were deep enough and lost less water through evaporation. Rather, several human-induced disturbances around these lakes shaped their morphology and habitat types. For example, efforts to dig up dykes and blocking water from flowing back to main channel could have facilitated or impeded species mixing at the same time. The local catchment around also contributed to the ability of the floodplain lakes to receive and retain water for longer periods. Floodplain lake surface area however, showed significant influence on fish diversity and abundance.

In conclusion, this study supports findings by Amoros & Bornette, (2002) that single metrics like in this case distance to main channel may not be enough to assess floodplain hydrological connectivity and associated biocomplexity. Several other aspects such as connection frequency, flow velocity and water permanency are particularly important in fish species distribution.

5.2 Ecological significance of floodplains in fish biodiversity conservation

Most aquatic organisms require access to diverse habitats in their life cycle to meet requirements of different life history stages (Bayley, 1988; Tockner & Stanford, 2002). In this regard, a variety of habitats must exist, and organisms must be able to migrate between them. Moreover, migration requires that connectivity between aquatic habitats is maintained.

During this study, a total of 15 fish species were sampled representing 33% of the total fish species that have been recorded in lower Tana River and its floodplains (Seegers *et al.*, 2003; Nyingi, 2013). However, direct comparisons with previous studies was not appropriate because, in this study fish sampling was exclusively done using monofilament gillnets which might have excluded fish species of certain sizes, morphology and which were not active swimmers. Gillnets have been found to be selective in catching fish of certain girth sizes and length (Hamley, 1975). In addition, two of the floodplain lakes, Dalu and Kongolola, were heavily invaded by invasive weed, *Prosopis sp.*, bushes that limited fish sampling. Besides, increased predation by hundreds of piscivorous birds was also observed.

That notwithstanding, among the 15 species sampled, Red-tail labeo (*Labeo sp.*) was listed as vulnerable under the International Union for Conservation of Nature (IUCN) red list. This species was still undescribed and had been reported as possibly endemic to the lower Tana River (Nyingi, 2013). In addition, *Synodontis zanzibaricus, Marcusenius devosi* and *Paraillia somalensis* was listed as data deficient while *Synodontis serpentis* had not been evaluated and therefore their conservation status was unknown. Moreover, the higher relative abundance (Table 7) for both species reported as migratory and non-migratory (Appendix II) showed that the floodplain lakes were very important for fish biodiversity conservation. Gregori's labeo *(Labeo gregorii),* Zanzibar barb *(Enteromius zanzibaricus),* Red-fin robber *(Brycinus affinis)* and Sabaki tilapia (*Oreochromis spirulus)* species had higher relative abundance in the floodplain lakes (Table 7). These species are generally herbivores and invertivores; a trophic category sustained by floodplain habitats. *L. gregorii,* is a highly migratory species that first colonizes the floodplains for spawning and nursey habitats. This was explained by the high relative variations in its length and weight measurements taken during this study (Figure 13).

5.3 Fish growth patterns and body condition in the floodplain lakes

This study revealed spatial variation in fish wellbeing across the floodplain lakes (Table 11). In all the four floodplain lakes, trends toward poorer fish body condition was observed for less diverse lakes, connected to the river main channel for the shortest period and of poor water quality characteristics. Not surprisingly, the mean sizes of the most abundant fish species were higher at lake Shakababo and Gumba than at Dalu and Kongolola (Table 10). Probably, the larger surface area and depth of these two lakes meant better water quality and foraging conditions for the fish. Similarly, the high abundance of fish species sampled at Lake Shakababo and Lake Gumba could be associated to their stability. The two lakes had minimal changes in their morphology and water quality characteristics during the study period. Habitat characteristics and lake morphology have been reported to influence fish growth in floodplains (Thorp *et al.*, 2006). These variables directly contribute to the stability of floodplain lakes and have also been shown to influence floodplain fish growth in the Zambezi River floodplain (Winemiller & Jepsen, 1998).

Length-weight relationships for the selected species indicated positive linear correlation (Figures 13 and 14). However, in this study the sampled fish were not sorted into males and females. As a general pattern, the two selected fish species exhibited allometric growth ($b < 3 > b$) in the floodplain lakes (Table 10). In allometric growth, fish become thinner with increase in length. This agreed with the expected range for most tropical fish species is $2.5 < b < 3.5$ (Froese, 2006). Results that *Oreochromis spirulus* showed uneven growth pattern (Figure 14) in the length-weight relationship at Lake Shakababo is an indication of increased competition and possibly hybridization with the introduced *Oreochromis niloticus*. *O. niloticus* are invasive in nature and can hybridize native species (Eknath & Hulata, 2009). For example, Nile tilapia stocks mistakably introduced to boost fisheries in Lake Victoria and those that escaped from aquaculture farms from the lakes catchment have hybridized and almost entirely displaced the endemic *Oreochromis esculentus* (Lowe-McConnell 1982 cited in Eknath & Hulata, 2009). Generally, growth exponent (b values) and fish body condition (Kn values) obtained in this study indicated that the floodplain lakes provided more favorable environment for fish growth and reproduction.

5.4 Significance of seasonal rainfall and hydrological connectivity

Flooding in the lower Tana River occurs twice a year because of bimodal pattern of precipitation experienced in the river's catchment area (Leauthaud *et al.*, 2013). These two flood seasons, appears to be highly variable and, in some years, may not inundate the entire floodplain. During this study, the first flooding event occurred between June to late August 2018. The second and short flooding event occurred in November and early December 2018. Although overbank flows were observed to majorly cause floodplain inundation, initial local rains in the floodplains prior to flooding first soaked the soil surface and thus hastened surface run-off.

Nevertheless, lateral connectivity was found to be a key driver in determining how much water each floodplain lake received. Three hydrological phases of river-floodplain connectivity were deduced in the four floodplain lakes studied (Table 4). First, the connectivity phase was characterized by overbank flows that lasted between June to early September. This connectivity phase varies depending on the flood pulse which is also known as the 'transport phase' (Junk *et al.*, 1989). This is a period of material exchange between floodplain lakes and main river. Hence, organic matter accumulated in the floodplain in dry period was mobilized and turned floodplain lakes into heterotrophic condition (Tockner *et al.*, 1999). Further, Winemiller & Jepsen, (1998) expounds that the connection of lakes with the main river channel during peak floods provides the input of well-aerated river water, which protects the lakes against degradation. Alluding to fish species recruitment, Winemiller (2004) explained that increasing river discharge to the floodplain lakes enhances lateral movement of fish between the river channel and floodplain habitats.

The second phase was termed intermediate, a phase characterized by little surface connection with the main channel. Furthermore, the lakes were more open and of high water transparency. The third phase, disconnectivity, was characterized by still waters of lentic type. According to Tockner et al. (1999), disconnectivity phase is a period of limiting nutrients and primary productivity in the floodplain ecosystems.

During this study, it was also observed that floodplain topography influenced the flow velocity, duration of inundation and connectivity across the floodplain lakes. For example, the faster loss of connectivity at Lake Gumba was primarily due to the higher bank height of the main river. These findings support similar observations made by Karim *et al*. (2012) in the tropical floodplains of Australia. All the four floodplain lakes in this study had remained dry, with only partial inundation during the last decade until the major flooding of 2018. They were therefore relatively new habitats with unstable biological interactions. While this is true, it could still be argued that fish colonization of the floodplain lakes of River Tana occurs between June – August period when frequency and duration of connection is greatest.

5.5 Impact of changes in water quality on floodplain fish assemblages

During this study, significant variation in water characteristics, which could be attributed to changes in water depth and degradation of organic matter in the floodplain lakes was observed (Table 5). Variability of water quality characteristics because of changes in hydrological connectivity influence fish species growth and assemblage in floodplain ecosystems (Amoros & Bornette, 2002). Conductivity, pH, dissolved oxygen, salinity, and water clarity were noted to have strong influences on fish distributions in the floodplain lakes (Table 12).

Electrical conductivity was negatively correlated with total fish abundance across the floodplain lakes. Lake Dalu and Kongolola had higher conductivity, which also varied most, compared to Lakes Gumba and Dalu. Likewise, the two lakes were shallow and had receded into small water pools in pre-flood season. A similar study in the floodplain lakes of River Rufiji had shown that conductivity was most likely related to floodplain stability and negatively affected fish diversity and abundance (Hamerlynck *et al.*, 2011). In contrast, water clarity (measured using turbidity tube) and dissolved oxygen were positively correlated to total fish abundance. Water clarity (turbidity) is likely to influence fish abundance by obscuring visibility thus reducing foraging ability and increasing predatory risks (Bonner & Wilde, 2002). Highest fish abundances were also found at the deeper lakes (viz. Lake Shakababo and Lake Gumba). Once disconnected in post flood period, floodplain lakes tended to be more saline and had higher conductivity values. Fish abundance has been suggested to increase because deep lakes are more resistant to evaporation (Winemiller *et al*. 2000).

5.6 Floods, Fisheries and Livelihoods

Fishing in the lower floodplains of Tana River is an important source of livelihood to the deltaic communities. It was revealed that the floodplain lakes were valuable sources of fish, a common shared resource. The results of this study indicated fishing was majorly carried out both on permanent and part-time basis. Those who practiced part-time fishing, did so to supplement other livelihood activities such as farming and livestock rearing. Similar trends of fisheries utilization have been reported in the Upper Zambezi floodplains (Abbott *et al.*, 2007).

Fish supply in the floodplain lakes of Tana River Delta was highly dynamic. Fisher-folk said that fish was higher after flooding periods. However, no catch data were available for floodplain lake fisheries. As explained by the local fisheries officer, access to the floodplain was limited during periods of flooding. The seasonality of these floodplain lakes had further caused scarcity of larger and high-value species, such as Lung fishes and Cat fishes that were especially targeted for commercial markets by fisher-folk. The loss of connectivity with the main river channel due to infrequent flooding was the major reason for floodplain lake drying. In addition, construction of barriers to block water from entering floodplain lakes by certain community members with competing interest on the use of the floodplain for farming further exacerbated the problem.

The Tana Delta fisheries were dominated by men fishers in the floodplain lakes while women processed, marketed, and sold fish as they could obtain at the fish landing sites. It also appeared women had become highly adaptive in exploiting fisheries resources during flooding. A case in point was when they optimized fishing effort by using illegal fishing gears, such as mosquito nets to harvest fish in shallow water pools surrounded by farms. Findings concerning fisheries exploitation in the eastern floodplains of Caprivi in Namibia (Purvis, 2002.) also reported that at peak floods all family members participated in fish harvesting. Similar observations were made in Tana River floodplains where women and children would fish for daily consumption and to supplement family income.

Several reasons could explain the success of women in fish trading. This study found that majority of women fish traders relied on fish supply from their fishing husbands while cases of transactional sex were also reported. Against this backdrop, women traders had also become more innovative in ways of sustaining their fisheries activities. One such means was said to be through informal cooperative movements locally known as 'chamas' that would provide financial support. On the other hand, reasons given for men's prowess in fishing were closely associated to masculinity. While giving a detailed account of gender and development in south Indian fishery, Hapke, (2009) explained that women do not just engage in the actual harvesting of fish, it is also an insult to men's masculinity if women, understood as the "weaker" sex, assist in any way. In Tana River floodplains however, these observations further appeared to be reinforced by strong underlying cultures. These cultural attitudes toward women fisher-folk appeared complex and entrenched on many levels in the various ethnic groups of the floodplain. For instance, among the Pokomo ethnic group, women were said to be a sign of bad luck at the fishing sites when they do fishing.

5.7 Conservation and management of Tana River floodplain fisheries

The Tana River Delta communities lived in harmony with the ecosystem, practicing conservation informed by traditional knowledge systems (Terer *et al.*, 2004). Findings of this study further revealed floodplain lakes were previously managed at village level using customary rules. Management regimes because of customary rules were broadly limited to restriction on certain gear usage, conflict resolution mechanisms and access rights to fishing zones. The study also revealed that such regulations were rarely adhered to. However, during this study, formal governance was predominant and conducted by Kenya Fisheries Service (KeFS), County Department of Fisheries and Beach Management Units. Considerable effort had gone into establishing adaptive strategies, such as delineating important fishing zones and forming BMUs at every fish landing sites (Government of Kenya, 2016). While this is true, operationalizing such mechanisms in the studied floodplain lakes had been difficult owing to the seasonality of the lakes.

Accordingly, conservation and management of fisheries including enforcing regulations in the entire floodplain was the responsibility of both county and national governments, but their capacity to do this effectively was limited. Comments from fisher-folk also indicated that the government seemed only interested in revenue collection through trade and fishing licenses. Very little effort had been done to improve fishermen and women traders' welfare. Most fishermen lacked appropriate fishing gear and fish storage facilities. Purvis *et al.* (2003) and Abbott *et al.,* (2007) reported similar challenges concerning lack of government commitment in managing and regulating fisheries activities in the floodplains of Upper Zambezi River in Botswana and eastern floodplains of Caprivi in Namibia, respectively.

Another important finding of this study was the interest the County Government of Tana River (CGTR) had taken in revamping the fisheries at Lake Shakababo. The concerted efforts to bring back water into the lake were a positive indicator that the lake would become permanent just like Lake Moa in eastern part of the delta. Furthermore, restocking the lake with the commercially important Nile tilapia meant it was going to be a productive fishery in future. However, this study raised concern (see section 5.1.3) that tilapia introduction was likely going to have an impact on the lakes fish species diversity and probably to the other floodplain lakes when connectivity is restored. Nile tilapia are invasive in nature and can hybridize with native species (Eknath & Hulata, 2009).

While the intentions of CGTR seemed genuine, it appeared they overlooked an important aspect in managing community resources. Local fisher-folk reported they were not involved in planning for introductions and enforcing closed fishing period in Lake Shakababo. Involvement of local community enhances a strong sense of ownership and commitment in sustainable management of resources. The fact that at the time of this study local fisher-folk and other lake users were mulling forming a Beach Management Unit (BMU) around Lake Shakababo further reinforces their intention to manage the lake by themselves. Food and Agricultural Organization (F.A.O) has recommended community based natural resource management to curb overexploitation of small-scale fisheries resource and improve governance (F.A.O, 2003)

5.8 Hindrances to sustainable utilization and conservation of fisheries

The four floodplain lakes under this study were seasonal and not under Beach Management Units (BMUs). BMUs as a co-management system are mandated to prevent or arbitrate conflicts in the fisheries sector while sustainably conserving fisheries resources. Their absence therefore meant the government had the sole responsibility of fisheries management around the studied lakes. Like any other natural resource management program, lack of community participation was likely to lead into more conflicts and unsustainable utilization as was already being reported at Lake Shakababo.

During this study, several inadvertent limitations to sustainable utilization and conservation of fisheries in the floodplains were also reported. These included: inadequate capital to buy quality and appropriate fishing gear; lack of cold storage facilities; traditions barring certain genders in fish harvesting; and some cultures also reportedly denounced eating certain fish species. Similarly, environmental conditions such as the prolific spread of *Prosopis sp.* bushes and poor condition of roads linking villages limited fisheries exploitation.

There were also competing interests from alternative livelihood systems such as farming and livestock rearing on the use of the floodplain. This was particularly reported at Lake Shakababo where members of Pokomo ethnic group, traditionally farmers, attempted to block the brook that brought in flood water from the Oda channel. They preferred using the lakebed for farming instead.

The extended dry periods in the recent past coupled with almost no major flooding led to extensive shift in livelihood systems in the floodplains. In this regard, exploitation of fishery resource seemed to be the immediate alternative to augment dwindling fortunes from farming activities and livestock production. As a result, increased commercialization of fishery due to increasing demand was reported.

Issues relating to transactional sex, though not freely discussed, could lead to higher prevalence of HIV-AIDS thus weakening labor force in fisheries sector. The economic vulnerability of female fish traders is often seen as the driver for participation in transactional sex (Béné & Merten, 2008). Women fish traders are often competing to access fish stock; this is particularly during lean seasons when demand for fish is high.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDANTIONS

6.1 Conclusions

The purpose of this study was to establish the impact of river flooding on fish biodiversity and abundance, and the patterns of utilization of fisheries resources by local communities in the River Tana Delta. This was accomplished by studying four floodplain lakes over a period of eight months spanning through pre flooding, flooding, and post flooding.

First, this study investigated how the hydrological connectivity of the floodplain wetlands affected fish diversity and abundance. The results found insignificant seasonal variation in fish species abundances with seasonal hydrological connectivity showing inconsistent association with fish species abundance. Although, this study never investigated species specific use of the floodplain wetlands, the general patterns indicated that Tana River floodplains were critical in sustaining fish diversity of the main channel; the diverse habitats were important for fish spawning, breeding and juvenile foraging.

Secondly, this study determined how fish diversity in floodplain wetlands of Lower Tana varied with space and season. Generally, results indicated that fish species distribution was mostly associated with habitat quality and morphological characteristics of the studied floodplain lakes. Similarly, this study found that habitat quality was key in shaping floodplain fish community assemblages. Moreover, floodplain lake morphology appeared to have strong associations with fish species richness and abundance. Higher values of species richness and abundance were found at lakes that were deep enough (3-5m) and had large surface area.

Lastly, this study investigated the influence of seasonal flooding regimes in the floodplain lakes on fishing activities. Based on the information collected on fisheries patterns, it was concluded that livelihoods were greatly affected when floodplain lakes dried out. Furthermore, the abundant and multispecies nature of floodplain fisheries were exploited using different gears both for subsistence and commercial purposes. However, there was an urgent need to institute a functional co-management system through Beach Management Units for the fisheries resources of the lower Tana River floodplain lakes.

6.2 Recommendations

Further research

- This study recommends further research in understanding specific factors that determine fish movement behavior between floodplain wetlands and main river channel during flood regimes;
- Furthermore, more research is needed to understand fish population and community dynamics at the floodplain landscape during peak and low floods. This will be particularly important in identifying critical fishing zones for conservation;
- It is also important to understand the extent of fish species mixing by comparing fish populations in main river channel and floodplain lakes before and after floods. This will enable fisheries resource managers to quantify the impact of frequent river discharge into floodplains on fisheries;
- The County Government of Tana River (CGTR) in partnership with relevant research institutions to assess Lake Shakababo and Gumba fisheries and provide technical guidance and financial support to BMUs in managing the resource;

Management actions

- This study recommends reviving Lake Shakababo Beach Management Unit and establishing another at Lake Gumba;
- In addition, the study recommends improving the interconnectivity of floodplain lakes and main river channel. This can be achieved by desilting the floodplain lakes and opening of barriers that block connectivity with the main river channel or brook;
- The study also recommends involving elders in conflict resolution and incorporating indigenous knowledge of fish behavior in fisheries management;
- Fishers should be provided with cost-efficient fish drying technology (solar heaters) to reduce deforestation from use of firewood.

Policy interventions

- CGTR in partnership with Kenya Fisheries Service, the local BMU and other stakeholders to develop fishery management plans for Lake Shakababo and Gumba;
- CGTR and BMUs to identify and develop post-harvest, marketing, and processing opportunities to fish traders; and
- Formation of Fish Vendors Association around Tarasa, Minjila and Garsen markets.

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LIST OF APPENDICES

Appendix I: Fish samples curated, catalogued, and added to NMK Freshwater Fish Database

Catalogue number	Species name	Family	Locality	Collector(s)	Longitude	Latitude	S.L (mm)	Date	Determiner
FW/4692/1-12	*Synodontis zanzibaricus*	Mochokidae	Lake Kongolola, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 26.647'	040^0 11.042'	54.7-79	23.vi.2018	Gathua J.2018
FW/4693/1-	*Brycinus affinis*	Alestidae	Lake Kongolola, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 26.647'	040^0 11.042'	60.0-82.4	23.vi.2018	Gathua J.2018
FW/4695/1-41	*Schilbe intermedius*	Schilbeidae	Lake Kongolola, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 26.647'	040^0 11.042'	72.5-128	23.vi.2018	Gathua J.2018
FW/4699/1-12	*Labeo sp. (red tail)*	Cyprinidae	Lake Kongolola, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 26.647'	040^0 11.042'	67.2-111.18	23.vi.2018	Gathua J.2018
FW/4701/1-5	*Labeo gregorii*	Cyprinidae	Lake Kongolola, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 26.647'	040^0 11.042'	73.3-95.5	23.vi.2018	Gathua J.2018
FW/4702/1-30	*Brycinus affinis*	Alestidae	Lake Kongolola, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 26.647'	040^0 11.042'	60-82.4	23.vi.2018	Gathua J.2018
FW/4704/1-6	*Labeo mesops*	Cyprinidae	Lake Kongolola, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 26.647'	040^0 11.042'	67.68-82.6	23.vi.2018	Gathua J.2018
FW/4786/1	*Oreochromis spirulus*	Cichlidae	Lake Gumba, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 24.066'	040^0 10.218'	140.2	14.x.2018	Gathua J.2018
FW/4787/1-23	*Brycinus affinis*	Alestidae	Lake Gumba, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 24.066'	040^0 10.218'	79.9-90.4	14.x.2018	Gathua J.2018
FW/4788/1-10	*Labeo sp. (red tail)*	Cyprinidae	Lake Gumba, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 24.066'	040^0 10.218'	83.2-107	14.x.2018	Gathua J.2018

Fish samples curated, catalogued, and added to NMK Freshwater Fish Database									
FW/4792/1-30	*Enteromius zanzibaricus*	Cyprinidae	Lake Gumba, Tana Delta	Ouma D., Gathua J., Njagi E.	02^0 24.066'	040^0 10.218'	63.1-74.4	14.x.2018	Gathua J.2018
FW/4796/1-27	*Enteromius zanzibaricus*	Cyprinidae	Lake Shakababo, Tana River system	Ouma D., Gathua J.	02^0 25.408'	040^0 10.439'	69-86.8	17.x.2018	Gathua J.2018
FW/4797/1-5	*Glossogobius giuris*	Gobiidae	Lake Shakababo, Tana River system	Ouma D., Gathua J.	02^0 25.408'	040^0 10.439'	73.7-106.1	17.x.2018	Gathua J.2018
FW/4798/1	*Brycinus affinis*	Alestidae	Lake Shakababo, Tana River system	Ouma D., Gathua J.	02^0 25.408'	040^0 10.439'	108.2	17.x.2018	Gathua J.2018
FW/4800/1-3	*Oreochromis spirulus spilurus*	Cichlidae	Lake Shakababo, Tana River system	Ouma D., Gathua J.	02^0 25.408'	040^0 10.439'	68.5-101.4	17.x.2018	Gathua J.2018

Appendix II: Ecological characteristics and conservation status of sampled fish

Species	TL/SL/FL	Migratory behaviour	Trophic category	Hypoxia tolerance	Environment	pH Range	IUCN Status
Labeo gregorii Günther, 1894	TL; 23.1 cm	Migratory	Herb-Invert	Intolerant	Benthopelagic		LC
Labeo sp. Vreven, E. 2004	Unknown	Unknown	??	Intolerant	Unknown		VU
Glossogobius giuris Hamilton, 1822	TL; 50.0 cm	Migratory	Invert-piscivore		Benthopelagic		LC
Schilbe intermedius Rupell, 1832	TL; 50.0 cm	Migratory	Invert-piscivore	Intolerant	Pelagic		LC
Synodontis serpentis Whitehead, 1962	TL; 12.4 cm	Unknown	??		Benthopelagic		Not evaluated
Synodontis zanzibaricus Peters, 1868	TL; 25.0 cm	Non-migratory	??		Benthopelagic		DD
Clarias gariepinus Burchell, 1822	TL; 170 cm	Migratory	Invert-piscivore	Tolerant	Benthopelagic	6.5-8.0	LC
Petrocephalus catastoma Gunther,1866	FL; 15.0 cm	Migratory	Invertivore		Demersal		LC
Enteromius zanzibaricus Peters, 1868	TL; 9.7 cm	Non-migratory	??	Intolerant	Benthopelagic	7.2-7.8	LC
Brycinus affinis Gunther, 1894	TL; 14.7 cm	Non-migratory	Herb-Invert		Pelagic		LC
Oreochromis spirulus Gunther, 1894	SL; 19.2 cm	Non-migratory	Herb-Invert	Intolerant	Benthopelagic		LC
Oreochromis niloticus Linnaeus, 1758	SL; 60.0 cm	Non-migratory	Herbivore	Intolerant	Benthopelagic		LC
Marcusenius devosi Kramer et al, 2007	SL; 121.0 cm	Non-migratory*	Invertivore		Demersal		DD
Clarotes laticeps Ruppell, 1829	SL; 80.0 cm	Non-migratory	Invert-piscivore		Demersal		LC
Paraillia somalensis Vinciguerra, 1897	SL; 6.9 cm	Non-migratory	Invertivore		Demersal		DD

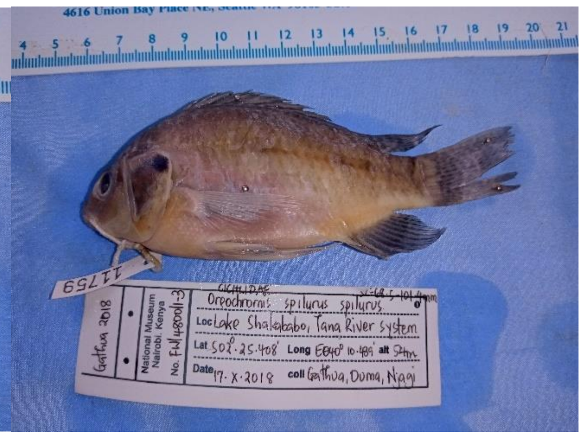
LC= Least Concern, VU= Vulnerable, DD= Data Deficient

Appendix III: Selected photos of fish species curated at Ichthyology Laboratory obtained from this study

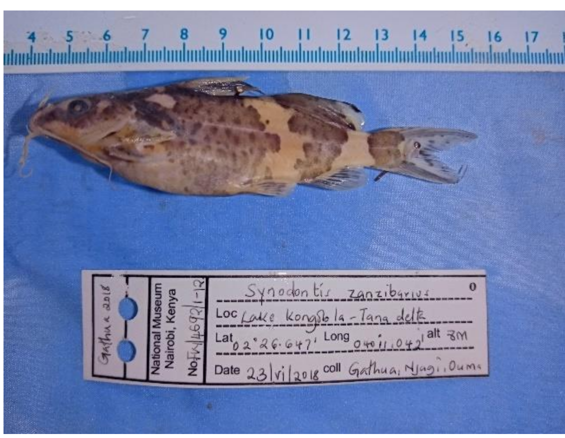
Labeo sp.

Schilbe intermedius

Enteromius zanzibaricus



Oreochromis spirulus spirulus



Synodontis zanzibaricus

Labeo sp. in storage jars

Appendix IV: Fish sampling data sheet

Site name:						
GPS Coordinates:						
Collectors:						
	Tag No.	**Common/Local Name**	**Scientific name**	**TL**	**SL**	**Weight (grams)**
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Appendix V: Water quality and environmental observation data sheet

Name of Investigator:		
Date:		
Site Name:		
Location:		
Time:		
Longitude:	Latitude:	Elevation:

Wetland/floodplain lake morphology			
Length			
Width			
Depth			

Brief description of site

Topography:

Vegetation:

Soils:

Anthropogenic activities:

Physico-chemical parameter observations						
	Point 1		Point 2		Point 3	
	Top	Bottom	Top	Bottom	Top	Bottom
Conductivity (macroS/cm)						
Water clarity (cm)						
Temp °C						
D.O (mg/l)						
pH						
Salinity						
Water level						

Appendix VI: Interview schedules data sheet

Hello, my name is David Ouma, studying towards a Master of Science in Biology of Conservation at the University of Nairobi. I am interested inunderstanding the effect of floods on ecology of fish and fisheries governance in floodplains of Tana River Delta.

<ASK TO SPEAK TO EXPERIENCED FISHERMEN, OR IF NOT THERE OR BUSY, ASK TO SPEAK TO ANOTHER ADULT FISHERMAN. THE PERSON INTERVIEWED MUST BE AT LEAST 18 YEARS OLD.>

I would like to ask a number of questions relating to you and fisheries around here. The interview will last about 15 minutes. Please note that all the information you provide will be kept confidential and will be solely used for academic purposes. There are no risks from participating and there are no right or wrong answers.

Do you agree to participate in this survey?

Thank-you.

INTERVIEW	
Investigators name	
Date of Interview:	Day|_________|Month|_________| Year |________|
Location/Village name	
Fishing site nearby	
Respondent ID Code	

	SECTION A: Background data	**Codes**
1.	Gender	1= Male 2= Female
2.	Marital status	1= Single 2= Married
3.	Age Category	1= Minor (below 15) 2= Youth (15-24) 3= Adult (over 24)
	SECTION B: Fishing patterns	**Codes**
4.	Why do you fish?	1= Subsistence 2= Commercial 3= Both

5.	Who does fish in the family?	4= Man 5= Woman 6= Children 7= Man & Woman 8= All
6.	Do you fish throughout the year?	1= Yes 2= No
7.	What other source of livelihood do you have?	1= Farmer/Irrigation/Recession Agriculture 2= Pastoralist 3= Trader/Businessperson 4= Other, specify____________
8.	What are the target species?	
9.	What are the most preferred species?	
10.	How often are the preferred species caught?	1= Frequently 2= Less frequently 3= Rarely
11.	What is the significant value of the preferred species?	1= Nutritional value 2= Commercial value 3= Cultural value 4= Any other, specify____________
	SECTION C: Flood dynamics	
12.	When did this water body (Shakababo etc.) dry up and how does it get its water/connectivity?	
13.	What are the reasons it dries/d up? How much rain is required to sustain its fisheries?	
14.	How does it impact on your livelihood as a fisherman?	
15.	What period of the year do you experience floods here in the Delta?	1= March – April – May 2= June – July – August 3= October – November – December 4= Any other period, please specify_________
16.	What changes have you observed in flood peaks of the past 5-10 years?	
17.	When do you fish most in relation to the flood peaks mentioned in 15 above?	

18.	What unique species are brought in by floods?	
	SECTION C: Fishing gear assessment & Fisheries income	
19.	What type of fishing gear/s do you use? Are they specific to the fishing seasons?	
20.	Of the mentioned in 19 above which ones are passive gears?	
21.	How much time do you spend fishing per day?	1= < 3 hours 2= 3 -6 hours 3= whole day 4= Passive fishing
22.	How do you value your catch?	1= Kilograms 2= Bunch 3= Any other method, please specify_______________
23.	What is the value in 22 above?	
	SECTION B: Fisheries Governance	
24.	How do you agree on where and when to fish?	
25.	How are the agreements mentioned in 22 above affected by floods?	
26.	Do you participate in any fisheries governance structurer? (Beach Management Units (BMUs), Customary, Fisher-folk Associations etc.) 1= Yes 2= No If yes which one ……………………………………	
27.	How has BMUs affected fisheries here?	
28.	What forms of customary laws exist/ed in fisheries governance?	
29.	What is your relationship with the Fisheries Department? Permits? Seasonal closures?	
30.	Are there conflicts related to access to fisheries?	1= Yes 2= No

31.	If Yes in 28 above, when are the conflicts more intense?
32.	How are conflicts relating to fisheries resources are solved?

THANK YOU

Investigator comments:

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