FISH AND FISHERIES OF BANGWEULU WETLANDS, ZAMBIA

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"I am aware of the University's Policy on Plagiarism. All of the work presented in this thesis is my own. I have not included ideas, phrases, passages or illustrations from another person's work without acknowledging their authorship."

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ABSTRACT

Bangweulu Wetlands is a 6000 km^2 public-private-partnership conservation area in north-eastern Zambia, lying on the south-eastern margins of the Bangweulu Swamps, Congo River system. The area is important for wildlife conservation, tourism and as a fishing ground for the local inhabitants. This study provides a baseline of the fish and fisheries of this area.

The conservation area is situated on the transition zone between woodland, floodplain and swamp. A total of 42 fish species representing 12 taxonomic families were collected. The fish fauna of the area was characterised by a diversity of small cyprinids (14 species), cichlids (9 species), clariid catfishes (4 species) and mormyrids (4 species). Species such as *Clarias gariepinus*, *C. ngamensis*, *Marcusenius macrolepidotus*, *Tilapia rendali*, *T. sparrmanii* and several small *Barbus* species were shared with adjacent floodplain systems such as the upper Zambezi and Kafue rivers.

Fishing was undertaken by fishing groups consisting of a fisherman and his family, or a group of men fishing together. Access to the fishing grounds was controlled by traditional fishing leaders, who collected tribute from fishermen. Fishing groups utilised fixed, distinct fishing areas determined by ancestry. The most important time for fishing was during the drawdown phase of the floodplains, from March until June. During the dry season fewer groups were engaged in fishing, with many having returned to farming activities.

The main fishing methods of the floodplain fishery were basket traps and mosquito-mesh funnel nets set into earth fish barriers (fish weirs) constructed on the plains, various mesh sizes of gillnets, hook longlines and seine nets. The use of fish spears, drag baskets and piscicides was of lesser importance. Most fishing gears were constructed of a variety of natural and modern, manufactured materials.

The fishery was multi-species and 23 fish species were recorded from in catch. The three most important species in the catches were *C. gariepinus*, *T. rendalli* and *M. macrolepidotus*. Together these contributed 67% by weight to the catch. Catch-per-unit-effort (CPUE) for the different gears was 0.4 ± 0.3 kg.trap.night^{-1} for basket traps, 2.7 ± 4.6 kg.net.night^{-1} for funnel nets, 0.3 ± 0.5 kg.50 m net.night^{-1} for gillnets, 3.5 ± 6.3 kg.100 hooks.night^{-1} for longlines, 1.79 ± 1.11 kg.haul^{-1} for mosquito-mesh seine nets and 6.87 ± 6.27 kg.haul^{-1} for larger-mesh seine nets. The weight of average daily landings of fishing groups, using a variety of gears

was 7.8 ± 7.4 kg. Fishermen were able to maintain the same catch rate between dry and wet seasons, with no significant differences ($p < 0.05$) in daily landings between seasons. Yield per fisherman for a seven month season, which required 2-3 relocations due to falling water level, was 1.64 t based on catch assessment, and 1.9 t from a socio-economic survey. A tentative yield per area estimate for the area was 217 $kg.ha^{-1}$ over the three month shallow-floodplain fishing season.

Most fish landed in the fishery were processed into sundried or smoke-dried products. These were used for 1) home consumption, 2) trade with village farmers (from up to 70 km inland of the fishing grounds) in exchange for staple starch meal, and 3) sold to urban fish traders, reaching markets as distant as Lubumbashi in Democratic Republic of Congo. Fish traders toured fishing camps to buy fish, supporting auxiliary industries such as transport and accommodation services. The price for dried fish at source was 3.14 ± 1.34 USD/kg and the market price reported for the Zambian Copperbelt was 6.14 ± 2.54 USD/kg. Typical returns on investment in fish trading were estimated as 68-77%.

The fishery was considered to be biologically and socially sustainable. By harvesting a seasonally transient assemblage of species with high productivity and biological turnover rates and with life histories adapted to high mortality, fishermen were able to maintain a stable and viable livelihood. Management recommendations for the area were that a fisheries management plan be developed that would seek to strengthen the traditional system of rights-allocation, address problems between fishing and tourism activities, and enhance communication between fisheries and conservation stakeholders. To do this it was recommended that: 1) conservation authorities recognise the importance of the fishery, 2) no changes to current effort levels and fishing methods were necessary, 3) points 1 and 2 above be used to improve communication and trust between conservation authorities and fishermen, 4) customary resource-access mechanisms be understood and strengthened so that local inhabitants' rights to the resource are protected, 5) fishermen help formulate and accept conservation and tourism rules, 6) tourists and guides be made aware of the function of the fishery, 7) a fisheries management forum of key community, government and conservation stakeholders be formed to shape and implement the fisheries management plan, 8) locally-adapted bylaws be created to legitimise crucial floodplain gears currently considered illegal (e.g. mosquito-net gears, fish weirs), 9) no intervention to formalise fish trading be made, and 10) a trained person with a fisheries background be hired oversee the implementation of the recommendations.

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Contents

CHAPTER 1

Introduction

Bangweulu Wetlands is a conservation area situated on the south-eastern floodplains of the Bangweulu Swamps in Muchinga Province, Zambia. Home to the endemic black lechwe antelope (*Kobus leche smithemani*) and a significant population of the enigmatic and threatened shoebill stork (*Balaeniceps rex*), the area has had various forms of formal conservation support since 1969 (Grimsdell and Bell 1975).

The swamp and floodplain ecosystem is inhabited and utilized by three main tribes, the *Bisa*, *Unga* and *Batwa*. The natural resources of the Bangweulu basin, especially fish, form the basis of these communities' livelihoods. The value of this resource, and its dependence on the health of the ecosystem with its flooding cycles and vast herds of wildlife, had always been recognized, and conservation planning has permitted the indigenous people of the area to continue with their way of life (Grimsdell and Bell 1975).

In 2008 African Parks, a conservation management company formed a public-private partnership with the Zambia Wildlife Authority (ZAWA) to manage the Chikuni and Bangweulu game management areas (GMA) (African Parks 2008). The land, classed as GMA and not as a national park, is owned by the local communities and their chiefs rather than the government. The 6000 km^2 conservation area falling under African Parks' mandate is named Bangweulu Wetlands, and at its head is a board with representatives from African Parks, ZAWA, the community and other stakeholders. African Parks has been using donor funding to build infrastructure in Bangweulu Wetlands, with the long-term goal being that the will contribute significantly to its own operating costs (African Parks 2011a).

Lying 700 km from the capital Lusaka, Bangweulu Wetlands is a fairly remote wildlife destination in Zambia. Nevertheless, it attracts significant numbers of visitors, primarily birders seeking sightings of shoebill, trophy hunters attracted by the endemic black lechwe antelope and self-drive tourists. The highly visible human population utilising the swamps puts the area at a disadvantage when competing with wildlife destinations offering an 'exclusive wilderness experience'. While the co-existence of man and nature in this rich ecosystem is quite special, it does constrain mainstream tourism development.

To most observers unfamiliar with the ecology of floodplain habitats, the harvesting methods and the small size of fish caught appear problematic (Bell-Cross 1971, Kolding and van Zwieten 2011). The widespread use of small meshed nets such as mosquito nets and catches of fish predominantly under 10 cm in length leads to erroneous assumptions of gross overfishing and unsustainable practice, to the extent that it can negatively affect a visitor's experience of the area. As an example, van Aarde (2009) in the closing address of a wildlife management symposium remarked "But for the beauty of the [Bangweulu] area I was struck by…the sizes of fish delivered by netting…most of the fish that this lady is holding in her hand is[sic] particularly small." He goes on to say: "One reason for the decline in the catch is a…social uplifting[sic] program to control malaria that is typical of life on the swamp. They issued the fishermen with mosquito nets…ended up as custom made fishing nets and thus the indiscriminant[sic] overexploitation of fish" (van Aarde 2009, pp: 38-39).

The other main conflict between the large human population and conservation goals is the disturbance of sensitive species. While some species such as the herds of black lechwe antelopes are able to live in close proximity to humans, other species such as the specialised aquatic antelope, the sitatunga (*Tragelaphus spekei*), become shy and secretive. Some species such as elephants and hippos are actively harassed by fishermen, and there have been cases of tampering with shoebill nests and chicks (African Parks 2011a). Research on shoebill ecology is currently underway, and one of the objectives is to understand the role of human disturbance on this species.

While the communities in the area have always hunted the wildlife (Brelsford 1946, Grimsdell and Bell 1975) the pressures of commercial meat poaching are suppressed by the law enforcement priorities of Bangweulu Wetlands. Patrolling activities are challenging in a landscape with people distributed throughout, and a complex set of strategies have to be employed to be effective. Further challenges presented by a widely distributed fishing community are the unsightly fishing gears, litter and radio music, sometimes played until late at night in close proximity to the tourist camp.

Therefore, with conservation and tourism aims in mind, it would appear desirable to set aside areas closed to most human activity. While plans to create a large 'closed area' were briefly entertained, the dependence of the local people upon the fish resource for their livelihood, their complex system of land and right allocation, as well as the constantly fluctuating environment led Bangweulu Wetlands to seek a more feasible way of addressing these conflicts by involving fisheries stakeholders in decision-making.

In 2009 a proposal for fishery research was developed by African Parks and the South African Institute of Aquatic Biodiversity and field work commenced in early 2011. The urgent need for the Management of Bangweulu Wetlands to understand the functioning of the fishery was made all the more poignant when the fishing community, fearing loss of access to their fishing grounds, hounded the District Commissioner and Department of Fisheries staff out of their village and stoned a Bangweulu Wetlands vehicle during a sensitisation visit (African Parks 2010).

This research project aimed to provide Bangweulu Wetlands with a broad understanding of the fishery by investigating the fishing activities and methods employed on the floodplain habitats of Bangweulu Wetlands, and by describing the fish diversity and fisheries biology of the area. Improvements in community relations have already been partly achieved through the adaptive management approach of Bangweulu Wetlands, which integrated research findings from this study into its approach as they came to light.

This thesis is presented over seven chapters. This introductory chapter (Chapter 1) is followed by a description of the geography, natural history and aquatic habitats of the Bangweulu area and the study site (Chapter 2). As little was known about the fish communities in this remote area, an annotated checklist and characterisation of the fish biodiversity collected in the area, and well as their significance to floodplain ecology and fisheries, is presented in Chapter 3. A description of fishing methods used in Bangweulu Wetlands is given in Chapter 4, followed by an analysis of the catches in the fishery (Chapter 5); examining their composition, the catch rates of different gears and production and yield estimates for the fishery. This is followed by a description of the processing and trade of the fish catch, with inferences drawn on the economic importance of the resource (Chapter 6). The final chapter is the concluding discussion of the thesis, where a short set of management recommendations are presented based on findings of the study (Chapter 7).

Chapter Objectives

The specific objectives of the four data chapters are as follows:

CHAPTER 3: Fish Biodiversity

1) Present an annotated checklist of fish species collected in the area, with tentative species names, local names, photographs, collection maps, and notes on their habitat and importance to the fishery.

2) Discuss the composition of the fish community in terms of its similarity to adjacent drainage systems.
3) Determine the degree of similarity of fish species occurring in tributary-river and floodplain habitats in order to understand the importance of the different habitats to biodiversity conservation.
4) Briefly draw inferences about the life-histories and adaptations of some key species based on studies done on the same or similar species in similar environments elsewhere in Southern Africa.

CHAPTER 4: Fishing Methods

1) Describe how fishing activities change with the seasons and the spatial fluctuations in floodwaters.
2) Provide detailed descriptions of the specific fishing methods used in the shallow floodplain fishery of the Bangweulu Wetlands area.
3) Present and discuss changes and trends in the fishery, in order to inform future management decisions.

CHAPTER 5: Catch Composition

1) Determine the species composition of the different gears used in the fishery.
2) Assess the size structure of the main target species in the catch.
3) Establish estimates of catch-per-unit-effort (CPUE) of fishing gears and compare these with other floodplain fisheries.
4) Estimate daily and annual catch of a typical fishing group using the catch assessment and results of a socio-economic survey.
5) Compare seasonal catch and gear use values to the information obtained by interviews presented in the 'Fishing Calendar' (Chapter 4).

6) Attempt to derive an estimate of fish harvested per unit area in the floodplain such that a total yield for the study site can be projected.

CHAPTER 6: Catch Processing and Trade

In this chapter, the catch processing and trading patterns observed in the study area are examined in order to understand the role that the fishery plays in the livelihoods and economy of the inhabitants of Bangweulu Wetlands. Details on various fish products are presented, as well as an attempt to calculate standardised prices for comparison with the literature. Some financial scenarios surrounding trading are also explored.

Together, these four data chapters serve to establish a broad baseline of fisheries data for Bangweulu Wetlands, which was the overall aim of this research study.

CHAPTER 2

Study Area

2.1 THE BANGWEULU BASIN

The study area was situated on the south-east margins of the Bangweulu Swamps, about 1200 m above sea-level. This complex consisting of swamp, marginal floodplain and open lake lies in the south of the shallow Bangweulu- Mweru freshwater ecoregion (Thieme et al. 2005). The catchment of the Bangweulu System is about 190,000 km^2 in extent (Grimsdell and Bell 1975). A feature of the Bangweulu Basin is the large Lake Bangweulu (2303 km^2), which lies at the basin's north-western end and is surrounded by numerous smaller lakes (Hughes and Hughes 1992). The lake is contiguous with the swamp (approx. 7000 km^2) on its eastern shore (Hughes and Hughes 1992). The swamps are fed primarily by the Chambeshi River, with a number of smaller rivers emptying into the swamps on the northern, eastern and southern margins, and the basin is drained by only one river, the Luapula in the south-west (Figure 2.1).

The Chambeshi is the longest tributary of the Congo River (Debenham 1952). The Luapula River draining the swamp and lake complex flows out of the south-west corner of the basin (Figure 2.1). Going north, the Luapula empties into Lake Mweru. The outlet of Lake Mweru is the Luvua River, which eventually becomes the Congo River after it is joined by the Lualaba River in the Democratic Republic of Congo.

The Bangweulu Basin appears to have formed by epeirogenic downwarping (depression of the earth's crust not associated with tectonic faulting), which lead to the formation of a 'Palaeo-Lake Bangweulu' about 3 million years ago (Cotterill and de Wit 2011). The resultant shallow basin filled with alluvium over subsequent millennia. There is some evidence to suggest that the area is still experiencing movements, and even small movements could have large effects on the flooding and drainage of the area (Hughes and Hughes 1992). After 1936, a large central portion of the swamps known as the Lunga Bank became permanently inundated, forcing the population there to resettle (Brelsford 1946). It is thought that this was caused by warping in the basin floor (Grimsdell and Bell 1975).

Figure 2.1: Map of the Bangweulu Basin, showing the catchment, major rivers, swamps and lakes. The star indicates the location of the study area on the margins of the Bangweulu Swamps (after Debenham 1952).

The Bangweulu Swamps are shallow and rather featureless: there are few islands, and few channels or open water lagoons. The few islands, pools and channels that do occur are associated with the large river deltas; much of the swamp can be thought of as a deep floodplain. The swamps have broad margins, being greatest in extent to the south and east. The basin has a shallow topography, with low water velocity, and low rates of erosion and deposition (Debenham 1952).

The Bangweulu Basin is an area of very high rainfall, which falls over a short rainy season from December to March. The swamps themselves have a higher rainfall than surrounding areas likely due to condensation of local evaporation (Grimsdell and Bell 1975). Mean annual rainfall values for the catchment vary between 1118 mm and 1312 mm (Grimsdell and Bell 1975). The Chambeshi River attains its peak flow from the end of March to the beginning of April (Debenham 1952). However there is a lag period between peak rainfall and swamp and lake flooding. The peak water levels there occur between May and June, at a time when the water of the swamp margins is receding rapidly (Brelsford 1946). This lag is probably due to the 'sponge effect' of the swamp vegetation and the ill-defined channels (Debenham 1952).

The most important driver of this system is the seasonal flooding during the rainy season from December to March. The shallow gradients of the basin mean that the effect of this variation in water depth is felt over a very large area (Kolding et al. 2003). The entire ecology of the basin is adapted to the variation in flood level. Most species of mammals, fish and birds migrate following the extent of flooding, and in the case of plants enter into phases of dormancy between aquatic or terrestrial phases (Grimsdell and Bell 1975). The human inhabitants have also adapted their activities to the changes in water level (Chapter 4). Following the definition of Junk et al. (1989, p: 112), the area can therefore be classified as floodplain habitats, these being *"areas that are periodically inundated by the lateral overflow* *of rivers or lakes, and/or by direct precipitation or ground water; the resulting physicochemical environment causes the biota to respond by morphological, anatomical, physiological, phenological and/or ethological adaptations, and produce characteristic community structures".*

A number of tribes utilise the swamps. The areas of permanent swamp are the domain of the *Unga* tribe (Brelsford 1946), a people who rely on the swamp for their livelihoods. The *Unga* and the less-numerous *Batwa*, remnants of the original swamp inhabitants, cultivate minimally in the waterlogged swamp, and therefore rely on trade with the swamp margin farmers for their staple carbohydrates. Historically the people were hunters and dried meat was the main product for barter, however fish has replaced game meat as the economic mainstay of the swamp inhabitants (Brelsford 1946). The margins on the south-east are in *Bisa-Lala* territory, and the study site fell within the chiefdom of Chiundaponde, a *Bisa* chief.

The south-eastern floodplains are generally not considered true swamp, but rather seasonally inundated floodplain (Debenham 1952, Grimsdell and Bell 1975). Brelsford (1946) referred to the area as the 'Itili Flood Plain', which fell outside of his study area. Grimsdell and Bell (1975) give an accurate spatial description of the habitats, classing the different floodplains from permanent floodplain through to peripheral grasslands. These areas vary from being flooded for a few weeks to a few months. Termite mounds are very common on the drier parts, where they support the growth of some trees and bushes. A wide range of wildlife species are found within the different habitats of this marginal zone, and conservation, hunting and tourism focusses on this zone. Bangweulu Wetlands encompasses a broad range of habitats across a gradient from catchment woodland through to permanent swamp, with the greatest part being over the marginal floodplains.

The present fisheries study was based out of Chikuni Research Station within Bangweulu Wetlands. The station was built on an island selected and developed during the early 1970's by the Black Lechwe Research Project (Grimsdell and Bell 1975) and has an airstrip and wildlife scout outpost. It is situated on the margins of the Lukulu Delta, and on the edge of the Chimbwe Plain. This is one of the short-grass floodplains and is one of the most important grazing lawns and courting grounds of the black lechwe antelope (Grimsdell and Bell 1975).

The area around Chikuni offers a wide range of habitats represented in the greater swamp system, and was therefore an ideal study site, being accessible and close to the logistical support offered by the Bangweulu Wetlands park. The area supports the greatest variety of wildlife and a large range of bird species use the different habitats through the year. Apart from the great concentration of black lechwe (*Kobus leche smithemani*), the area is also home to the endemic Bangweulu tsessebe (*Damaliscus superstes*), Cape buffalo (*Syncerus caffer*), hippo (*Hippopotamus amphibius*), Nile crocodile (*Crocodylus niloticus*), plains zebra (*Equus burchelli*), sitatunga (*Tragelaphus spekei*), common reedbuck (*Redunca arundinum*), oribi (*Ourebia oribi*), spotted hyena (*Crocuta crocuta*) and a tiny remnant population of five elephant (*Loxodonta africana*).

The Lukulu River provides a diverse range of habitats along its length (summarized below) from catchment stream to its floodplains. The delta does not open into the permanent Bangweulu Swamps, some 10-15 km north-north-west of Chikuni at the nearest (Grimsdell and Bell 1975), but disperses into a vast area of deeper floodplain that becomes dry late in the year (September to December). Thus the Lukulu and some of the other rivers entering the south- east do not contribute water to the deeper, main swamp basin and Luapula River later in the dry season; their sub-basins are cut off by the floodplains that fall dry at this time. Therefore, though the Lukulu River flows year-round, much of its dry-season discharge maintains the delta or is lost to evapo-transpiration out on the plains (Grimsdell and Bell 1975).

The depth of flooding in the main swamps fed by the Chambeshi River can affect the flooding on the margins. The water flooding the margins comes from local rainfall and from the Lukulu River catchment, and the rate of escape of this floodwater to the greater basin is determined to some degree by the water levels there (Grimsdell and Bell 1975). These three factors (rainfall, catchment discharge and swamp level) affect the temporal and spatial characteristics of each year's flooding, which in turn have an effect on the ecology and the fishes.

Limnological and physicochemical data for the region are presented in Table 2.1, supplemented with readings from the study site taken in July 2012. Mean temperatures measured at Samfya on Lake Bangweulu are: 21 °C annual mean, 24 °C mean temperature in the hottest month October and 16.5 °C mean temperature in the coldest month July (Hughes and Hughes 1992).

Table 2.1: Limnological and physicochemical data for the Bangweulu system (adapted from, and all literature sources in: Kolding et al. (2003)).

Data	Value	Unit	Source
Mean annual water level fluctuation	1.2	m	Dept. of Water Affairs
Min. water level as percentage of max.	46	%	
Conductivity	26.5-34.3	$\mu S.m^{-1}$	Bos and Ticheler 1996
Conductivity on Lukulu Delta at Chikuni	25-27	$\mu S.m^{-1}$	This study
pH	6.3-6.9		Toews 1977
Oxygen saturation	40-100	%	Bos and Ticheler 1996
Water temperature	18.3-27.3	°C	Toews 1977
Water temperature in Lukulu Delta, July 2012	14.8-20.8	°C	This study
Turbidity in Lukulu Delta	1.15-29	NTU	This study

In addition to studying the fish diversity and fishery of the Lukulu Delta and its floodplains around Chikuni, sections of the Lukulu River within the Lavushi Manda National Park were also surveyed. This park is managed by ZAWA and Kasanka Trust Limited, in a public-private partnership. While most past ichthyological surveys have focussed on the swamps(Worthington 1933, Jackson 1961, Kolding et al 2003), few (Ricardo-Bertram 1943, van Steenberge 2009) have included the catchment streams and their associated habitats and fauna.

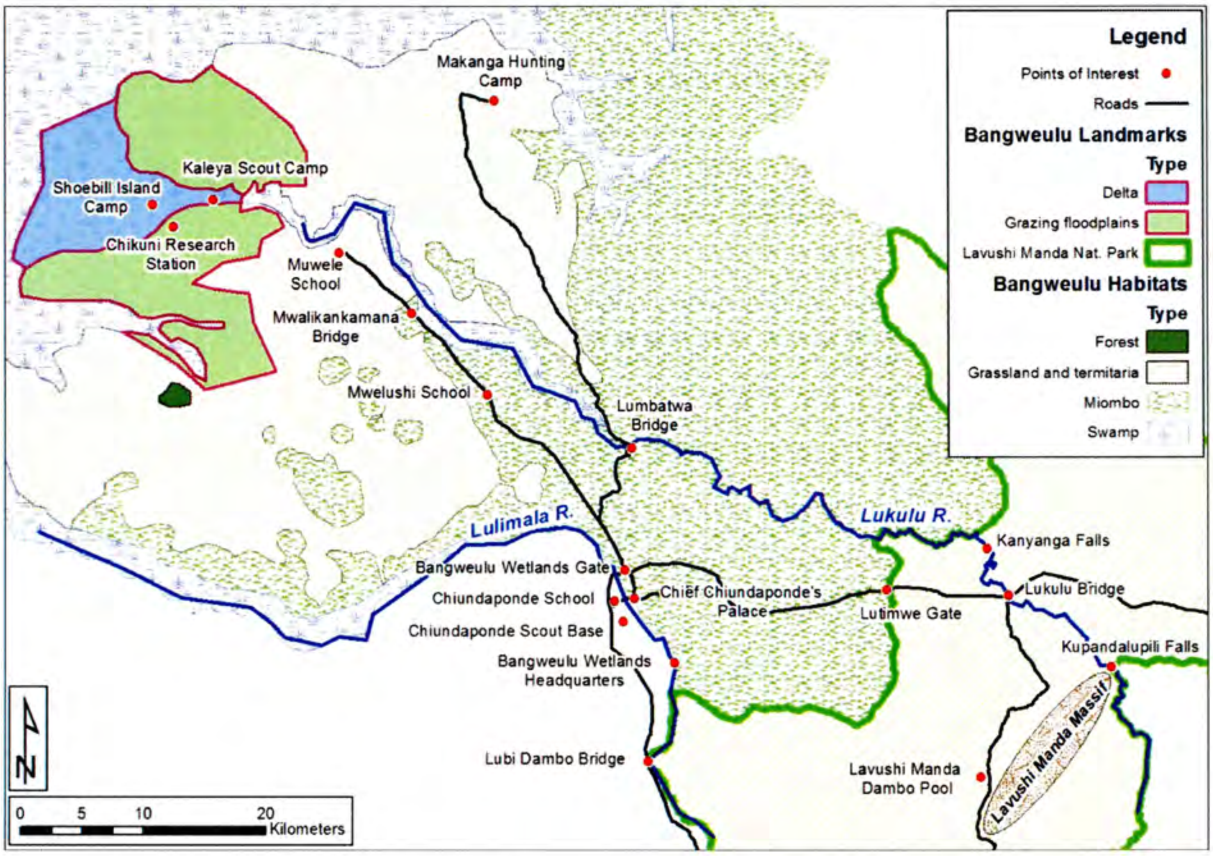

Figure 2.2: Map of the study area on the south-eastern margins of the Bangweulu Swamps, within Bangweulu Wetlands and showing the adjacent Lavushi Manda National Park. Key points of interest mentioned in the text are indicated on the map. The habitat marked 'swamp' should be considered deeper floodplain.

2.2 SUMMARY OF AQUATIC HABITATS IN THE STUDY AREA

Aquatic habitats inside the conservation area follow a shallow altitudinal gradient, from catchment streams through their delta and floodplains to deep floodplains or true swamp. Details of the study area are presented in Figure 2.2. Landmarks on the map that are referred to in the text are in **bold** in the following sections. Figure 2.3 shows a selection of habitat photographs.

Lukulu River- rocky upper reaches

The upper Lukulu River inside the Lavushi Manda National Park is rocky, with alternating pools and rapids. The banks are heavily vegetated with trees, with a narrow grassy floodplain on either side. Rocks in the rapids are thickly covered with a fern-like aquatic plant (*Hydrostachys polymorpha*), and the water is generally clear, with a milky colour after rain. It has a very high volume late in the rainy season, but it quickly returns to its base level flows for the dry season. The water appears nutrient-poor, and exogenous nutrient input (from outside, e.g. dead leaves) is likely very important. Invertebrates such as crabs, freshwater shrimp and aquatic insects occur at low densities. In this stretch of river there are two low waterfalls, Kupandalupili Falls (Figure 2.3a) and lower down the river, Kanyanga Falls. The lower falls appear to be a barrier for some fish species (Chapter 3). A typical section of the river can be seen at **Lukulu Bridge** (Figure 2.2).

Lukulu River- middle reaches

The middle reaches of the Lukulu River are typified by a deep river channel, with a sand-sediment bottom and dense growths along the river banks of *Syzigium guineense* (waterberry), which has a willow-like growth habit (Figure 2.3b). A typical section is in the northern sector of Lavushi Manda National Park and near the new **Lumbatwa Bridge** across the Lukulu in Bangweulu Wetlands (Figure 2.2). This short section forms the transition zone between the woodland and floodplain reaches of the river.

Lukulu River- lower reaches

The lower reaches of the Lukulu River before forming the delta are covered by dense papyrus and floating grass mats covering the meandering main channel (Figure 2.3c). Only in some areas is the channel uncovered, and these areas change. It is not known what causes the papyrus mats to break up or move, but it could be a cyclical event involving flooding and vegetation density thresholds. The main channel is deep (> 3 m), and the 'river' with its adjacent floating papyrus-covered 'floodplains' is 300-700 m across. A typical section lies adjacent to the road between **Mwelushi School** and **Muwele School** (Figure 2.2).

Lukulu Delta

The Lukulu Delta starts with a narrow neck at Muwele Village and fans out widely in the Chikuni area, although a central, meandering main channel can still be discerned throughout the delta. The delta is typified by dense stands of vegetation; floating mats over deeper water, and rooted reed beds (*Phragmites* spp.) and sedges in shallower water. There are open pools and lagoons (Figure 2.3d) covered with water lilies (*Nymphaea* spp.), and other aquatic plants (mostly various species of *Ceratophyllum*, *Ottelia* and *Potomageton*) grow on the bottom of channels with flowing water. The edges of the delta have numerous fish weirs constructed on them (Chapter 4). The islands in the delta are low and flooded annually, with the uninhabited islands being favoured by buffalo, elephant and other wildlife.

The dense reedbeds and papyrus of the channels are burned from October to December, and the ecological effects of this activity are not known. The dense vegetation and deeper channels of this delta provide good refuge for most fish species (Chapter 3). **Shoebill Island Camp** is in the delta (Figure 2.2)

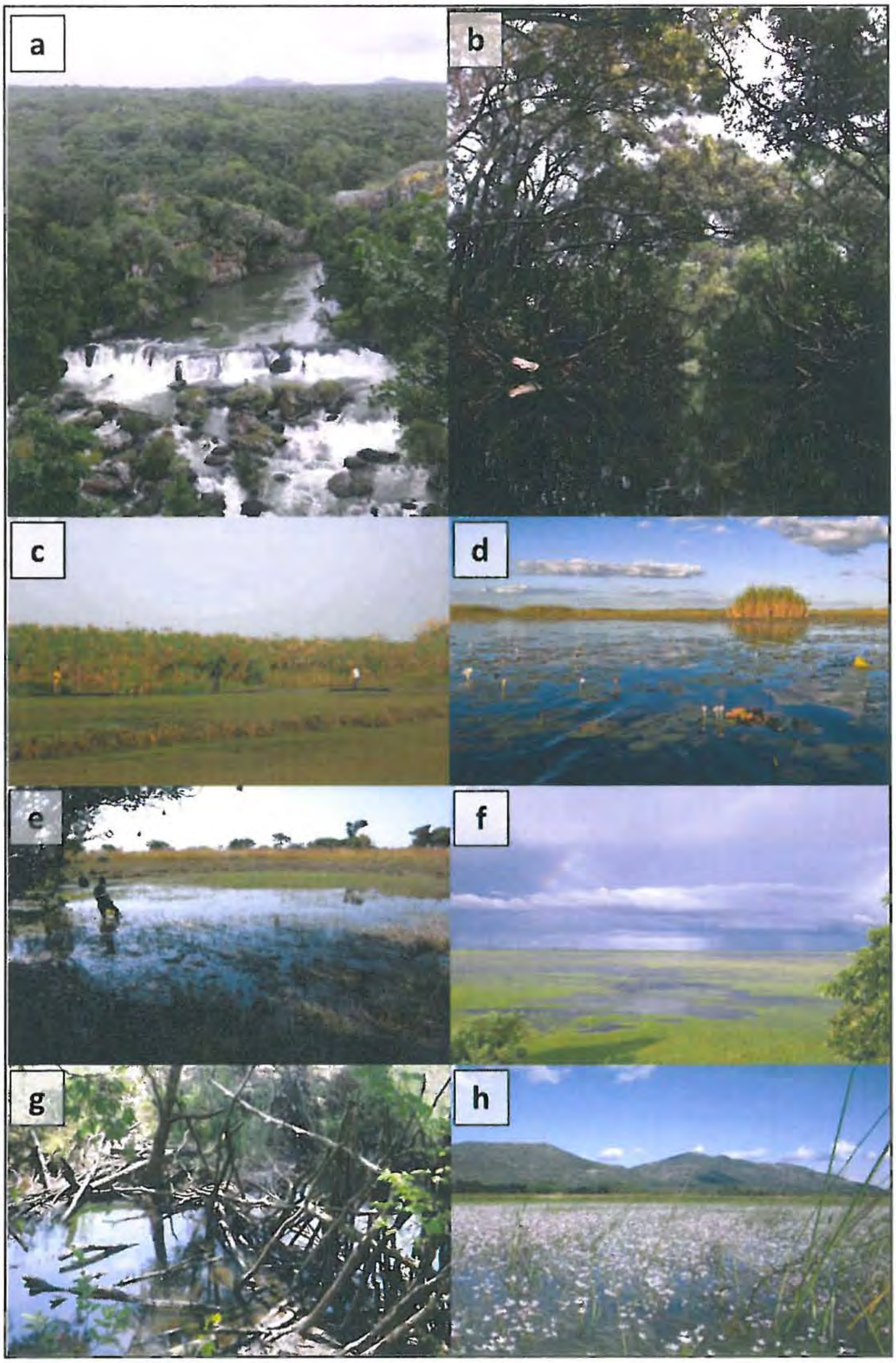

Figure 2.3: Some representative habitats in the study area: a) Kupandalupili Falls, upper Lukulu River; b) Lukulu River, forested middle reaches; c) papyrus covered channel at head of Lukulu Delta, lower reach of the Lukulu River; d) a lagoon in the Lukulu Delta; e) pool in wooded floodplain; f) Chimbwe Plain, shallow grazing lawn floodplain; g) Lulimala Stream, Nkondo; h) dambo pool inside Lavushi Manda National Park. Photos: a, c, f-h) Carl Huchzermeyer; b) Richard Peel; d) Morgan Trimble; e) Roger Bills.

Floodplains- woodland pools

The last section of the river before it forms a delta is surrounded by wide wooded and grassland termitaria plains that are inundated (mostly by rainwater) for a few weeks at the end of the wet season. Fish migrate into this shallow water, where they are caught by fishermen using low fish weirs. The shallow floodwaters seed woodland pools with fish, most of which dry out during the dry season (Figure 2.3e). Many of these pools contained populations of the annual Bangweulu killifish *Nothobranchius rosenstocki* which survive drying pools by laying drought-tolerant eggs in grassy humus (Chapter 3). These pools can be found near **Mwalikankamana Bridge** and **Lumbatwa Hunting Camp** (Figure 2.2).

Floodplains- swamp margins

During the peak time of the floods in late February and March the shallow floodplains and lechwe grazing lawns become flooded. The area of water that is inundated is considerable due to the flat topography of the plains. This water is flowing, well oxygenated and is warm due to its shallow depth (< 60 cm deep). The vegetation on the floodplains is primarily terrestrial, with emergent semi-aquatic grasses and sedges and some aquatic species that will lie dormant once the plains dry out. The large amounts of black lechwe antelope dung that accumulate during the dry season provide a rich suspended organic medium that must play a significant role in the aquatic food chain (Grimsdell and Bell 1975). **Chikuni Research Station** (Figure 2.2) is situated on the margins of Chimbwe Plain, a shallow floodplain and grazing lawn (Figure 2.3f).

Floodplains- deep plain and swamp

Areas further away from the riverine-influenced parts of the delta can be classed as deeper floodplain that remains flooded for a longer time (December to September), and with parts that only dry completely in low-water years. These areas are dominated by various sedges, bullrushes and coarse grasses. These extensive plains have very few islands, which limits fishing activities. There are few deeper open-water refuges for fish later in the season and occasionally large numbers of fish are reportedly stranded in shallow, vegetation covered depressions and pools.

True swamp, defined as areas permanently inundated fell outside of the area accessible to this study. Parts of the Lukulu Delta could perhaps be considered as similar to permanent swamp. At the northern boundary of Bangweulu Wetlands there are again deep water habitats around the islands in the chiefdoms of Bwalya-Mponda and Nsamba. These islands, channels and deep pools are part of the large Chambeshi River system that enters the Bangweulu Swamps from the east.

Lulimala Stream

The Lulimala Stream flows through part of the study area, and also forms a swamp delta nearer where the swamp waters begin to consolidate into the Luapula River in the south-west of the basin. It is a relatively small stream. The section at the **Bangweulu Wetlands Headquarters** (Figure 2.2) at Nkondo is deeply incised, shallow and with a soft silty bed and well-wooded banks (Figure 2.3g). The base flow during the dry season is low (< 1 m deep), and there are only a few small fish species present. During the rainy season the stream increases its flow considerably (up to 3.5 m deep), even flooding grassy pools and dambos over its banks.

Dambos and dambo pools

Dambos are grassy drainage lines in woodland areas. Fish can sometimes be found in these wetlands, especially nearer to streams. Some dambos have small lakes or pools in them, as can be found near the **Lavushi Manda Mountains** (Figure 2.3h). The dambo environment is usually very nutrient poor: surrounding soils are shallow and leached (Grimsdell and Bell

1975) and the water is acidic with few dissolved minerals. As a result only a few fish species are found here in very small numbers.

*   *   *

A great many more habitats and microhabitats are found within each of these broad divisions, which are a necessary oversimplification. Each of the habitats discussed also changes in character with the seasonal fluctuations in water level, to the extent that most floodplains become completely terrestrial in character for many months.

CHAPTER 3

Fish Biodiversity

3.1 INTRODUCTION

Floodplain-rivers are some of the most diverse ecosystems known, with a high diversity of habitats that vary both on a temporal and spatial scale (Ward et al. 1999). The Bangweulu basin has a history of fish collections, the earliest being from Lake Bangweulu in 1904 (Worthington 1933). Worthington (1933) describes the contents of a collection made by Pitman in 1931-1932 during a government game-department faunal survey, which includes fish collected from the Lukulu River in the current study area. An expedition by Ricardo-Bertram (1943) lists 67 species occurring in the Chambeshi River, the Bangweulu Swamps and Lake Bangweulu. Other collections from the region are from the Joint Fisheries Research Organization (JFRO) surveys 1952-1963 (Jackson 2000) and from various collecting expeditions (2001-2011) by researchers affiliated with the South African Institute of Aquatic Biodiversity (SAIAB). Van Steenberge's (2009) study in Kasanka National Park near the Luapula River west of Bangweulu Wetlands provides the most recent and taxonomically updated list from the area, and includes 49 species found in that national park.

Bangweulu Wetlands lies within the Bangweulu-Mweru freshwater ecoregion. A freshwater ecoregion is typically a large area where prevailing environmental conditions result in characteristic communities and assemblages of aquatic species differing from adjacent systems (Abell et al. 2008). The Bangweulu-Mweru ecoregion is defined as the basin containing the Lake Bangweulu, Lake Mweru and Luapula River systems (Chapter 2-Figure 2.1). It begins at the source of the Chambeshi River, and ends at the outflow of Lake Mweru (Thieme et al. 2005, Abell et al. 2008). The ecoregion comprises predominantly floodplain-river and shallow lake habitats which contain 28 endemic fish species, seven endemic mollusks and endemic birds and mammals (Thieme et al. 2005).

Determining the fish diversity of Bangweulu Wetlands was important for two reasons: 1) for biodiversity conservation and 2) for understanding the fishery. Bangweulu Wetlands holds the mandate to protect the area's flora and fauna, and to do that effectively the species occurring in the area and their distributions need to be known. The fisheries research for this baseline study also relied on understanding the species composition of the area, so that comparisons could be made and inferences drawn about the fish community, its adaptations to the environment, and importance to fisheries in other systems in Southern Africa.

This chapter therefore aims to:

1) Present an annotated checklist of fish species collected in the area, with tentative species names, local names, photographs, collection maps, and notes on their habitat and importance to the fishery.
2) Discuss the composition of the fish community in terms of its similarity to adjacent drainage systems.
3) Determine the degree of similarity of fish species occurring in tributary-river and floodplain habitats in order to understand the importance of the different habitats to biodiversity conservation.
4) Briefly draw inferences about the life-histories and adaptations of some key species based on studies done on the same or similar species in similar environments elsewhere in Southern Africa.

3.2 METHODS

Collections

Fish biodiversity collections were made opportunistically throughout the study period (March 2011-July 2012), from sampling areas representing all of the major habitats.

Fish were collected from fishermen's catches, but also through directed sampling using a 5 m seine net, a long handled D-shaped hand net, a small hand net, angling and electrofisher (SAMUS 725MP®).

Fish were identified in the field using Skelton (2001), and notes were taken of the local knowledge around each species, including its habits, habitat, abundance and any other relevant facts. The local names for the different fish were also recorded.

Voucher specimens were sedated and killed with an overdose of clove oil emulsion. They were photographed submerged in clear water against a white background. Tissue voucher samples were taken from the dorsal muscle or as a fin-clip from one of the paired fins and preserved in 70% ethanol. The specimens were fixed in 10% formalin solution, placed in labelled bags and stored in containers of 10% formalin in a cool, dark place at Chikuni Research Station. Details of each collecting event, the habitat and environment, and the specimens collected, were recorded on data sheets following the format used by the SAIAB. Specimens were subsequently catalogued into the national fish collection at SAIAB, where they were labelled and stored in 70% ethanol. These specimens and their data are available for study and loans through www.saiab.ac.za.

Once in the laboratory, identifications were verified using the taxonomic keys of Skelton (2001), and van Steenberge (2009). The validity of taxonomic names was verified using the online Catalogue of Fishes (Eschmeyer 2012).

Diversity analysis

The relative importance of habitat (tributary stream, river delta and its adjacent floodplain) to each fish family was shown by expressing the number of species of a family in each habitat as a percentage of the total number of species in each family. Differences in species composition between the three coarse habitat distinctions were analysed by calculating the percentage of the total fish fauna represented by each habitat, the percentage endemicity in each habitat and also by Jaccard's Index of Similarity between habitats (Rahel 2000). Percentage endemicity was calculated as:

$$\left(\frac{S_{unique}}{S_{habitat}}\right) * 100$$

where S_{unique} is the number of species unique to that habitat, and $S_{habitat}$ is the total number of species in that habitat. Jaccard's Index of similarity is used as given in (Rahel 2000):

$$\left(\frac{a}{a+b+c}\right) * 100$$

where a is the total number of species shared between two habitats, b is the number of species unique to one habitat, and c the number of species unique to the other. A value of zero indicates no similarity in faunal composition, while a value of 100 shows that the species communities are identical (Rahel 2000). The Jaccard's Index was used to show similarity between tributary stream, and delta/floodplain combined. It was also calculated to show differences between delta and floodplain, and between stream and floodplain. Three species for which confident verbal records were obtained of historical occurrence within the study area have been included in the checklist, but were not used in the analyses.

3.3 RESULTS

A total of 16 collections were made, at 12 sites at five main sampling stations between March 2011 and July 2012 (Figure 3.1). A sampling event was usually a single-day, directed effort at obtaining fish specimens from a particular habitat, except around the research station where small daily collections of one to five specimens were made from visited fishing camps, and recorded as an event spanning a period of two weeks to a month.

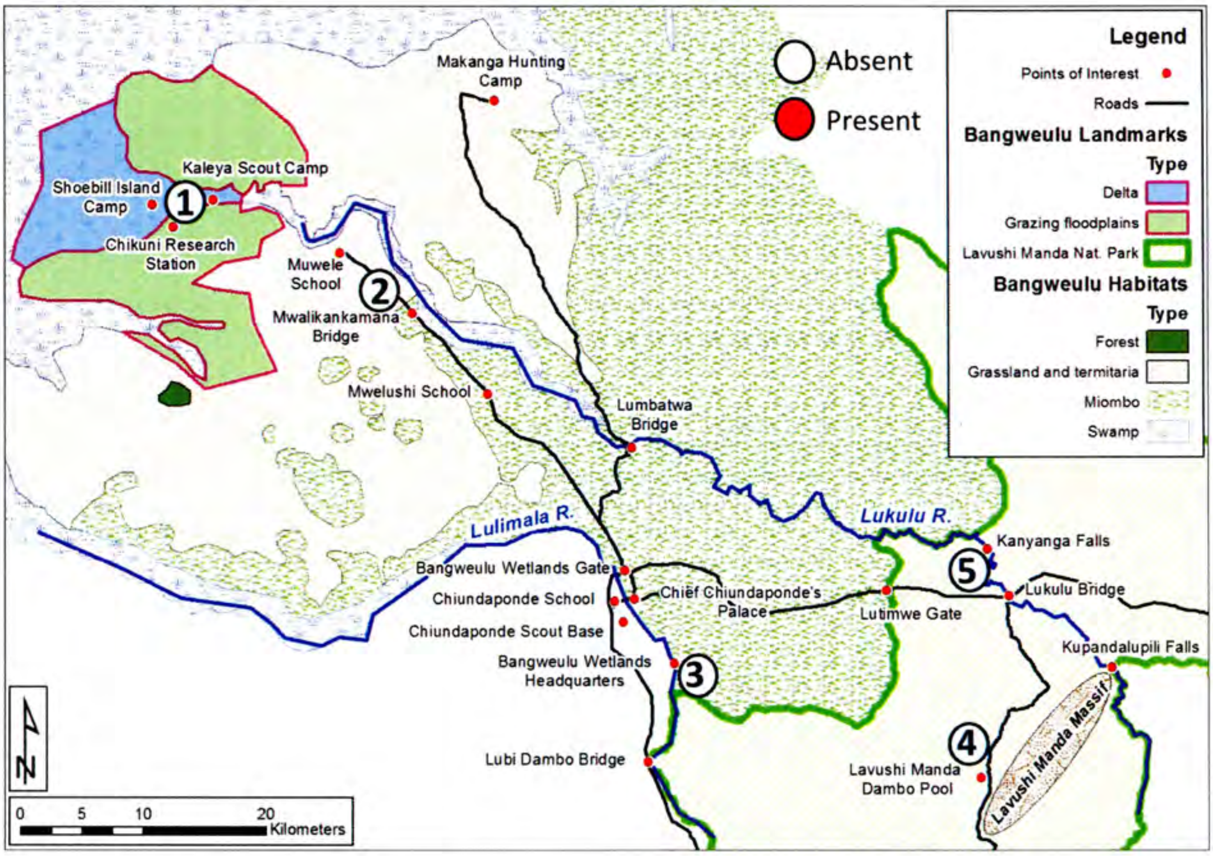

Figure 3.1: Map of the study area in Bangweulu Wetlands, on the south-eastern margins of the Bangweulu Swamps, Zambia. Sampling stations followed the course of the Lukulu River from its upper reaches in Lavushi Manda National Park to the Lukulu Delta, its adjacent floodplains and parts of the Lulimala Stream. Sampling stations were: 1) Chikuni-Chona Island- 5 sites; 2) Muwele pools- 2 sites; 3) Lulimala Stream- 2 sites; 4) a dambo pool inside Lavushi Manda National Park- 1 site; 5) upper Lukulu River- 2 sites. Individual sites are not shown but were clustered around the sampling stations. The white and red circles indicating presence or absence will be used to mark stations in the distribution maps of individual species.

Checklist of fishes:

A total of 42 species representing 12 families were identified from the area (Table 3.1). These are listed according to the order in which they appear in Skelton (2001). Photographs and distribution maps for each species are presented in Figures 3.2-3.12, which are followed by annotated species accounts.

Table 3.1: Fish species sampled from riverine, floodplain and delta habitats in the study area in Bangweulu Wetlands and Lavushi Manda National Park. Black cells show presence of a species in a particular habitat, while white cells show absence and grey cells show probable habitat for species that were not observed but for which verbal records were collected.

Fish Species	River	Floodplain	Delta
Family Mormyridae (Mormyrids)			
Mormyrus longirostris.- 'Mbubu', Bottlenose/Bottle fish	░		░
Cyphomyrus discorhynchus- 'Icimpumwe', Zambezi parrotfish	■		■
Marcusenius macrolepidotus- 'Mintesa', Bulldog		■	■
Petrocephalus squalostoma- 'Icele', Churchill		■	■
Pollimyrus stappersii - 'Ishimba', Dwarf stonebasher	■	■	■
Family Cyprinidae (Cyprinids)			
Barbus neefi- Sidespot barb	■		
Barbus bifrenatus- Hyphen barb	■	■	■
Barbus brevidorsalis- Dwarf barb	■	■	■
Barbus fasciolatus- Red barb	■		
Barbus radiatus- Beira barb			■
Barbus haasianus-Sickle-fin barb	■		■
Barbus trimaculatus- 'Mushipa', Threespot barb	■		■
Barbus eutaenia- Orangefin barb	■		
Barbus multilineatus- Copperstripe barb		■	■
Barbus afrovernayi- Spottail barb	■	■	■
Barbus paludinosus- 'Misenga', Straightfin barb	■	■	■
Barbus kerstenii- Redspot barb	■		■
Labeobarbus trachypterus - 'Mpifu'	■		
Labeo cf. cylindricus- Redeye Labeo	■		
Family Distichodontidae (Citharines)			
Hemigrammocharax minutus- Multibar citharine	■		
Family Characidae (Characids)			
Brycinus peringueyi- Dwarf tigerfish	■		
Micralestes sardina- Redeye robber	■		
Rhabdalestes rhodesiensis- 'Itala', Slender robber	■	■	■
Hydrocynus vittatus- 'Manda', Tigerfish	░		░

Suborder Siluroidei (Catfishes)
Family Amphiliidae (Mountain catfishes)
Zaireichthys sp.- Sand catlet
Family Schilbeidae (Butter catfishes)
Schilbe intermedius- 'Lupata', Silver catfish
Family Clariidae (Air-breathing catfishes)
Clarias gariepinus- 'Inyenda', Sharptooth catfish
Clarias ngamensis- 'Inkose', Blunt- tooth catfish
Clarias stappersii- 'Bomba', Blotched catfish
Clarias theodorae- 'Mulonfi/Mulonge', Snake catfish
Heterobranchus longifilis- 'Sampa', Vundu
Family Mochokidae (Squeakers)
Synodontis nigromaculatus- 'Cingongongo/Cinyimba', Spotted squeaker
Family Aplocheilidae (Annual killifishes)
Nothobranchius rosenstockii- 'Lombwe-sweta', Bangweulu killifish
Family Poeciliidae (Topminnows)
Aplocheilichthys spp. 'Bwelele', Topminnows- various species
Family Cichlidae (Cichlids)
Pseudocrenilabrus philander- 'Cikundu', Southern mouthbrooder
Sargochromis mellandi- 'Mbilya', Brown bream
Serranochromis robustus - 'Nsuku', Largemouth bream
Serranochromis angusticeps- 'Polwe', Thinface largemouth
Serranochromis thumbergi - Brownspot largemouth
Tilapia sparrmanii- 'Matuku', Banded tilapia
Tilapia ruweti- 'Cifinsa', Okavango tilapia
Tilapia rendalli- 'Mpende', Redbreast tilapia
Oreochromis macrochir- 'Nkamba', Greenhead tilapia
Family Anabantidae (Labyrinth fishes)
Microctenopoma intermedium- 'Nkandiya', 'Kashilukafunte', 'Nkandakatopolyo', Blackspot climbing perch
Ctenopoma multispine- 'Nkomo', Manyspined climbing perch

Total species recorded per habitat:	28	25	31

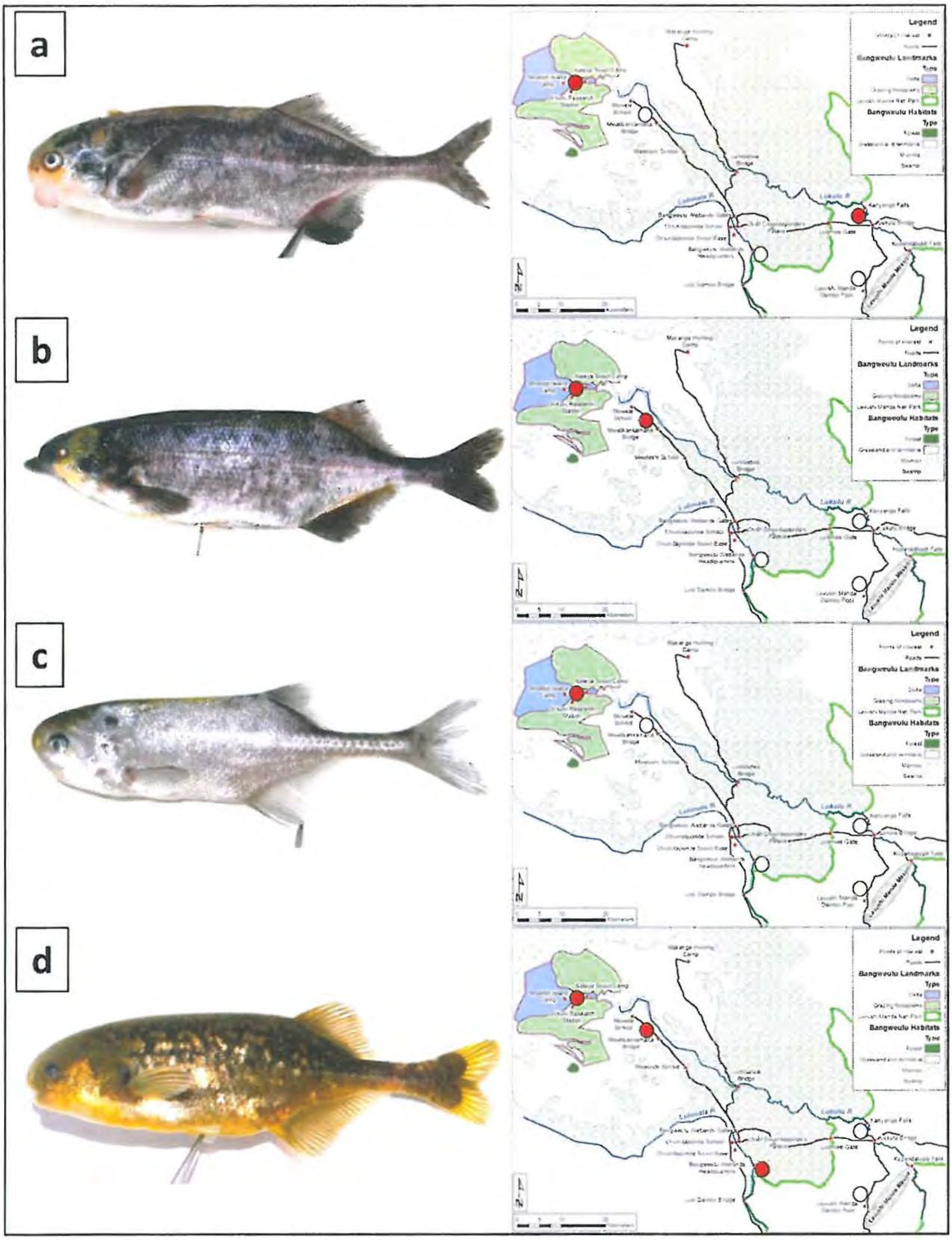

Figure 3.2: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Cyphomyrus discorhynchus* (C. Huchzermeyer);b) *Marcusenius macrolepidotus* (CH); c) *Petrocephalus squalostoma* (CH); d) *Pollimyrus stappersii* (R. Bills).

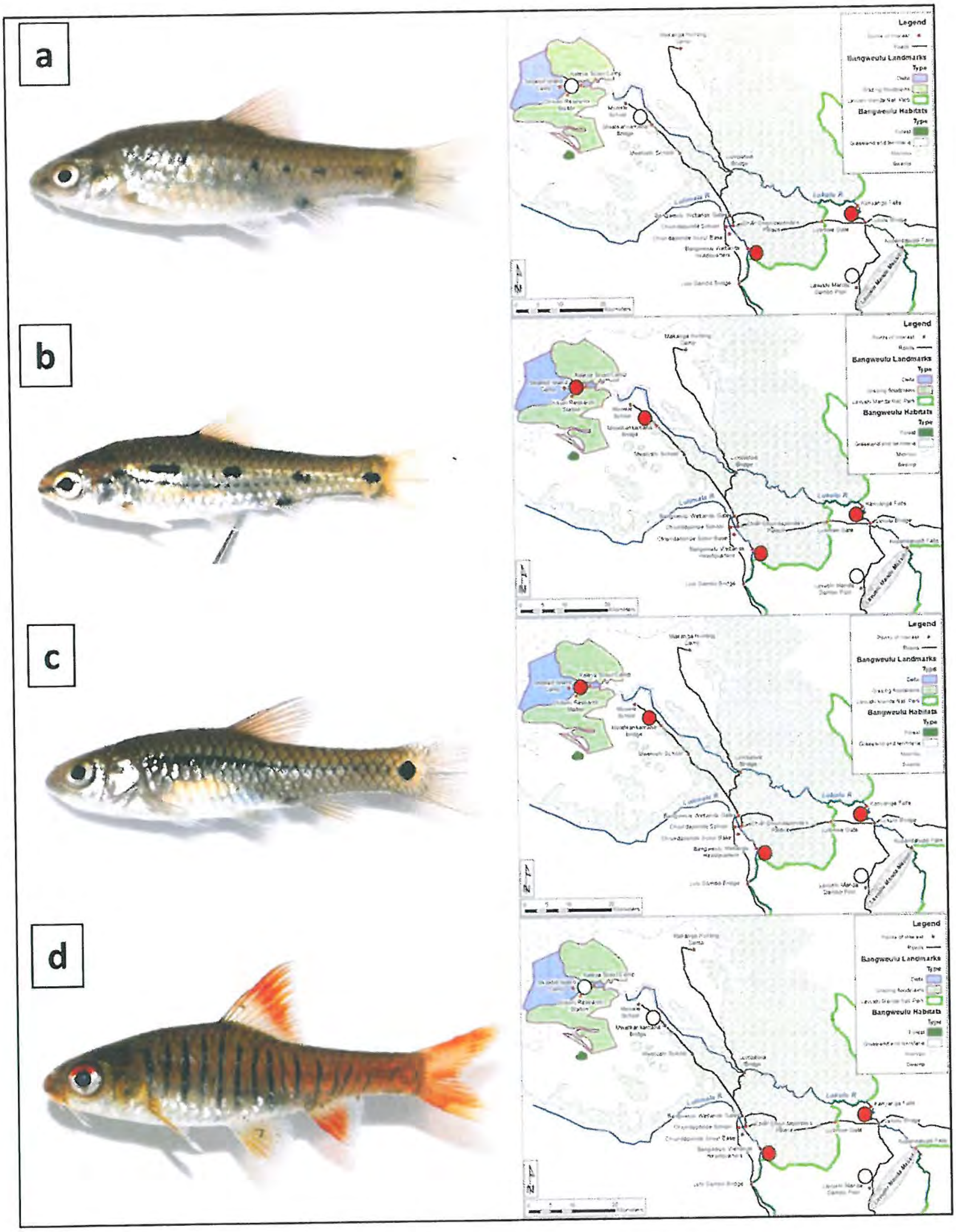

Figure 3.3: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Barbus neefi* (RB);b) *Barbus bifrenatus* (RB); c) *Barbus brevidorsalis* (RB); d) *Barbus fasciolatus* (RB).

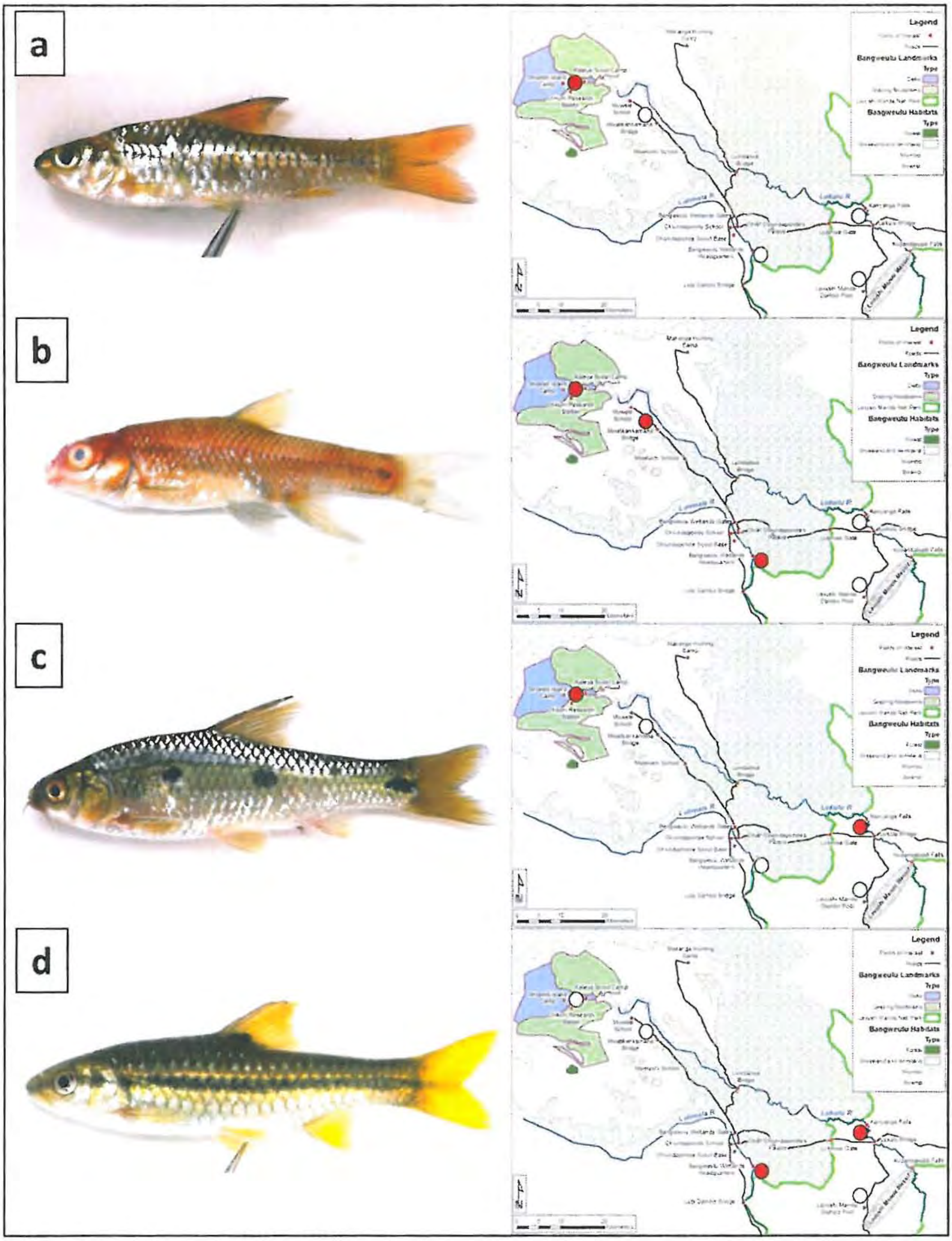

Figure 3.4: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Barbus radiatus* (CH);b) *Barbus haasianus* (CH); c) *Barbus trimaculatus* (CH); d) *Barbus eutaenia* (RB).

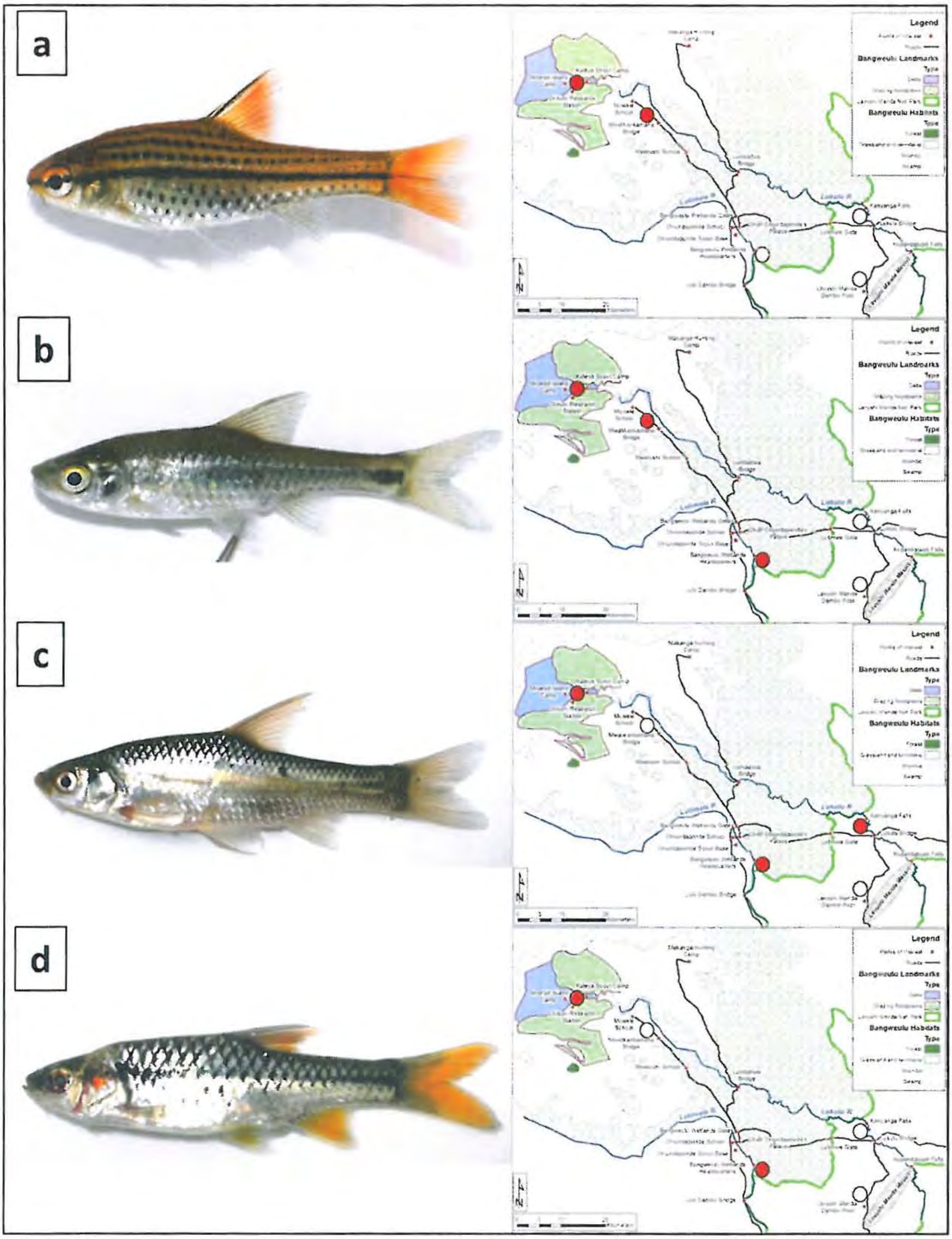

Figure 3.5: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Barbus multilineatus* (RB);b) *Barbus afrovernayi* (RB); c) *Barbus paludinosus* (CH); d) *Barbus kerstenii* (CH).

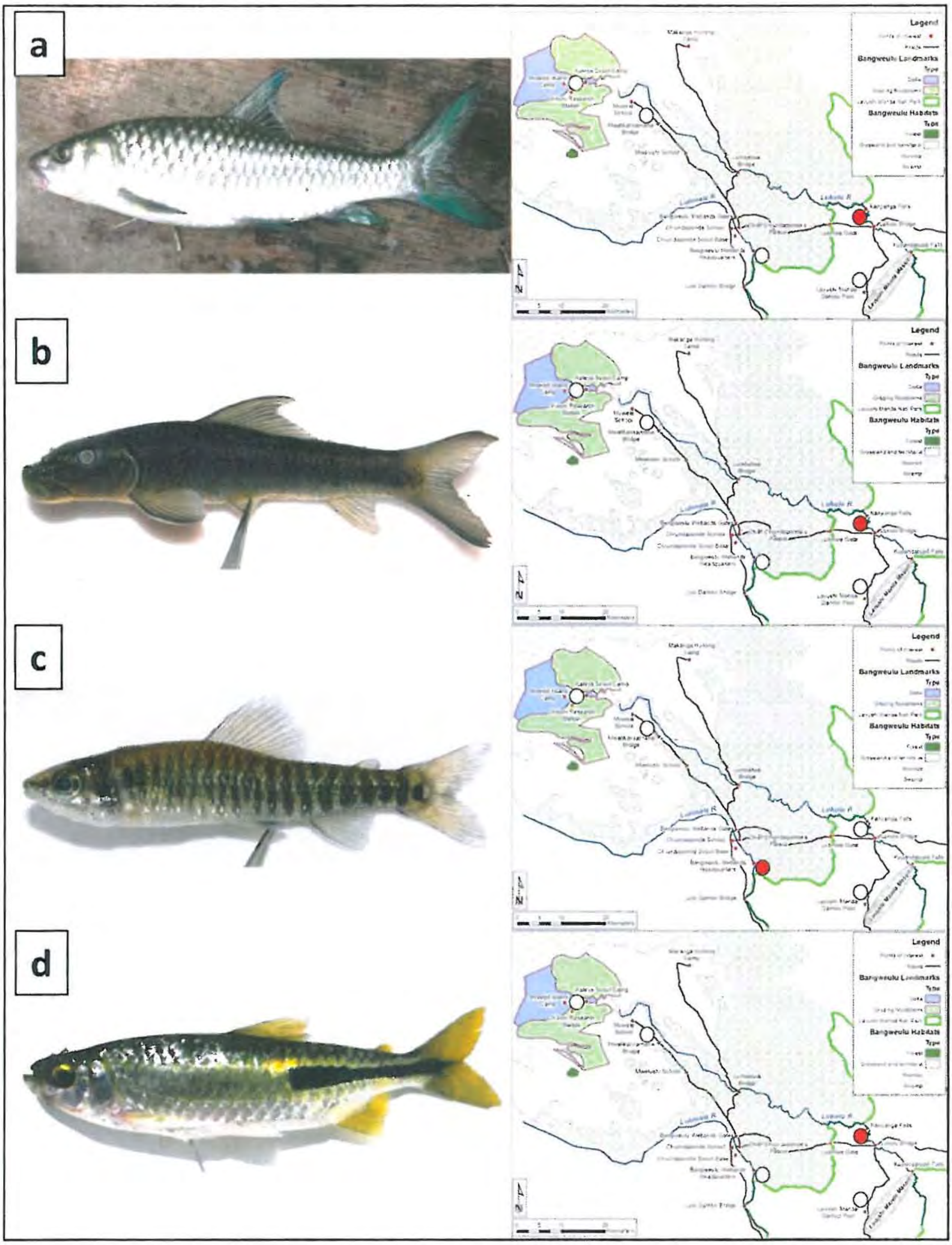

Figure 3.6: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Labeobarbus trachypterus* (CH);b) *Labeo cf. cylindricus* (RB); c) *Hemigrammocharax minutus* (RB); d) *Brycinus peringueyi* (CH).

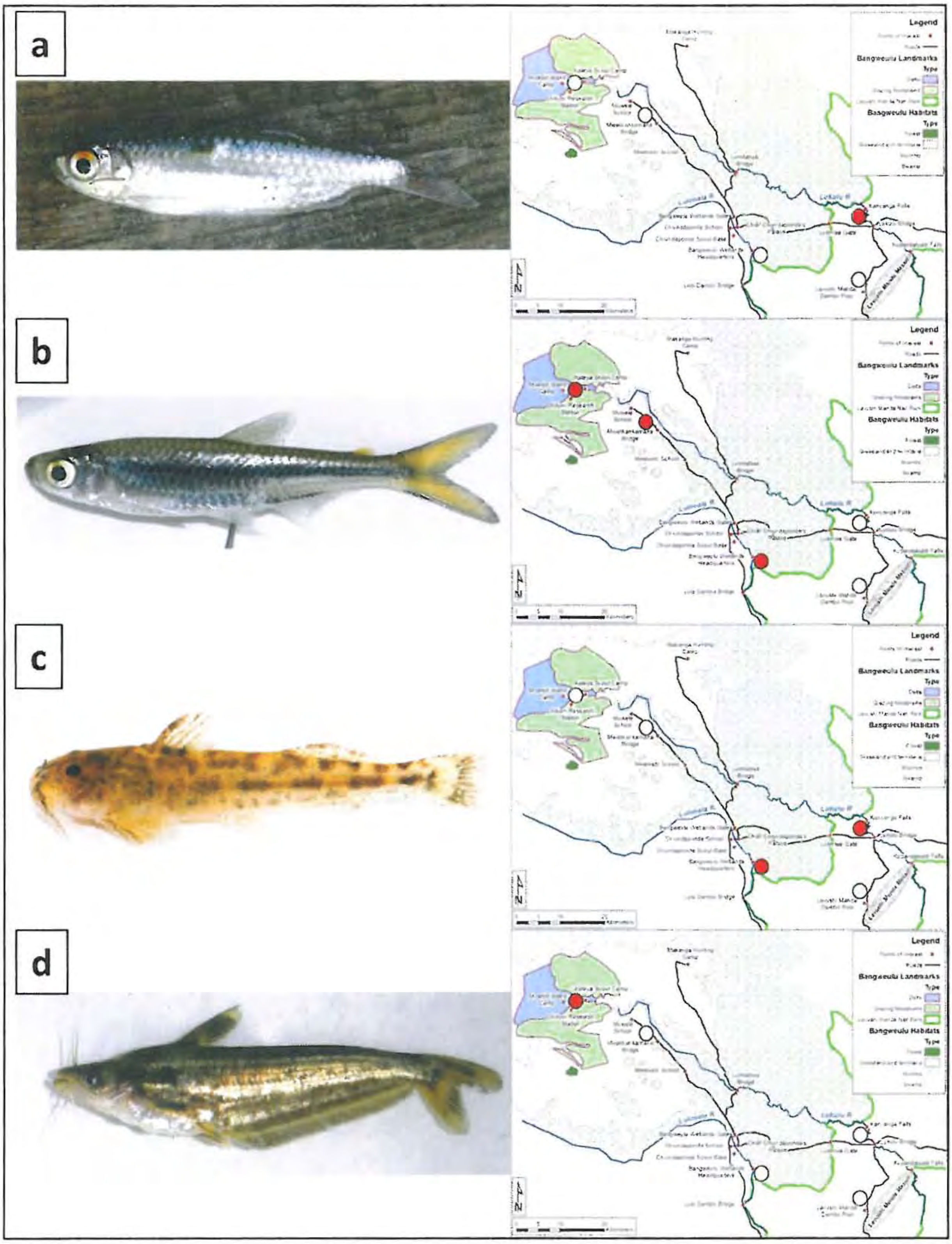

Figure 3.7: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Micralestes sardina* (CH);b) *Rhabdalestes rhodesiensis* (RB); c) *Zaireichthys sp.* (RB); d) *Schilbe intermedius* (CH).

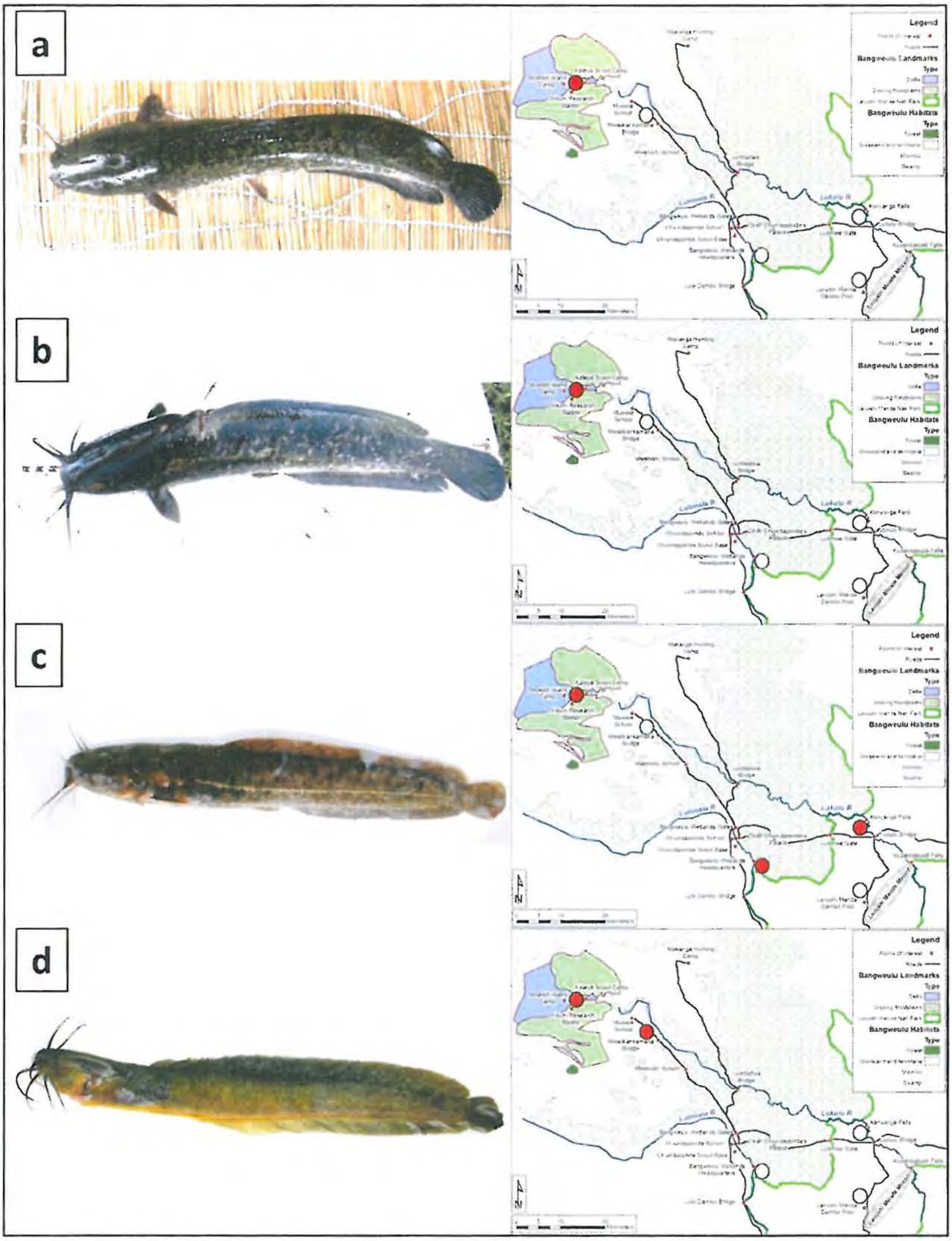

Figure 3.8: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Clarias gariepinus* (CH);b) *Clarias ngamensis* (CH); c) *Clarias stappersii* (CH); d) *Clarias theodorae* (CH).

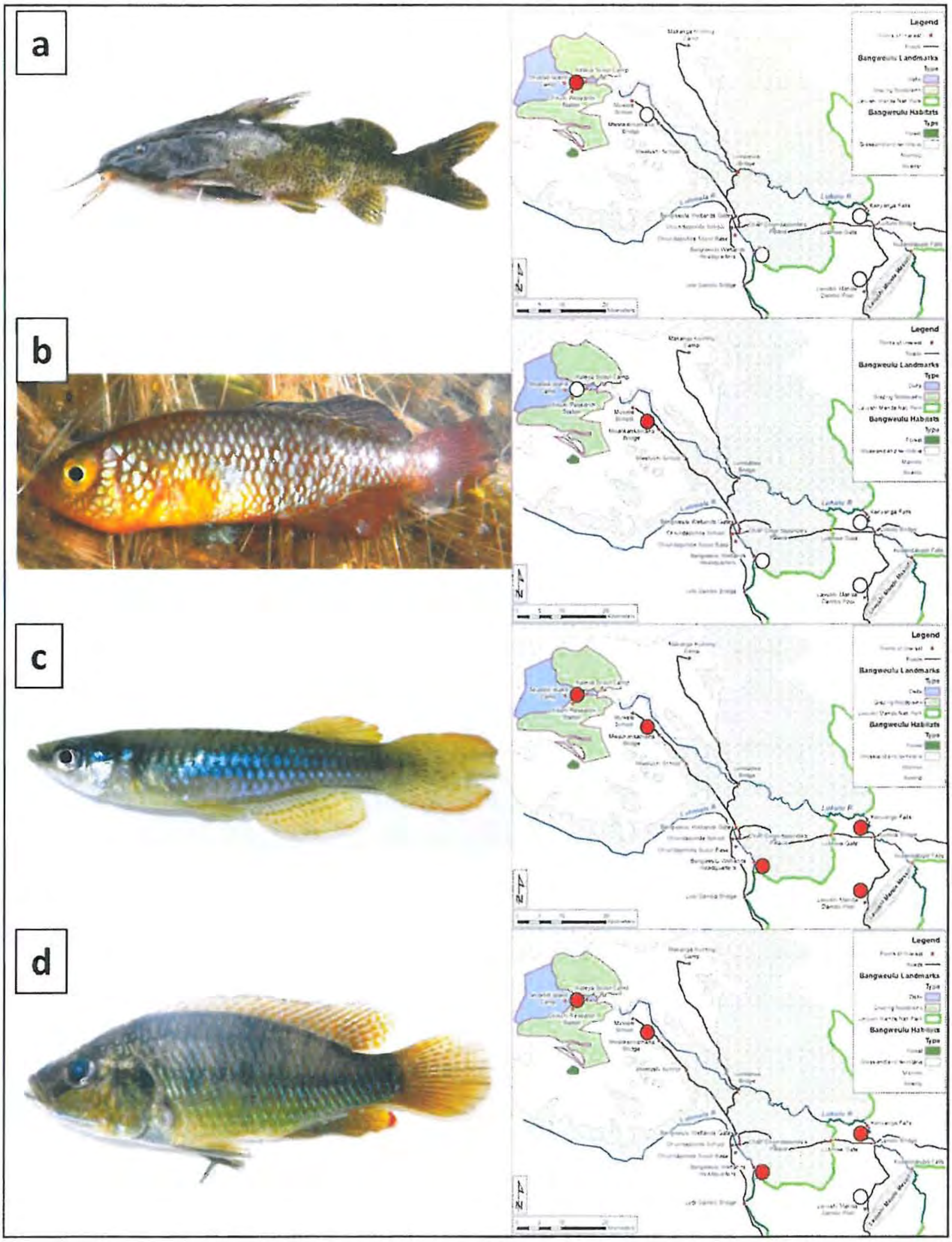

Figure 3.9: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Synodontis nigromaculatus* (CH);b) *Nothobranchius rosenstocki* (CH); c) *Aplocheilichthys sp.* (CH); d) *Pseudocrenilabrus philander* (CH).

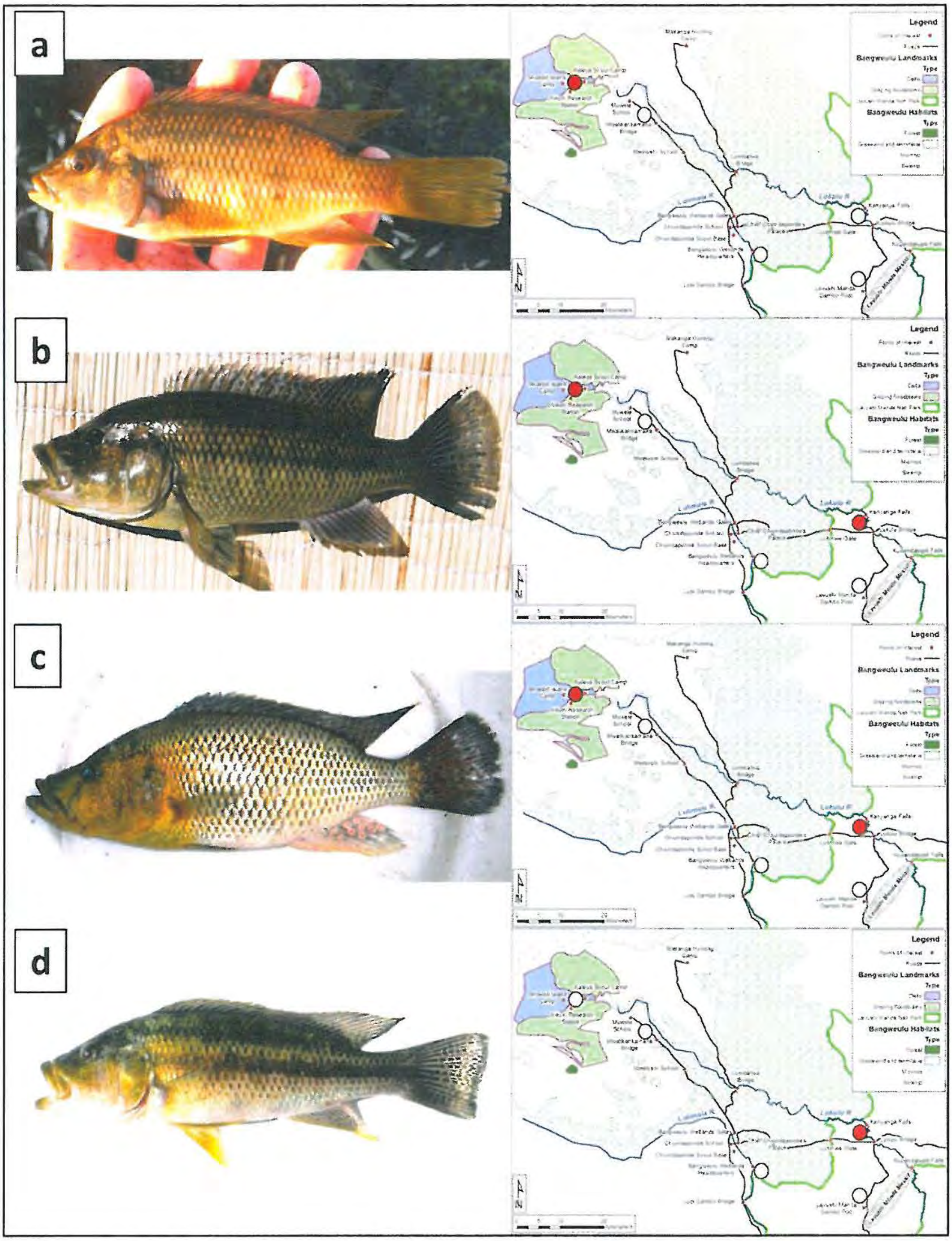

Figure 3.10: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Sargochromis mellandi* (CH);b) *Serranochromis robustus* (CH); c) *Serranochromis angusticeps* (CH); d) *Serranochromis thumbergi* (CH).

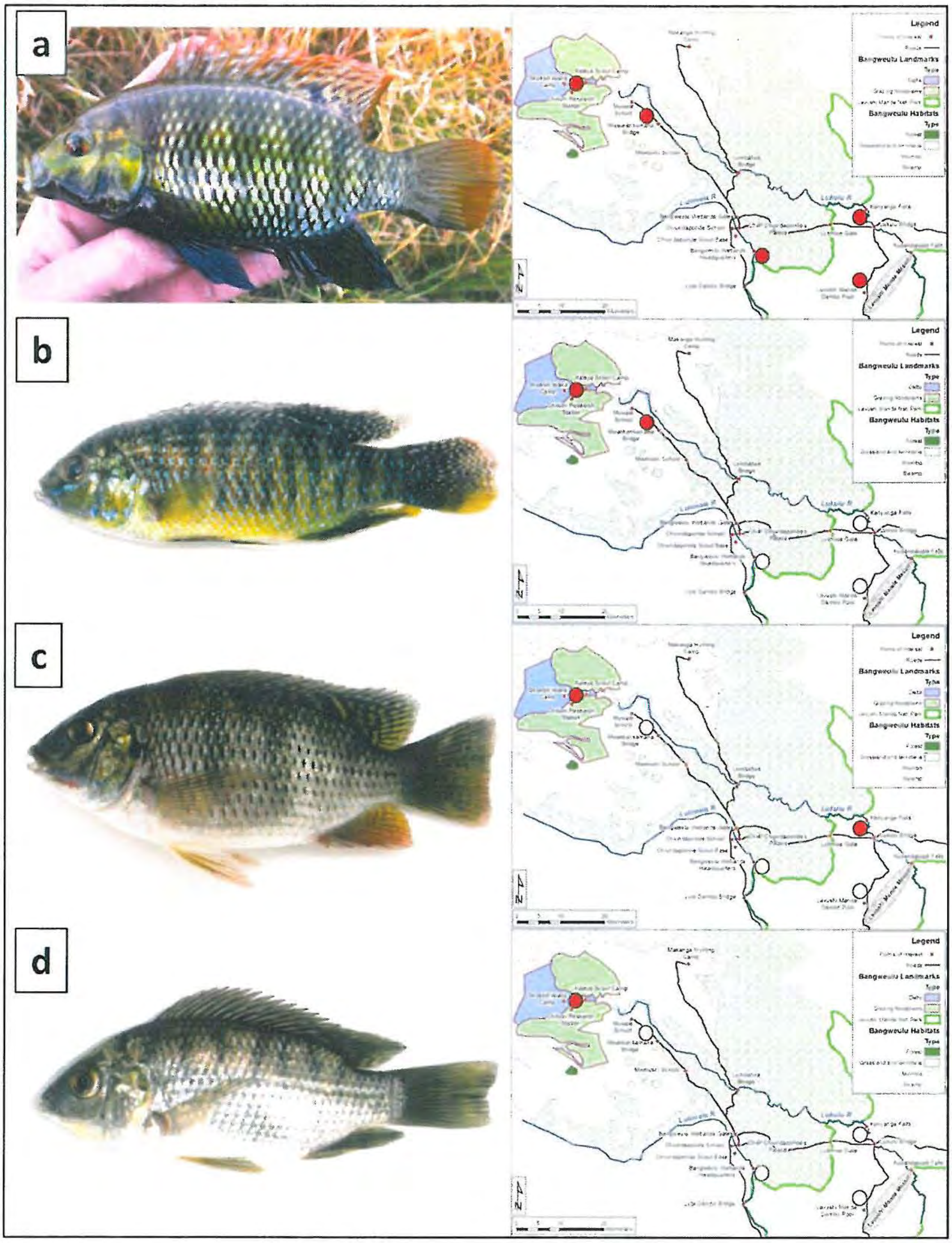

Figure 3.11: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Tilapia sparrmanii* (CH);b) *Tilapia ruweti* (CH); c) *Tilapia rendalli* (CH); d) *Oreochromis macrochir* (CH).

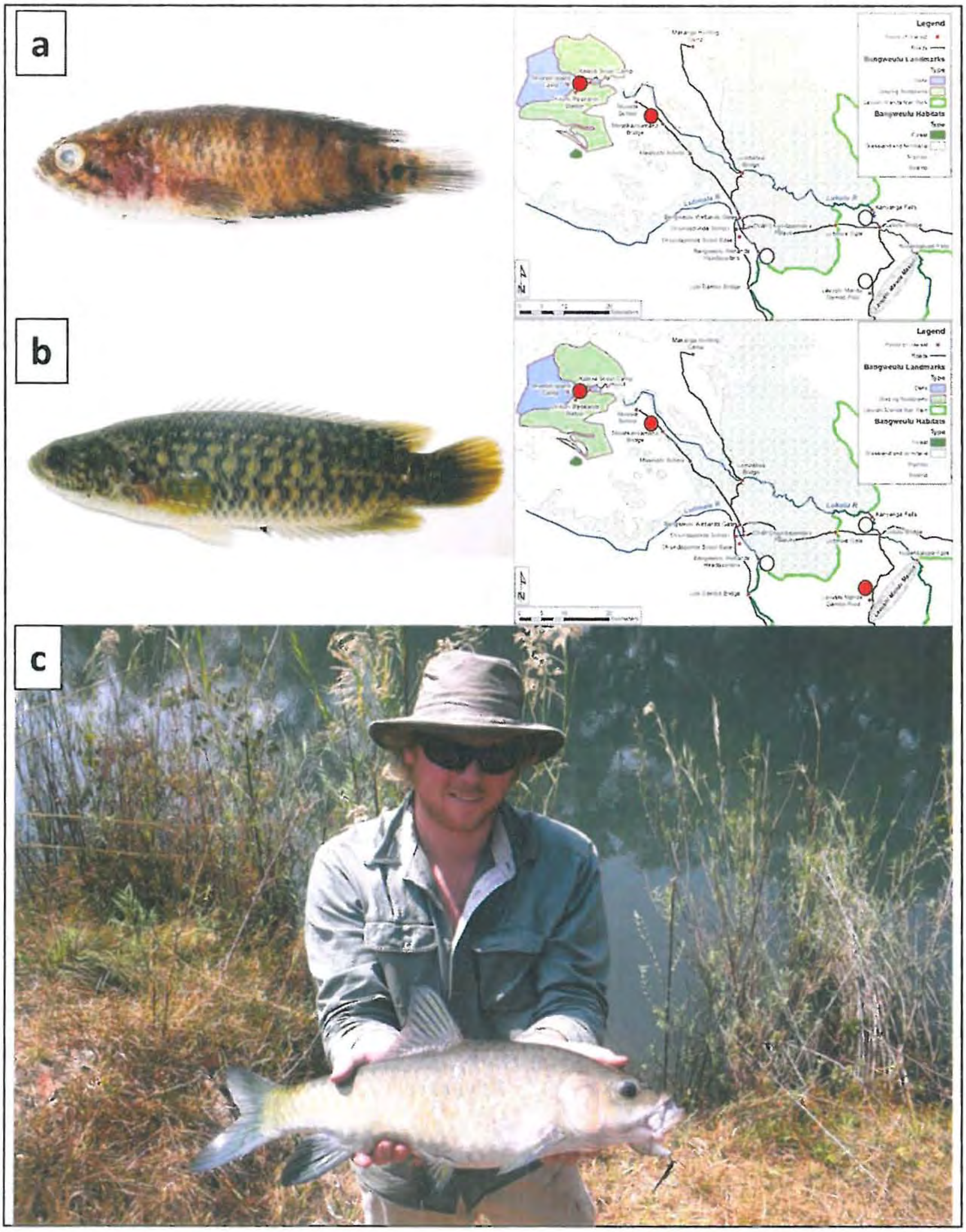

Figure 3.12: Specimen photograph (left) and its distribution map (right). Top to bottom: a) *Microctenopoma intermedium* (CH); b) *Ctenopoma multispine* (CH); c) Richard Peel with a large 'Mpifu' (*Labeobarbus trachypterus*) caught on an artificial lure in the Lukulu River (CH).

Family Mormyridae (Mormyrids/Elephant-snout fishes)

Cyphomyrus discorhynchus **(Peters, 1852). 'Icimpumwe', Zambezi parrotfish (Figure 3.2a).**

Distribution and habitat: Occurs throughout the Lukulu Delta and swamp, inhabiting vegetated channels. A juvenile was also found among rocks above Kanyanga Falls (Figure 3.2a).

Size and biology: Shoals of adults caught in June contained fish measuring 80-150 mm fork length (FL), while juveniles (< 80 mm FL) were seen in catches in November and in the later part of the flooded season (March to May).

Importance: The species appears only sporadically in fishermen's catches, and seems to move in shoals, often together with adult *Marcusenius macrolepidotus*. Mostly recorded from seine net catches where it was occasionally a significant part of the catch. Also caught in basket traps and in funnel nets. Marketed as the more abundant mintesa (*M. macrolepidotus*), either smoked or sun-dried if small.

Notes: Mwape (2003) interpreted the Bemba name of this fish, '*Chipuma*'-'*mabwe*', as 'hitting'-'stones'. A senior fisherman stated that the word '*cipuma*' refers to the hump on its head and speculated that the fish could use this hump to push its way through the thickest vegetation, or perhaps even rocks. The English name of related small mormyrids (*Pollimyrus* spp.) is 'stonebasher' (Skelton 2001), and this is likely a translation of the Zambian vernacular name for the group.

Marcusenius macrolepidotus **(Peters, 1852). 'Mintesa', Bulldog (Figure 3.2b).**

Distribution and habitat: Widespread in swamp and floodplain habitats (Figure 3.2b), inhabiting shallow water where there is aquatic and emergent vegetation for it to hide amongst during the daytime. During the flooded season it forages widely on plains at night, returning to hiding areas in thick vegetation during the day. Larger fish retreat to channels in the delta, but can still be found in shallow (< 0.5 m deep) water.

Size and biology: A nocturnal, medium sized species (typically 80-250 mm FL, up to 150 g) appearing to have an extended spawning season and rapid growth rate, with a definite flood-season peak in spawning. According to fishermen, small groups of large adults (> 150 mm FL) can apparently be observed in very shallow water at night, spawning during flooding. Male fish have a distinct indentation at the base of the anal fin (Pezzanite and Moller 1998), which becomes apparent at maturity (around 120 mm FL). Male fish attain a larger size than females and fish over 200 mm FL are considered large.

This fish has a single gonad, with the testis or ovary forming only on the right-hand side of the fish's visceral cavity. Fish sampled from October to November were found to be maturing, and none of the gonads were ripe yet. Fish sampled in March had finished spawning, though some showed freshly spent gonads. A large size range of juveniles were observed in April, from fish that had already reached 100 mm FL to some tiny 20 mm FL long fish that could only have been spawned a few weeks earlier, perhaps after late rains in March.

Importance: As one of the most important species in the fishery around Chikuni (Chapter 5), they were caught by almost all methods throughout the year. During the flooded season they were caught in gillnets (mostly adults in 51 mm and 64 mm stretched-mesh size nets), funnel nets and in basket traps. Juvenile and medium-sized fish were very important in the fish weir catch, and in the low-water season from July to November the fish became the most important part of the nocturnal seine net catch. Large migrations of mintesa are described from deeper swamp weir catches by Brelsford (1946).

Adult fish (120-250 mm FL) were gutted, scaled and smoke-dried after firming in the sun. Smaller juveniles (called *uluya*) were simply sundried, sometimes after scaling, and together with scaled *Barbus trimaculatus* form the bulk of a higher-quality sundried fish product called *kasepa* in the trade (Chapter 6). A greater proportion of mintesa in the mix reportedly had a favourable effect on the price. This fish was predominantly marketed and consumed on the Zambian Copperbelt.

Notes: The mintesa can die off in large numbers if there is a heavy first flood pulse coming down the Lukulu River into the papyrus beds at the head of the delta. The fish reportedly come to the surface and breathe rapidly at the surface, occasionally with large mortalities. A possible explanation is oxygen-depletion in the water due to large amounts of organic sediments being stirred up by the floods and the resultant greater aerobic bacterial activity, a periodic occurrence also reported from papyrus habitats in the Okavango Delta (Bills and Marshall 2004). Local fishermen claimed that large amounts of ash from burnt reed beds act as an irritant to the fish, and this could also cause mortality.

The viscerae of this species have large fat deposits. When large catches were made, the viscerae were boiled and the oil at the surface collected and bottled as cooking oil for home use. It was not traded.

Petrocephalus squalostoma **(Boulenger, 1915). 'Icele', Churchill (Figure 3.2c).**

Distribution and habitat: This small mormyrid was found in the Lukulu Delta in vegetated, shallow channels (Figure 3.2c).

Size and biology: Rarely exceeds 100 mm FL, the tiny mouth on the underside of the head and bright silver and gold colours when fresh make this fish easily distinguishable from the other mormyrids found in the area. It is endemic to the Bangweulu-Mweru ecoregion, where it occurs together with the recently described *Petrocephalus frieli* (Lavoué 2012). This new species was not observed in the study area, although it appears in a photograph in van Steenberge (2009), labelled as *Petrocephalus catastoma*, a species which has not been confirmed from the ecoregion (Lavoué 2012).

Importance: It was rarely seen, mostly in fish weir and mosquito-mesh seine net catches.

***Pollimyrus stappersii* (Boulenger, 1915). 'Ishimba', Dwarf stonebasher (Figure 3.2d).**

Distribution and habitat: This common fish was widespread in the Lukulu Delta, and in streams and rivers (Figure 3.2d). Its habitat comprised vegetation around swamp channels, and in forested streams such as the Lulimala at Nkondo headquarters it was collected in thick tangles of tree roots hanging into fast-flowing water.

Biology and size: This is the smallest mormyrid in the area, never exceeding 80 mm FL. Like most of the species in the area, this fish likely breeds during summer. Ripe fish were observed from January to March. This, and the large size range caught throughout the year, indicates that the breeding season may be extended over many months in summer.

Importance: Numerically this fish was very important in catches, but its small size made it contribute little to the overall weight of catches. Large numbers were caught in fish weirs in mosquito-netting funnel nets and basket traps, and also in mosquito-mesh seine nets at night. Together with *Pseudocrenilabrus philander*, this fish made up a large portion of the lower-quality *kasepa* sundried fish product.

***Mormyrus longirostris* Peters, 1952. 'Mbubu', Bottlenose/Bottle fish**

This large mormyrid (> 400 mm FL) is known from the Bangweulu region, where it inhabits deep channels near the Luapula and Chambeshi rivers (Jackson 1961). No evidence of this fish species was found anywhere near Chikuni, but a 70-year-old fisherman distinctly remembered them occurring in the Lukulu Delta during exceptionally high-flood years. It likely still persists in the area, but was not reported from catches during the study period.

Family Cyprinidae (Cyprinids)

Genus ***Barbus***:

This is a very diverse group in the region, and most species are shared with the Okavango/upper Zambezi systems. The collective vernacular term used for barbs is *misenga*, with *Barbus trimaculatus* being the only common species with a widely used vernacular name, *mushipa*. *Barbus trimaculatus* and *B. paludinosus* were very abundant, relatively large barbs (80 mm and 130 mm FL respectively), which made them important to the fishery. Smaller species were far less important, and most catches were made in mosquito-mesh seine nets and funnel nets. Traditionally they would only have been caught in dipping baskets or with poison.

***Barbus neefi* Greenwood, 1962. Sidespot barb (Figure 3.3a).**

Distribution and habitat: This barb was collected from rapids in the Lukulu River and in the Lulimala Stream at Nkondo (Figure 3.3a). It was not found in swamp habitats.

Size and biology: This small to medium sized species (40-60 mm FL) was uncommon.

***Barbus bifrenatus* Fowler 1935. Hyphen barb (Figure 3.3b).**

Distribution and habitat: Collected from both floodplain and stream environments (Figure 3.3b). On the plain it appeared to prefer vegetated water adjacent to channels with flow.

Size and biology: A small, robust species attaining 60 mm FL, it was often found inside the stomachs of predatory cichlids and catfishes during the floods.

<u>Importance:</u> Caught in gears that used mosquito netting as mesh. This was the second most-common small barb caught in funnel nets around Chikuni.

***Barbus brevidorsalis* Boulenger, 1915. Dwarf barb (Figure 3.3c).**

<u>Distribution and habitat:</u> A species from stream and woodland pool environments, also encountered in the delta around Chikuni (Figure 3.3c).

<u>Size and biology:</u> A very small species, mostly less than 30 mm FL, though larger individuals up to 40 mm FL were collected.

<u>Importance:</u> This species formed a large part of the catch in funnel nets that were used in fish weirs further from the rivers. One bag of small dried fish brought from woodland fish weirs contained almost exclusively this species. Able to disperse widely, it was also found in remote, temporary pools which it shared with the annual Bangweulu killifish, *Nothobranchius rosenstocki*.

***Barbus fasciolatus* Günther, 1868. Red barb (Figure 3.3d).**

<u>Distribution and habitat:</u> This colourful barb occurred on the margins of streams and rivers, but not on the floodplain (Figure 3.3d). Collected from the Lulimala Stream and seen in the Lukulu River. Elsewhere it is known to inhabit swampy habitats (Skelton 2001).

<u>Size and biology:</u> A small delicate barb, up to 70 mm FL, it appears to swim close to the substrate and against the sides of streams, not in open water.

<u>Importance:</u> Was seen caught in baited bottle traps set by children at a bridge over the Lulimala River. Likely also caught when streams were poisoned and in stream fish weirs that used mosquito netting.

***Barbus radiatus* Peters, 1853. Beira barb (Figure 3.4a).**

Distribution and habitat: An uncommon barb occasionally encountered near swamp channels in the Lukulu Delta (Figure 3.4a).

Size and biology: A fairly large barb ranging from 60-100 mm FL.

Importance: Two 100 mm fish were seen from seine nets, and smaller fish were seen in funnel net catches when flows through the fish weirs were still high.

Notes: Fishermen from deeper in the swamps recognized the fish and said it occurred in greater numbers there. The name they used for it was *Inchunga*. One local fisherman also mentioned the name *Chitulu*.

***Barbus haasianus* David, 1936. Sickle-fin barb (Figure 3.4b).**

Distribution and habitat: This widespread barb was found in grassy shallows in streams (Lulimala), dambos, woodland pools and in the swamps around Chikuni (Figure 3.4b).

Size and biology: The smallest barb in the area, with individuals rarely exceeding 30 mm FL. Males had elongated pelvic and anal fins, and over summer were tinged with a bright pink-orange. At other times of the year the fish were brown in colour.

Importance: Seen in funnel net catches, but easily overlooked.

***Barbus trimaculatus* Peters, 1852. 'Mushipa', Threespot barb (Figure 3.4c).**

Distribution and habitat: This species occurred throughout the area in swamp and floodplain habitats. It was not collected from the Lulimala Stream but was found in the Lukulu River, below the rapids at Kanyanga Falls (Figure 3.4c). It favoured channels and deeper pools usually where there was some water movement.

Size and biology: Attained 130 mm FL, with males distinctly smaller than females (fish > 100 mm FL were all female). Gonads ripened in November, and by March gonads were completely resorbed, indicating that spawning had occurred well before then. No small or immature fish were observed from August-December, indicating a limited summer breeding period and rapid growth. Typical sizes were 70-90 mm FL for males and 100-120 mm FL for females.

Importance: This important small species was caught in small-mesh gillnets (25 mm and 38 mm stretched-mesh), basket traps, funnel nets and seine nets. The high oil content of this fish made it a popular eating fish in its dried form. The fish were carefully sundried because of their high oil content. Fishermen noted a marked reduction in the population of this species in early 2012. A very short spawning period could make recruitment more sensitive to fluctuations in flooding conditions, and poor early flooding in the 2011/2012 rainy season may have affected recruitment in 2012.

***Barbus eutaenia* Boulenger, 1904. Orangefin barb (Figure 3.4d).**

Distribution and habitat: This barb was found exclusively in streams and rivers, and was common in both the Lukulu and Lulimala rivers, where it favoured shady, deep water near trees and rocks (Figure 3.4d).

Size and biology: This large barb (120-130 mm FL) had a large mouth, and was possibly more predatory than other barbs. The thick black line down its side may aid in camouflage in the dark, forested streams it occurs in. Many of the other fish species in these streams had a similar colouration (*Barbus kerstenii, Brycinus peringueyi* and young *Serranochromis robustus*).

Importance: Caught when stream sections are fished with poison and traps.

Barbus multilineatus **Worthington, 1933. Copperstripe barb (Figure 3.5a).**

Distribution and habitat: This ubiquitous barb was collected in a wide variety of habitats, from swamps to isolated pools and in dambos (Figure 3.5a).

Size and biology: A very small fish (25-40 mm FL), it was very abundant in grassy shallows. Young fish had bright red fins, which fade to orange in adults. Some individuals had a broad orange band running from the eye right through the fork of the tail, and less pronounced black stripes.

Importance: Very common in catches from mosquito-mesh funnel nets, where it made up the greatest proportion of small barbs caught. It was not very valuable though, and was added to the '*baby lila*' mix of dried fish.

Barbus afrovernayi **Nichols and Boulton, 1927. Spottail barb (Figure 3.5b).**

Distribution and habitat: Found in streams and in the delta (Figure 3.5b).

Size and biology: Small, rarely exceeding 40 mm FL. During the flooded season some individuals had a purple iridescent colour on their sides.

Importance: The fish was caught only in mosquito net meshes.

Barbus paludinosus **Peters, 1852. 'Misenga', Straightfin barb (Figure 3.5c).**

Distribution and habitat: This fish occurred throughout the area in all inflowing streams, swampy streams, the Lukulu Delta and swamp (Figure 3.5c). It preferred shallow areas of open water, often outside of currents and near grassy cover.

Size and biology: The usual size ranged from 40-70 mm FL, and a large size range of fish was found throughout the year, possibly indicating an extended breeding season. A few individuals reached large sizes (120 mm FL). An elongate form of *B. paludinosus* collected in the Lukulu River above Kanyanga Falls appears to be a different species, based on DNA-barcoding (Thuuli Maakinen, SAIAB, *pers. comm.*)

Importance: This fish was caught in small-meshed gillnets and in seine nets, especially in shallow waters at night. It was also important in basket traps and funnel nets. If a catch contained large numbers of barbs they were usually either almost exclusively *B. paludinosus* or *B. trimaculatus* and rarely a mixture between the two species. The two species may therefore not shoal together, despite inhabiting similar habitats. This fish had a lower fat content than *B. trimaculatus* but was still a significant addition to better grades of *kasepa* product.

***Barbus kerstenii* Peters, 1868. Redspot barb (Figure 3.5d).**

Distribution and habitat: This species was collected in both streams and swamp channels (Figure 3.5d).

Size and biology: A medium-sized barb (up to 80 mm FL) with a distinctive red spot on the gill cover, lending the fish its common name.

Importance: A very minor part of the catch, with adults occasionally being caught in seine nets, and smaller fish (< 50 mm FL) found in catches from funnel nets set in weirs adjacent to channels.

***Labeobarbus trachypterus* Boulenger, 1915. 'Mpifu', Blue-fin yellowfish (Figure 3.6a).**

Distribution and habitat: This was the largest fish collected in the upper Lukulu River inside Lavushi Manda National Park. Juveniles were collected at the lower Kanyanga Falls on the

Lukulu River, in a rock crevasse just above the falls. Adults were collected from above Kupandalupili Falls and in pools below Kanyanga Falls (Figure 3.6a).

Size and biology: Large specimens of 650 mm FL and 4-5 kg in weight were sampled by angling. Small shoals were observed moving along the margins of the large pools. Fish in the genus *Labeobarbus* are known to be very slow growing and late maturing, which puts them at risk in areas where they experience fishing pressure (Ellender et al. 2012). This is one of the species reported by Luapula River fishermen to have become locally depleted through fishing (Guveya and Kokwe 2007).

Importance: Members of this genus are popular angling fishes, renowned for their fighting strength (Skelton 2001). The Mpifu was an angling target during colonial days (Jackson 1961). They are likely to become an important recreational catch-and-release angling species inside Lavushi Manda National Park (Figure 3.12c).

Notes: The central African *Labeobarbus* need taxonomic revision (Roger Bills, SAIAB, *pers. comm.*). This species was described from one small specimen (Boulenger 1915), and the descriptions of this and related species are ambiguous. Therefore the name *L. trachypterus* is tentative (Jackson 1961).

Labeo cf. cylindricus **Peters, 1852. Redeye labeo (Figure 3.6b).**

Distribution and habitat: This fish was collected in strong rapids amongst water fern below the Kanyanga falls in the Lukulu River inside Lavushi Manda National Park (Figure 3.6b). They prefer fast-flowing water with a rocky substrate.

Size and biology: This is a small to medium-sized, robust *Labeo*. The single specimen collected was approximately 150 mm FL. The photograph was taken after preservation in formalin, and does not show its live colours, which were dark brown. These fish have a mouth adapted to rasping algae off rocks, and feeding tracks were seen on rocks in the waterfall plunge pools. A live *Labeo* was also observed amongst a mixed shoal of juvenile *Labeobarbus* swimming at the edge of a large rock in a pool below the Kupandalupili Falls on the Lukulu River inside Lavushi Manda National Park. It was elongate in shape with clear lateral stripes.

Notes: Related to the famous 'Luapula salmon' (*Labeo altivelis*), which was renowned for its huge spawning run up the Luapula River out of Lake Mweru and fished to complete collapse by the 1950's (Jackson 1961). It occurs in tributaries of the Luapula River at Kasanka National Park near Bangweulu Wetlands (van Steenberge 2009).

Family Distichodontidae (Citharines)

Hemigrammocharax minutus **(Worthington, 1933). Multibar citharine (Figure 3.6c).**

Distribution and habitat: Collected from the Lulimala Stream at Nkondo in shallow areas of the stream shaded by forest, where it was never abundant (Figure 3.6c).

Size and biology: A small species attaining a length of 80 mm FL.

Family Characidae (Characids)

Brycinus peringueyi **Boulenger, 1923. Peringue's robber, Dwarf tigerfish (Figure 3.6d).**

Distribution and habitat: Sampled from the upper reaches of the Lukulu River, below Kupandalupili Falls and also below Kanyanga Falls (Figure 3.6d). They appeared to prefer the main stream and deeper pools of the river. They were not found in the Lukulu Delta or in the main swamps, although they were found in the swampy Kasanka River inside Kasanka National Park (van Steenberge 2009).

Size and biology: A medium-sized characin, most were 150-180 mm FL, and one very large fish over 200 mm FL was also caught. The species is a fast, active fish with sharp, triangular cutting teeth and strong jaws. The striking black line on the side of the body is very dark in life.

***Micralestes sardina* Poll, 1938. Redeye robber (Figure 3.7a).**

Distribution and habitat: This fish was collected from rapids on the upper Lukulu River, below Kupandalupili Falls, during the very high flows of March 2012 (Figure 3.7a). It appeared to favour fast-flowing water.

Size and biology: This robust characin reached 80 mm FL, and had an aggressive behaviour, investigating large fishing lures, baited hooks and anything that fell into the water. In life the upper half of the eye was red, the fins tinged with orange, with an iridescent blue line running down the body. These features are less visible in the photograph (Figure 3.7a). Large numbers of juveniles were found in the shallows amongst grass, indicating that this species had spawned earlier in the summer.

***Rhabdalestes rhodesiensis* (Ricardo-Bertram, 1943). 'Itala', Slender robber (Figure 3.7b).**

Distribution and habitat: This slender, silvery fish was widespread in flowing waters of the Lukulu Delta (Chikuni) and its floodplains, and also abundant in the Lulimala Stream (Figure 3.7b). It was not seen in the upper sections of the Lukulu River.

Size and biology: The fish attained 50-60 mm FL. A surface-dwelling species, inhabited open water with some current, and was only found on shallow floodplains during the high-water period. At night it could easily be seen in torch light, as a long slender fish swimming very close to the surface.

Importance: This species was rarely a large component of the catch, caught in mosquito-mesh funnel nets and in mosquito-mesh seine nets. Favoured for being similar to *Kapenta* (freshwater sardine species from lakes that are popular in urban areas), though catches were rarely large enough even for home consumption.

***Hydrocynus vittatus* Castelnau, 1861. 'Manda', Tigerfish.**

This well-known predator has historically been recorded from main channel of the Lukulu River at the head of its delta, where it is listed in Pitman's 1936 faunal survey of Zambia (Pitman 1936). Ian Manning, an early conservationist who lived in the area in the 1970's confirmed their presence, as well as elsewhere in the swamp (Ian Manning, independent consultant, *pers. comm.*). Older fishermen remember the fish occurring in the delta though only during exceptionally high-water years, many decades ago. The lack of maintenance on artificial swamp channels in the past half-century may have limited the dispersal range of the tigerfish, which could have used these deep channels to penetrate the area from the Chambeshi River Delta, where it is an important catch (Kolding et al. 2003). Another verbal record was obtained from a labourer inside Lavushi Manda National Park that they occur in that section of the Lukulu River, though none were observed or caught there during sampling trips. Reports were been received of a riverine fish called *Akalondo*, which was variously described as a tigerfish, a large catfish or a large cyprinid.

Family Amphiliidae (Mountain catfishes)

***Zaireichthys* sp. Roberts, 1967. Sand catlet (Figure 3.7c).**

Distribution and habitat: Collected from the Lulimala Stream and was seen but not collected at the Lumbatwa Bridge over the Lukulu River (Figure 3.7c).

Size and biology: This tiny (< 40 mm total length (TL)) catfish lives among sand and fine gravel in currents in the stream, best caught by pulling a drag net through the bottom sediment. Most people around the Lulimala Stream were not as familiar with fish species as people from the swamps, and nobody appeared to know of this small fish.

Family Shilbeidae (Butter catfishes)

***Schilbe intermedius* Rüppel, 1832. 'Lupata', Silver catfish (Figure 3.7d).**

Distribution and habitat: This catfish was widespread in the Lukulu Delta (Figure 3.7d). Preferring flowing water in both shallow and deeper channels near vegetation, in the dry season it appeared to be limited to the main, deeper channels in the delta. Fishermen claimed that this fish migrates widely during the flooded season.

Size and biology: In the Bangweulu Wetland area it reached a small size (< 180 mm FL). Jackson (1961) mentions an additional two species occurring in the Bangweulu-Mweru ecoregion, which attain lengths greater than 300 mm FL.

Importance: The silver catfish was caught mostly in basket traps and small-mesh gillnets, and occasionally in funnel nets and seine nets. After capture, the venomous spines were removed, and the fish usually sundried. This fish was reportedly very abundant in some areas of the swamp nearer the Luapula River, and made up a large proportion of the dried fish in a bag of fish brought from that area.

Family Clariidae (Air-breathing catfishes)

***Clarias gariepinus* (Burchell, 1822). 'Inyenda', Sharptooth catfish (Figure 3.8a).**

Distribution and habitat: This species, the most widespread on the African continent, was widespread and abundant in the Bangweulu swamps and floodplains, dispersing widely during the rains. It was not seen or collected in the upper reaches of the Lukulu River or the Lulimala Stream (Figure 3.8a).

The species requires cover during the daytime in the form of thick vegetation, emerging to forage in very shallow water at night. Large numbers sheltered under floating vegetation and under papyrus mats. Juvenile catfish penetrated very far inland during the flood season, often being found many kilometres away from any channel amongst shallowly flooded grass. Large adults (> 500 mm TL) were found in the deeper channels of the Lukulu Delta.

<u>Size and biology:</u> The largest individual observed measured 1100 mm TL and weighed 8.5 kg. Fish heavier than two kilograms were rare. Fish below 200 mm TL were rare in catches late in the season (October-November). This may indicate that all fish recruited in the season had already attained a larger size after 8-10 months. Growth rates appeared to be variable as there was a large size range among presumed 'young-of-the-year' juveniles. The majority of the fish examined during November were mature and ready to breed. A nocturnal spawning migration reportedly occurs when the flood waters first inundate the floodplains, called *Chilambo*. During the 2011/2012 summer, this event reportedly occurred around the second to third week of January. The juveniles dispersed widely, and when the water on the floodplains began to recede (April 2012) large numbers of these juveniles were observed accumulating against fish weirs near the research station, attempting to return to deeper channels.

The fish is dependent on gulping air from the atmosphere, and they can be heard 'gulping' deep inside thick vegetation such as papyrus beds. Fish sheltering under floating grass mats sometimes formed 'breathing holes'. The flagship species for the Bangweulu tourism and conservation effort, the threatened shoebill stork (*Balaeniceps rex*), capitalises on this behaviour, and selects foraging sites where catfish must force their way through the floating vegetation to breathe (Ralf Mullers, Fitz-Patrick Institute, *pers. comm.*).

Importance: In the Bangweulu floodplain fishery, this was one of the most important fish species by weight. Smoke dried catfish are favoured in the urban markets in southern DRC (mostly in the city of Lubumbashi). The majority of adults were caught on longlines, and large numbers of juveniles were caught in basket traps and funnel nets.

During the dry-season catfish could be speared in considerable numbers from isolated pools. A similar method is employed by the Lozi tribe on the Barotse Floodplains around Liuwa Plain National Park (Richard Peel, Rhodes University, *pers. comm.*).

Notes: The local generic common name for larger clariids was *muta* for larger (> 300 mm TL) and *popa* for smaller fish.

***Clarias ngamensis* Castelnau, 1861. 'Inkose', Blunt-tooth catfish (Figure 3.8b).**

Distribution and habitat: This species was found alongside the sharptooth catfish. It was widespread in the Lukulu Delta, where it inhabited both shallow and deeper vegetated waters, possibly not ranging as far away from channels as *C. gariepinus* (Figure 3.8b). They appeared to favour deeper (> 2 m) water than other *Clarias* species.

Size and biology: This species was generally smaller than *C. gariepinus*, with large fish typically measuring 350-400 mm TL. Small fish below 200 mm TL are found throughout the year, and young-of-the-year juveniles were always much smaller than the same age class of *C. gariepinus*. The growth rates seemed more uniform, as juvenile cohorts were all of similar size.

According to local fishermen, this species also moved onto the plain adjacent to channels together with *C. gariepinus* during *Chilambo*. Several larger (350 mm TL) females dissected in March 2012 had retained eggs.

The bite of *C. ngamensis* is considerably more forceful than that of *C. gariepinus*, and this corresponds with the difference in dentition, with *C. ngamensis* having a grinding plate of rounded teeth (Skelton 2001). Preliminary observations detected no difference in diet between the two species, both having usually consumed small fish. Additional distinguishing characteristics between the two species were a smaller mouth, thicker barbels and a more compact body in *C. ngamensis*.

Importance: Not as abundant as *C. gariepinus*, and only in dry season seine catches was it sometimes caught in equal numbers to that species. It was caught using all the same methods as for *C. gariepinus*. This fish was not distinguished from *C. gariepinus* in the trade, with larger fish also being called *muta* and smaller fish *popa*.

Notes: The flesh of *C. ngamensis* had a darker colour that remained pink when cooked as opposed to the yellowish flesh of *C. gariepinus*, and also had a better flavour.

***Clarias stappersii* Boulenger, 1915. 'Bomba', Blotched catfish (Figure 3.8c).**

Distribution and habitat: Widespread in the area (Figure 3.8c), preferring riverine habitats. Occurred in channels with moving water in the Lukulu Delta, and was common higher up in the Lukulu River in rapids and among rocks. It was the only clariid collected in the Lukulu inside the Lavushi Manda National Park, and it was also present in the Lulimala Stream among tree roots on the bank.

Size and biology: Little is known about this fish. Juveniles (< 100 mm TL) were seen in May-August and adults reached a size of 500 mm TL.

Importance: Occasionally caught on hooks or in basket traps, mostly close to channels. It was rare in catches in the Lukulu Delta, making up a small portion of the longline catch where these were set near channels. The fish has short, venomous spines and when caught it was usually immobilised by a gash through the spinal cord.

***Clarias theodorae* Weber, 1897. 'Mulonfi/Mulonge', Snake catfish (Figure 3.8d).**

Distribution and habitat: Abundant and widespread in swamp and in the Lukulu Delta (Figure 3.8d), where it favoured thickly vegetated waters, living amongst the roots and stems of floating vegetation and flooded reeds, and also in pools covered by water lillies.

Size and biology: Small fish (< 50 mm TL) were found in May and June, possibly indicating an extended spawning period. The largest fish (280 mm TL; Figure 3.8d) collected was caught in a baited trap in the pool in front of Chikuni research station.

Importance: The snake catfish was very important in the fishery. Though small, they were dried whole and then smoked. These were reportedly the most favoured of all the clariid products on the Congo-border fish markets. The fish were caught mostly in basket traps, and occasionally large numbers were caught in funnel nets set in weirs near vegetation. It was rarely caught on hooks.

Notes: The pectoral spines of this fish are short but venomous. When certain parts of the swamps dry out, this is reportedly one of the very abundant species caught by 'digging' open floating vegetation mats.

***Heterobranchus longifilis* Valenciennes, 1840. 'Sampa', Vundu.**

This very large catfish species (> 1200 mm TL) was not observed or collected in the area. Older fishermen reported that the fish was a rare catch on hooks from the deeper channels of the Lukulu River at the head of the delta near Muwele village. It likely still occurs in this area.

__Family Mochokidae (Squeakers)__

Synodontis nigromaculatus **Boulenger, 1905. 'Cingongongo/Cinyimba', Spotted squeaker (Figure 3.9a).**

Distribution and habitat: This fish had a limited distribution in the Lukulu Delta, where it inhabited vegetated waters adjacent to deeper channels (Figure 3.9a). Only very occasionally observed at Fibili fishing camp, near Chikuni. Reported to occur higher up in the Lukulu Delta at Muwele village, where it was said to be more common. It also likely occurs in the deep middle reaches of the Lukulu River, near the Lumbatwa Bridge.

Size and biology: Adults of various sizes were observed (130-170 mm FL), though one juvenile of 80 mm FL was also collected. Very few fish (< 3) were seen during the flooded season, until November when five fish were caught in one week in the same locality. This was after the first proper rain shower, and the movement of the fish could have been related to breeding.

Importance: Caught in gillnets, seine nets and basket traps, it was neither economically important nor favoured for eating by the local fishermen.

Notes: This fish appeared to be nowhere abundant in the Chikuni area, unlike in other river systems such as the Zambezi (Peel 2012). The venomous spines were usually removed with a knife as soon as a fish was landed. The name *Cingnongongo* is onomatopoeic, referring to the sound made by the fish when captured; the squeaker produces this rapid grinding sound by moving its pectoral spines, which have a toothed socket joint not unlike a gear cog.

Family Aplocheilidae (Annual killifishes)

***Nothobranchius rosenstockii* Valdesalici and Wildekamp 2005. 'Lombwe-sweta', Bangweulu killifish (Figure 3.9b).**

Distribution and habitat: Probably widespread in the correct habitat, it was collected from woodland pools on the western bank of the Lukulu River near Muwele village and a tributary stream near Muwele (Figure 3.9b). It likely also occurs on the opposite bank of the river (Lumbatwa plains) where similar pools occur. The habitats the fish were found in were vegetated marshy pools and stream banks.

Size and biology: These small fish did not exceed 40 mm TL in length. They are interesting in that members of this colourful genus have the unique ability to produce eggs that can survive in dry pools where the adults no longer survive, hatching with the next season's rains. They appeared to prefer dense mats of drowned grass, and they lived near the bottom; when collecting, deeper net pulls were required than for catching their surface-water relatives, the topminnows. In these habitats they coexisted with *Clarias* species, small *Barbus* species, *Tilapia sparrmanii*, *Aplocheilichthys* species, *Ctenopoma multispine* and *Marcusenius macrolepidotus*.

Importance: This colourful fish was only known to people living near the pools who would see them in their catches when they went to harvest the pools with traditional piscicides. There was one verbal record received of them being an occasional basket trap catch from a fish weir near Chikuni.

Notes: An interpretation of the vernacular name is that it means 'red sweater', referring to the colours of the male. The species was formally described from Kasanka National Park by Valdesalici and Wildekamp (2005). It has already become popular in the European aquarium trade, where aquarists have been breeding the species in captivity and distributing their eggs to other killifish keepers around the world.

Family Poeciliidae (Topminnows)

***Aplocheilichthys* spp. Bleeker, 1863. 'Bwelele', Topminnows- various species. (Figure 3.9c).**

This group of small fish species are difficult to identify in the field. There were at least three different species in the area, probably more. DNA barcoding will highlight species-level differences between specimens, and aid greatly with the identification of species in this group in the future. They have been grouped together for the purpose of this thesis.

Distribution and habitat: This group of fishes was very widespread, with various species in the Lukulu Delta (Chikuni), the Lukulu River inside Lavushi Manda National Park, the dambo sampled inside Lavushi Manda, the Lulimala River and pools in the woodland (Figure 3.9c). The fish were found near the surface amongst aquatic vegetation such as waterlilies, riverine margins with branches and roots, and flooded grasses. The reliance of these fish on cover was evidenced by the absence of these fish where lechwe or seine net fishermen had cleared waterlilies; adjacent intact patches had a visibly higher density of these fish. This genus must disperse widely during the rains as it was found in temporary pools in the woodlands. Unlike the killifish its eggs are not known to become dormant in damp vegetation of dry pools.

Size and biology: Small, slender fishes, they varied in size from 20-60 mm TL. They likely spawned throughout the summer, as females were observed with eggs in March/April, near the end of the flooded season.

Importance: These small fish were very abundant in the swamp, but never appeared in large numbers in catches. There were always a few in catches from mosquito-mesh gears.

Family Cichlidae (Cichlids)

***Pseudocrenilabrus philander* (Weber, 1897). 'Cikundu', Southern mouthbrooder (Figure 3.9d).**

Distribution and habitat: This dwarf cichlid was very widespread, found throughout the Lukulu Delta. It also occurred in the Lulimala River (Figure 3.9d). It was very abundant in shallow areas of the floodplain, occurring in water only a few centimetres deep.

Size and biology: This small fish varied in size from 20-70 mm TL, with males attaining breeding colours at 40 mm TL. The southern mouthbrooder likely spawned throughout the year as different size classes and juveniles were present throughout the year.

Importance: The species was an important catch in funnel nets, basket traps and mosquito seine nets. It had an extended occurrence in the catch due to its shallow water habitat, and it was usually one of the last species to move through fish weirs that were becoming dry.

***Sargochromis mellandi* (Boulenger, 1905). 'Mbilya', Brown bream (Figure 3.10a).**

Distribution and habitat: Reportedly common in Lake Bangweulu and the Luapula River, in Bangweulu Wetlands it was limited to channels of the Lukulu Delta (Figure 3.10a) where it was very rare (only 4 fish seen).

Size and biology: The largest fish seen was 150 mm TL, which they apparently rarely exceed.

Importance: Individual fish of this species were occasionally present in a seine net catch, but only when water levels were high. Only two young fish (70 mm TL) were seen as part of the catch in funnel nets in weirs adjacent to flooded channels.

Serranochromis robustus **(Günther, 1864). 'Nsuku', Largemouth bream (Figure 3.10b).**

Distribution and habitat: This widespread fish was found throughout the Lukulu River, its delta and the swamps (Figure 3.10b), ranging in habitat from rocky rapids and pools to quiet lagoons and channels with water lilies.

Size and biology: Large adults measured 350 mm TL and weighed 800 g. In Bangweulu it appeared to have an extended breeding season with a summer peak, as small specimens (< 120 mm TL) known as *matongo* were found until late in the year (September). Its mouthbrooding reproductive method probably makes it less dependent on flooding for successful breeding, though juvenile survival and growth would be highest when the plains are flooded. Young fish on the floodplain hunted near currents, and stomachs contained almost exclusively small *Barbus* species during the flooded season.

Importance: An important component of the fish weir fishery (juveniles), and gillnet and seine net catches (juveniles and adults), it was also occasionally hooked on longlines. It was prepared for sale mostly by smoke-drying after sun-firming, and was also split and salted.

Serranochromis angusticeps **(Boulenger, 1907). 'Polwe', Thinface largemouth (Figure 3.10c).**

Distribution and habitat: Widespread in the Lukulu Delta, it was also found in the Lukulu River below Kanyanga Falls, which appear to be a barrier to upstream occurrence of this species (Figure 3.10c). It favoured shallow, heavily vegetated areas such as waterlily pools, grassy backwaters and channels around fish weirs with submerged aquatic vegetation.

Size and biology: This was the largest cichlid observed in Bangweulu Wetlands, attaining over 400 mm TL and 1 kg in weight). The fish matured at a relatively small size (at 200 mm all fish examined were mature), probably reached within a year. In November the fish displayed bright yellow breeding colours and had ripe gonads. Also a mouth brooder, but uniform size in the juveniles pointed to a limited breeding period in early summer (December to January). The fish is laterally compressed, reducing its profile when seen from above or from the front. This likely makes it an ambush predator and the mouth folds out to a considerable size, enabling it to suck in prey from a distance. Juveniles had orange speckles on the face.

Importance: This fish was relatively important to the fishery, though not as abundant in catches as other large cichlids. Small and medium sized fishes (90-200 mm TL) were caught in fish basket traps and gillnets. Large individuals were scarce, but were caught in seine nets. The fish spoiled easily, and was usually smoked.

***Serranochromis thumbergi* (Castelnau 1861). Brownspot Largemouth (Figure 3.10d).**

Distribution and habitat: This medium-sized predatory cichlid was caught below Kanyanga Falls in Lavushi Manda National Park, and appeared to be absent from the swamp and floodplain habitat around Chikuni (Figure 3.10d). It was common in flowing water as well as in pools.

Size and biology: Fish of up to 300 mm TL were caught by angling. A smaller mouth, finer teeth and small brown spots on the flanks separate this from the more common *S. robustus*.

Notes: It is likely that this species also occurs in the Lulimala River system as a fish caught in a small dambo lake periodically linked to the Lulimala Stream appeared to be this species, identified from a photograph.

Tilapia sparrmanii Smith, 1840. 'Matuku', Banded tilapia (Figure 3.11a).

Distribution and habitat: A common species, distributed throughout the Bangweulu Wetlands area, in the Lukulu Delta, swamp, floodplains and rivers (Figure 3.11a). It preferred shallow habitats with little flow, where there is some cover in the form of grass or other vegetation.

Size and breeding: Fish larger than 150 mm TL were very rare, and most measured less than 120 mm TL. During summer some fish had a dark black ventral surface and pelvic fins, presumably their breeding dress. This is clearly shown in the fish in the photograph, caught in Kasanka National Park. In Bangweulu, intensely coloured individuals were observed from October to April. It likely had an extended breeding season, with multiple size classes occurring throughout the year. The occasional fish had a hump above the cranium.

Importance: An important catch in small-meshed (25 mm and 38 mm stretched-mesh) gillnets, especially during the high-water season. The fish was also caught in seine nets, basket traps and funnel nets. It was prepared mostly by sundrying after scaling and gutting. Small fishes left ungutted reportedly tasted bitter, lending the nickname "Chloroquin" (a bitter antimalaria medication) to the lower-quality *kasepa* mixture of dried fishes.

Tilapia ruweti (Poll & Thys van den Audenaerde, 1965). 'Cifinsa', Okavango tilapia (Figure 3.11b).

Distribution and habitat: Widespread around the Lukulu Delta and its floodplains (Figure 3.11b), this species favoured shallow, flowing water, often near thick vegetation.

Size and biology: Adults were small (60-80 mm TL). Males were told by their colourful breeding dress, and intense colours were still observed into March with receding waters.

Importance: A minor catch, usually too small to be caught in basket traps. It was seen in catches of funnel nets and traditional pull/dip baskets (*ulwanga*). Children caught this species in small-meshed (25 mm stretched-mesh) gillnets on a grassy flooded plain adjacent to the Lukulu River near Muwele Village. When sundried it changed to a black colour allowing it to be distinguished from other small sundried cichlids.

***Tilapia rendalli* (Boulenger 1896). 'Mpende', Redbreast tilapia (Figure 3.11c).**

Distribution and habitat: Widespread in the Lukulu Delta and also in the upper reaches inside Lavushi Manda National Park (Figure 3.11c). Also occurs throughout the vast shallow parts of the swamps elsewhere. Always associated with vegetated waters, it favoured the verges of channels with quite strong currents during the rains and lived in waterlily pools during the dry season. Fishermen said the species did not occur under floating mats of papyrus, making it reliant on open pools as dry-season refuges.

Size and biology: A medium-sized, vegetarian cichlid growing to 300 mm TL and 600 g in weight. The species guards its eggs and fry in a nest consisting of a cleared arena 0.8-1.5 m in diameter, into which a number of cup-shaped holes are dug. Nesting was observed from November to March, on the edges of pools and later on the flooded plain. By October and November no small (< 150 mm TL) fish were found in catches. Therefore the growth rates are likely to be fast, with fish maturing within a year.

Importance: One of the most important species in the Bangweulu fishery, small fish (< 100 mm TL) were caught in small-mesh gillnets and in funnel nets, while all sizes were caught in basket traps. Larger fish (> 250 mm) remained in deeper water (> 1 m) where they were targeted with seine nets and monofilament gillnets. This species was the most popular fish for eating fresh, and was sold in bunches of three to five fish. It was also smoked or salted, and fresh fish kept well, allowing it to be transported to the villages for sale.

Fishermen claimed that numbers of this species had increased in recent years, possibly in response to high flood levels in 2007-2009 that would have allowed better recruitment and survival. The recent adoption of more effective gears such as monofilament gillnets and coarse-mesh seine nets would also explain a perceived increase of this species in catches. Traders attested to never having been able to buy large amounts of this species in the past.

Notes: Adept at jumping, these fish could easily clear both fish weirs and seine nets. One of the species that likely benefits most directly from the heavy grazing of the area by lechwe antelopes: juveniles find rich grass-shoot forage on flooded lechwe grazing lawns, and the nutrient spike in the water that occurs when the lechwe dung gets flooded leads to excellent filamentous algal growth, a favoured food.

Oreochromis macrochir **(Boulenger, 1912). 'Nkamba', Greenhead tilapia (Figure 3.11d).**

Distribution and habitat: Rare, with a limited abundance and distribution in the Chikuni area, where it was found only in deeper channels of the Lukulu Delta (Figure 3.11d). Open water deeper than 2 m appeared to be the limiting habitat factor. It was reportedly more abundant in seine net catches higher up on the Lukulu Delta, adjacent to Muwele Village.

Size and biology: In the study site fish up to 300 mm TL were observed. Juveniles of 100 mm TL were seen in April in catches from deeper fish weirs, but these were rare. The fish is a mouth-brooder, with males building display nests in the bottom sediments (Skelton 2001).

Importance: Adults were occasionally caught in seine nets and juveniles were seen in catches from funnel nets and seine nets. In Lake Mweru this fish is a very important fishery species (Guveya and Kokwe 2007), and the shallow, heavily vegetated habitat of the Bangweulu Wetlands appear to be largely unsuitable for this species.

Family Anabantidae (Labyrinth fishes)

Microctenopoma intermedium **(Pellegrin, 1920). 'Nkandiya', 'Kashilukafunte', 'Nkandakatopolyo', Blackspot climbing perch (Figure 3.12a).**

Distribution and habitat: Widespread in the Lukulu Delta (Chikuni), it was also found at a tributary near Muwele village (Figure 3.12a). The fish inhabited dense vegetation, especially floating grasses.

Size and biology: Rarely exceeding 40-50 mm TL, this fish did not appear to be as amphibious as its larger relative, *Ctenopoma multispine*.

Importance: The fish was not abundant and was of minor importance to the fishery, caught in lift baskets and mosquito seine nets.

Notes: One of its vernacular names, *Kashilukafunte*, means 'mad thing', referring to the way it twists and summersaults when caught.

Ctenopoma multispine **Peters, 1844. 'Nkomo', Manyspined climbing perch (Figure 3.12b).**

Distribution and habitat: A very widespread species, it was seen throughout the swamp and collected from the Lukulu Delta, a dambo pool inside Lavushi Manda National Park, pools in plain- and woodland habitat and a tributary stream of the lower Lukulu River near Muwele village (Figure 3.12b). This fish inhabited surface water in dense vegetation.

Size and biology: A medium-sized fish reaching lengths of 180 mm TL, with the typical size range being 80-140 mm TL. The species was well-known for its amphibious habits, as it can breathe air into a 'labyrinth organ' inside the head and crawl over land using its extended, serrated gill covers for traction (Skelton 2001). As a result, this species moved extensively during the rainy season, often being the first fish to move through accumulated rain water on the plains, reaching far-lying fish weirs in woodland fringes more than 10 km from permanent water.

Importance: An important feature of the basket and gillnet fishery. It was often eaten fresh after roasting over coals, and if dried became fragile, affecting its marketability.

Notes: Among the local fishermen, this charismatic fish was frequently a source of mirth due to its tenacity and terrestrial-animal-like appearance. Fishermen reported that the onset of the rains triggers this fish to move, sometimes dispersing over land.

* * *

Habitat differences in community composition

The relative importance of each habitat to the species diversity within each family is given in Table 3.2. Two families (Distichodontidae and Amphiliidae) were found only in stream habitats, while one (Aplocheilidae) was peculiar to floodplains, and one (Mochokidae) to the delta environment (Table 3.2). Most of the remaining families were well represented in each habitat, with streams being slightly more important to cyprinid and characid diversity, while cichlids, clariids, mormyrids and anabantids have more of their diversity in floodplain and delta habitats (Table 3.2).

River and stream habitat contains 67% of the recorded species, while floodplains and delta held 60% and 74% of the species respectively. Streams had 10 endemic species (32% endemicity), floodplains only a single species (4% endemicity), and the delta had 13 endemic species (42% endemicity). Jaccard's index of similarity between river and pooled floodplain and delta habitats was 43%, while the index between delta and floodplain was 75%, and between river and floodplain the index of similarity was 12%.

Table 3.2: Relative importance (% number of species) of each fish family in habitats sampled in the study area. Values in bold indicate families endemic to a particular habitat.

Family	# species	% River	% Floodplain	% Delta
Mormyridae	4	50	75	100
Cyprinidae	14	86	43	64
Distichodontidae	1	**100**	0	0
Characidae	3	100	33	33
Amphiliidae	1	**100**	0	0
Schilbeidae	1	0	100	100
Clariidae	4	25	100	100
Mochokidae	1	0	0	**100**
Aplocheilidae	1	0	**100**	0
Poecilidae	1	100	100	100
Cichlidae	9	67	67	89
Anabantidae	2	50	100	100

3.3 DISCUSSION

Checklist of species

There appears to be no updated, published checklist available of fish species for the Bangweulu region. A recent report puts the number for the Bangweulu swamps and lake at 83 species of 13 families, without stating the source (Guveya and Kokwe 2007). Nearby floodplain-river and floodplain-lake systems have similar diversities. Lake Mweru and the Luapula River have 100 recorded species (Guveya and Kokwe 2007), the Upper Zambezi has 71 species belonging to 16 families (Bills and Marshall 2004) and the Kafue has 62 species in 15 families (Bills and Marshall 2004). Van Steenberge (2009) lists 49 species representing 11 families for the Kasanka National Park, which has many habitats in common with Bangweulu Wetlands. In a survey of species occurring in commercial catches in the main Bangweulu Swamps, Kolding et al. (2003) list 40 species in 10 families. The 42 species from 12 families found during this study therefore represent only a subset of the regional fauna.

Fish families important to the faunal composition of the above systems are small Cyprinidae (mostly small *Barbus* species), Cichlidae, Mormyridae and Characidae. These families all contain genera or species that are widespread across the floodplain ecosystems covered by the lists in the above-mentioned literature (e.g. *Clarias* species, *Barbus* species, *Tilapia* species, *Serranochromis* species, *Marcusenius macrolepidotus*, and *Brycinus lateralis*).

A few notable species known from the Bangweulu system were absent from this study's collections. Most of the absent species are larger fishes associated with the large Chambeshi and Luapula rivers, and their associated swamp channels. These were the tigerfish or 'manda' (*Hydrocynus vittatus*), the catfish 'mbowa' (*Auchenoglanis occidentalis*), the catfish 'mfusu' (*Chrysichthys mabusi*), the large vundu catfish or 'sampa' (*Heterobranchus longifilis*), the distichodontid 'lubala' (*Distichodus maculatus*) and the large mormyrids, bottlenose or 'mbubu' (*Mormyrus longirostris*) and cornish jack or 'lombolombo' (*Mormyrops deliciosus*) (Ricardo-Bertram 1943, Kolding et al. 2003). These are all large species, attaining sizes greater than 400 mm, and are associated with deeper, more permanent habitats around the large Luapula and Chambeshi Rivers (Ricardo-Bertram 1943). Verbal records of tigerfish, bottlenose and vundu from the study area all appear to be from periods of very high water cycles. It may well be that these species occur within the boundaries of Bangweulu Wetlands, especially in the north near the lagoons of the Chambeshi Delta near Nsalushi Island.

The collection made contains sufficient material for a detailed taxonomic study of the species and their relationship to others in adjacent drainage systems, but this fell beyond the scope of this thesis. It is likely that upon closer examination, some species from the area may prove to be new to science, and will need formal descriptions to separate them from the similar, related species that they have been assigned to for the purposes of this study.

The long duration of this field study allowed for a high coverage of the fish species occurring in the study area, particularly from floodplain habitats. Specimens collected included representatives of all the floodplain species known to occur in the study site by the fishermen, who could also list numerous fishes found in other parts of the swamps with different habitat.

Regional biogeography

It is well recognised that there is a high degree of similarity between the fish fauna of the Zambian Congo (Bangweulu-Mweru ecoregion) and the Upper Zambezi and Kafue systems (Worthington 1933, Ricardo-Bertram 1943, Jackson 1961, Bannister 1986, Thieme et al. 2005). The Bangweulu-Mweru ecoregion shares almost twice as many fish species with the Zambezi River as with the Congo River, and has few endemics (Ricardo-Bertram 1943). This pattern is explained by a history of shifting drainages across this region (Cotterill and de Wit 2011, Goodier et al. 2011), river capture events (Cotterill and de Wit 2011), and also direct movement across watersheds (Bell-Cross 1963), which are often weakly defined in this topographically low-relief region (Dixey 1943).

While most of the fish collected during this study key out to the 'Zambezian' species groups (Skelton 2001), closer morphological and genetic examination will likely lead to most of the Bangweulu-Luapula species being separated from their sisters species in the Zambezi system (Roger Bills, SAIAB, *pers. comm.*). Molecular evolutionary studies on selected taxa are beginning to tease apart these relationships (Katongo et al. 2005, Katongo et al. 2007, Goodier et al. 2011, Lavoué 2012) and there is good agreement between molecular dating techniques of the fish fauna and the geological dates to elucidate the history of the drainage of the Zambian region (Cotterill and de Wit 2011, Goodier et al. 2011). Such studies provide evidence for the various river-capture events that allowed the formation of the major rivers of the region (Kafue, Upper Zambezi, Bangweulu-Luapula), all of which share similar species (Cotterill and de Wit 2011).

Cotterill and de Wit (2011) discuss the existence of a 'palaeo-Chambeshi' river system 4-3.5 million years ago, which was divided into the Kafue and Bangweulu-Mweru systems by tectonic uplift. The Bangweulu-Mweru basin then became linked to the Congo via river capture. Waterfall barriers below Lake Mweru, and two on the Luapula River appear to be partial barriers for upstream migration of Congo-system fishes (Jackson 1961), although not for tigerfish, which are genetically well-mixed in the Bangweulu-Mweru system (Goodier et al. 2011). Finer-scale rearrangements of headwater tributaries need further investigation, but are recognized as having also contributed to the spread of species throughout the region, including the dispersal of tigerfishes throughout the region (Goodier et al. 2011). Other examples are the invasion of the Bangweulu-Mweru region by *Serranochromis* species that had speciated in the now-extinct Lake palaeo-Makgadikgadi, in the present-day Okavango and Upper Zambezi drainage (Katongo et al. 2007), and the widespread *Pseudocrenilabrus philander* (Katongo et al. 2005). Both *Serranochromis* and *P. philander* were common in the study area, and the latter is also found in small headwater streams and dambos, making it a species potentially able to cross shallow watersheds between systems.

Many floodplain species have been shown to undertake migrations, both within the main stream and laterally between a river and its floodplains (van der Waal 1996). Migratory species adapted to shallow environments (such as *Clarias*) are more likely able to cross shallow watersheds than species such as tigerfish that require a large, well-oxygenated, flowing body of water (Goodier et al. 2011). Worthington (1933) states that most of the fish species occurring across the Zambezi-Luapula watershed are species found in swampy habitat, which could have used shallow-gradient flooded grasslands or dambos to cross the watersheds. Bell-Cross's (1963) observations support this theory. He observed six species, a *Clarias*, a *Barbus*, an *Aplocheilichthys*, a *Tilapia* and a *Ctenopoma*, moving across the Zambezi-Congo watershed through a swampy dambo in north-western Zambia (Bell-Cross

1963). Further molecular studies of the various wide-spread and limited-range species are however necessary to continue elucidating the history and mechanisms of dispersal of the fish faunas inhabiting this drainage basin.

Differences in community composition between habitats

Biodiversity in floodplain ecosystems is driven by high amounts of variation in habitat on a temporal and spatial scale, as waters rise and recede (Ward et al. 1999). On a finer scale, this diversity is determined by: the nutrient status and productivity of the system, the level of disturbance (external environmental factors that impact upon populations), degree of habitat fragmentation and the sizes of different habitat patches, and connectivity between habitats (Ward and Tockner 2001). Highly productive environments can support a greater number of ecological niches, each exploited by different species. The effect of disturbance is that only a low number of resilient species survive in harsh, high-disturbance environments, while low-disturbance, stable environments also have a low diversity due to competitive exclusion between species. Variation in disturbance, both in intensity, time and space, results in the greatest diversity, as niches are created or removed, allowing for a range of species with lower competitiveness, strong competitors and resilient species to coexist (Ward et al. 1999). Habitat fragmentation allows for a greater range of habitats, and the size of these habitat patches determines the number of species adapted to living on the borders between habitats, as well as the number that require homogenous tracts of habitat. Lastly, the connectivity between habitats determines interactions between environments, and has a bearing on nutrient flow, habitat fragmentation and size and movement of species (Ward et al. 1999, Ward and Tockner 2001). Teasing apart the effects of these individual factors on the ecosystem is difficult, as they function as a complex set of interactions to determine an area's diversity (Ward and Tockner 2001).

Parts of the Bangweulu ecosystem (primarily Lake Bangweulu) are recognized as having a low aquatic productivity (Toews and Griffith 1979, Kolding et al. 2003), and this could have bearing on its species diversity and fish biomass, in both river and floodplain environments. Within the constraints set by the productivity factor, disturbance is likely the next most important driver of diversity in the study site.

The seasonal floodplains, which cover almost the entire south-eastern part of the Bangweulu basin (Chapter 2), can be viewed as a high-disturbance environment, where the greater part of this area becomes dry at some point in the flood cycle. Dry-season refuges such as the Lukulu Delta are very important for fish species containing both floodplain species and those more adapted to the range of habitats offered by this permanent source of water.

The lower diversity of the floodplain is shown by the lower species representation (60%) and low endemicity (4%). The high degree of similarity between the delta and floodplain (75%) highlights the contribution that the delta, as a refuge, makes to the fauna of its adjacent floodplains during the floods. High-disturbance environments (e.g. areas with high flood amplitudes) dictate that there will be fewer species, but that those species will have special adaptations for resilience (King 1995). Species found here show some interesting adaptations typical of resilience adaptations to a high-disturbance environment. Populations of *Nothobranchius rosenstocki*, the only species found exclusively on the floodplains away from permanent water bodies are capable of surviving the dry season by leaving their eggs in the damp peat at the bottom of drying pools. The eggs survive until the next season's floods (Skelton 2001). All other floodplain species have to migrate from permanent-water refuges. Those that reportedly migrated the furthest (*Clarias gariepinus* and *Ctenopoma multispine*) are both air-breathing and use pectoral fin spines and serrated gill-covers respectively to gain traction when crossing areas of dry land (Skelton 2001). Many other floodplain species appear to be able to tolerate low oxygen conditions. *Tilapia rendalli*, *T. sparrmanii*, *Serranochromis robustus* and the clariids could all remain alive for more than 30 minutes after being caught, if kept cool and in the shade.

Streams had the second highest species representation (67%) and endemicity (32%) and two endemic families. The intermediate similarity in species between river and floodplain/delta habitats (43%), and low (12%) similarity between river and floodplain lend support to the distinctness of the species community of tributary stream environments. The stream habitats retain a degree of habitat uniformity throughout the year, and here one could expect interspecific competition for the same food resources between species to come into play. Strong competition is likely to result in resource partitioning and niche-specialisation through behavioural adaptations and species exclusion (Ward et al. 2006). This is a possible explanation of the absence of typical 'generalists' such as *C. gariepinus* from the tributary rivers, and also of the very different set of small *Barbus* species between floodplain and stream habitats (Table 3.1).

The delta was most diverse (74% of all species) and 13% endemicity, and this was largely due to its wide-range of habitats, connection to the tributary river and its role as refuge for floodplain species. The absence of certain habitats, such as deep-water channels, and especially the lack of connection of Lukulu Delta channels to other deep-water habitats nearer the Chambeshi Delta, could explain the lack of certain species from the study site. The verbal records from fishermen of two species, tigerfish and bottlenose, occurring after high water cycles would appear to be linked to the greater connectivity during those years between habitats. Smaller-scale connectivity between river or delta channel and its adjacent floodplains results in a greater access to nutrient and resources during the flood, which could again increase the number of species found there, as these are able to make use of a greater range of habitats and food sources.

Life history adaptations

The fact that many of the species identified in this survey also occur in the Zambezi and related drainage systems means that the same species (or sister species of the same genus) are highly likely to share the same habits and life histories. The species accounts given in the checklist mentioned observations on the growth, breeding and maturity of certain species (*Barbus trimaculatus, Clarias gariepinus, C. ngamensis*, *Marcusenius macrolepidotus*, *Serranochromis robustus*, *S. angusticeps*, *Tilapia rendalli* and *T. sparrmanii*). These observations are generalizations made after casual visual inspection of fishes, and are therefore only approximate. Understanding the detailed biology of commercial species would be an important objective for future research in the Bangweulu system.

A fish's environment exerts selective forces upon it that determine its growth rate, mortality and reproductive strategies (King 1995). These forces are either 'density independent' (e.g. flood cycle, droughts, temperature) or 'density dependent' (competition for food and space, predation and parasite loads), with density referring to the density of individuals within the population or community. In general, stable environments contain stable populations of species, where density-dependent factors come into play (Kolding and van Zwieten 2006). Fishes living in unstable environments (high disturbance) are more likely to be impacted by external, environmental forces, and their numbers will fluctuate in response (King 1995, Kolding and van Zwieten 2006).

Floodplains are by definition unstable, high-disturbance environments where the disturbance often appears as a predictable cyclical event (e.g. regular annual flooding and drying), allowing species to adapt (Junk et al. 1989). Some generalisations on life-history strategies of floodplain species can be made. Adaptations include high mobility (Tockner et al. 2000), special physiological and anatomical adaptations (King 1995), early maturity and seasonal breeding, rapid growth, and opportunistic feeding (King 1995). Density dependent and density independent factors will also play different roles during different stages of the flood cycle (Welcomme 2001). During the flooded season when fish disperse onto plains they enter a rich environment where they can feed, grow rapidly and amass resources (Lowe-McConnell 1987). As floodwaters retreat, fish density increases with resulting increases in density-dependent impacts such as predation, food competition and parasites.

With Bangweulu Wetland's typical floodplain habitats and with a fish fauna closely shared with adjacent floodplain systems, it is possible to examine specific cases that highlight the patterns mentioned above. Evidence of migrations is provided by the high (75%) index of similarity between delta and floodplain in Bangweulu, where fish moved from the delta refuge and inhabited the inundated floodplain. This is supported by observations of wide dispersal of some species (*C. gariepinus*, *Barbus brevidorsalis* and *Ctenopoma multispine*) and by records from the Upper Zambezi showing migratory habits of a similar fish community (van der Waal 1996). Evidence for seasonal breeding is shown by the *Chilambo* period of *Clarias* species and *M. macrolepidotus* spawning migrations, which is usually short (< 2 weeks) in duration and coincides with the first floods. Many species breed throughout the flooded season while conditions are favourable, usually after an early peak. Observations include *T. rendalli* nesting and small juveniles of various species such as *M. macrolepidotus* and *S. robustus* being present over an extended period. Booth and Khumalo (2010) showed a *Marcusenius* species from Swaziland to have an extended spawning period over summer, and Bokhutlo (2011) found that *C. gariepinus* in the Okavango Delta were also ready to spawn over an extended time during the floods.

In conclusion, the diversity of fishes recorded in Bangweulu Wetlands was typical of a floodplain species assemblage. The fish communities of tributary streams had little overlap with those of the floodplains and therefore biodiversity conservation activities should aim to protect stream as well as floodplain fish communities. With the Lukulu Delta containing the highest diversity of species, as well as being an important dry-season refuge, any attempts to protect a nursery or no-fishing area for biodiversity purposes should include parts of this habitat, but should also consider the importance of the area to fishing. Some pools in the floodplain could also be protected, though with most of the floodplains drying completely every year this is less critical. Large parts of the upper Lukulu River lie within Lavushi Manda National Park, and are therefore already well protected.

CHAPTER 4

Fishing Methods

4.1 INTRODUCTION

Zambia has significant water bodies in the form of rivers, lakes and swamps distributed throughout this landlocked country. With fishing activities occurring on all of these water bodies, Zambia can be considered to be traditionally a fishing nation (Mortimer 1965). Zambia has seven major fishing grounds: Lake Tanganyika, Mweru-wa-Ntipa (lake and swamp), Lake Mweru, Bangweulu (lake and swamp), Kafue River, Upper Zambezi River and Lake Kariba (Mortimer 1965). With the exception of Lake Tanganyika, all these fishing grounds have a floodplain component.

African inland fisheries are typically multi-species fisheries that utilise a wide range of fishing methods to optimise harvests (Tweddle et al. 1978, Welcomme 1979, Kolding and van Zwieten 2011, Weyl 2003). Traditional fishing methods such as weirs and barrier traps, woven gillnets and hand-forged hooks have been supplemented or replaced by modern fishing materials, primarily nylon gillnets, seine nets and longlines (Brelsford 1946, Welcomme 1979, Jul-Larsen et al. 2003). In the 1940's and 1950's modern manufactured fishing materials were rapidly adopted and resulted in an increase in fishing efficiency and effort because they saved considerably on the time and labour involved in making gears from natural materials (Jul-Larsen et al. 2003). The diversity of species, habitats and fluctuating conditions on many of Africa's inland water bodies dictates that the use of a broad variety of fishing methods be maintained. This is especially true of floodplain fisheries, where utilising a wide range of fishing gears is required to optimally harvest different species of fish in fluctuating conditions and changing environments, ensuring a stable food and protein supply for most of the year (Bell-Cross 1971, Welcomme and Hagborg 1977).

The fishery of the Bangweulu swamps and floodplains can be characterised as an artisanal, small scale, multigear fishery (Chanda 1998, Kolding et al. 2003). The main swamp's fishing grounds in the *Unga* and *Batwa* tribal areas have been fairly well studied, with Brelsford (1946) providing a comprehensive account of the fishing activities of the swamp inhabitants at that time. Later studies examining the main swamp fishery include those of Ichikawa (1985), Imai (1985), Imai (1987), Chanda (1998), Imai (1998), and Kolding et al. (2003), all of which examined aspects of the year-round, commercial fishery based on gillnets (driven and stationary), seine nets and deeper-swamp weirs primarily operated by members of the *Unga* tribe.

The shallow floodplains of the present study site differ from the deeper swamp areas, most notably in the short amount of time that these shallow plains are inundated with water (Chapter 2). The fishery in these floodplains has never been formally studied, and the objectives of this part of the study were to:

1) Describe how fishing activities change with the seasons and the spatial fluctuations in floodwaters.
2) Provide detailed descriptions of the specific fishing methods used in the shallow floodplain fishery of the Bangweulu Wetlands area.
3) Present and discuss changes and trends in the fishery, in order to inform future management decisions.

4.2 METHODS

The data used to identify and describe the different fishing gears were gathered by direct observation during tours of the fishing areas and through interviews with key informants, fishermen and traders. Visits to fishing camps were done on a bi- to tri- weekly basis, during the periods March – June 2011, August – November 2011, and March – May 2012.

Fishing camp visits were conducted in a semi- structured way: the selected camp was accessed by 8 a.m. and fishermen were interviewed on return from the fishing grounds. Questions would enquire about the catch, fishing conditions, gears used at the time and the general quality of the catches for that week. The fisher's replies and remarks would usually determine the direction of the interview and discussions would try to draw out more details. Fishermen were encouraged to divulge any additional facts or theories related to fishing. Three main fishing villages within a 2 km radius of the research station were visited for gathering catch data, and these presented opportunities for observing gear construction and setting.

Gear use

Gear settings were observed on the fishing ground, either coincidentally or by prior arrangement. Seine netting was most frequently encountered, as this gear was used along the main waterways and during the daytime. Gillnets and longlines were also seen being used along the waterways and on the flooded plain in front of the research station. Visits to fish weirs to observe the checking of traps had to be done by prior arrangement: this was due to the strong sense of ownership over weir sections and because certain etiquette had to be observed when moving near fish weirs. These rules were in place to prevent the disturbance of fish near the trap entrances.

Key informant interviews

A total of ten important key informants contributed to the transfer of local knowledge to this study: these were two research assistants (Elijah Mofya and Brighton Mofya), a community coordinator employed by Bangweulu Wetlands (Lloyd Mulenga), an elected community committee member (Francis Lubinda), a fishing chief or *Chipupila* (Mwenda Chishinge), a wildlife scout who had been based at Chikuni for many years (Charles Kalumba), and four fishermen (Alapu Kale, Shepadi Mwewa, Chanda Mashati and Frederick Chanda). In addition, each fishing camp visit for catch assessment included a short interview about fishing methods, and almost every encounter with the local inhabitants resulted in some questions on fishing activities being discussed.

4.3 RESULTS

Distribution of fishing

The study area centred at Chikuni fell within the *Bisa* chiefdom of Chiunda Ponde. This chiefdom is divided into two rough geographical and occupational components: a higher lying woodland region dominated by farming activities, and the lower lying floodplain area dominated by fishing (Lusenga 2011). There was much intergradation between the two activities, with most of the inhabitants of the fishing region of Chiunda Ponde engaging in both fishing and farming. Some were full-time fishermen for the whole year, though this was not as common in the *Unga* and *Batwa* tribal areas deeper in the swamp.

Fishing activities occurred anywhere where water was found. Outside of the main floodplain and swamp fishing areas, evidence of fishing (discarded traps, fish poison and fireplaces) was found around streams, pools and temporarily flooded depressions. These areas reportedly yielded fish only over a short season, and were used for subsistence by farmers living nearby.

On the main fishing grounds, people and fishing activities were distributed depending on water level. The people engaged in fishing, even if only for part of the year, could be considered to be migratory. All fishermen had a permanent home in a village. In Bangweulu Wetlands these villages were on higher ground on the edge of the floodplains. The larger villages, Muwele and Mwelushi, are labelled in the map in Chapter 2: Figure 2.2. Among the *Unga* tribe in the swamps, these villages lie on the islands to the north of the Bangweulu Wetlands conservation area. People moved from their home villages to fishing camps during the fishing season. In the study area, the camps used early in the season for weir fishing were found on the shallower floodplain (Table 4.1). These were inhabited for two to three months, until the water dried. Many then move to camps on fish weirs on the deeper floodplain beyond the Lukulu Delta. A socio-economic survey conducted in the area in 2011 found that most fishermen used two and sometimes three camps during the year (African Parks 2011b). Later in the season (October to December), temporary shelters were made in the Lukulu Delta, where the last remaining water was (Table 4.1).

Resource allocation

In Bangweulu Wetlands, important fishing areas were controlled by a traditional fishing leader, or fishing chief, known as a *Chipupila*. Servile to the area chief, Chiunda Ponde, the distance from the chief's court (> 50 km) and the chief's old age (> 90 years old) allow them to operate largely autonomously. The *Chipupilas* are descended from notable people who had performed miracles or other commendable deeds, and were rewarded with fishing areas (and historically also hunting areas) to be under their control. Inheritance of this position is matrilineal, though various members of the same family sometimes shared this role. There were a few woman *Chipupilas*. The central responsibility of the *Chipupilas* was tribute collection on behalf of the chief, though this role appears to have become somewhat diminished. Most of the tribute collected from fishermen, in fish or money, was reportedly retained by the *Chipupila*.

The responsibilities of the *Chipupila* were to allocate the fish resource in his area fairly among those who use it, and to resolve conflicts. The *Chipupila*, like the village headman, had to know his or her people intimately: their names and clan affiliation, their ancestry and their relations to one another, in order to keep the peace. A person wishing to fish in a certain area needs to approach the *Chipupila* controlling the area, and pay a fee. The *Chipupila* decides where the applicant may fish, and the size of the area (and hence density of fishermen) is determined by the productivity and yield. The larger fishing grounds (> 5x5 km) are those in areas that flood for only 3-4 weeks each year, while the fishing territories in the Lukulu Delta are much smaller and have a higher density of fishers due to year-round access to fish. A fisher failing to utilise his area effectively stood the risk of having it allocated to someone else. As a result, people who had left the swamps to seek employment or those engaging in other economic activities often appointed extended family members to fish in their area too.

The *Chipupilas* were also supposed to play a spiritual role in the area, and were referred to by Zambian park staff (in English) as 'spiritual leaders'. During the study, it was no longer practice to perform a ceremony and make an offering to ancestral spirits at the start of fishing and in new areas. The process of blessing new fields is apparently still practiced in the agricultural areas, but appears to have diminished in the swamp fishery.

During the study, only one case of a *Chipupila* attending to the spiritual health of the area was witnessed. This took the form of a large meeting of traditional healers and affected families in an attempt to cleanse the area from bad spirits after a fisherman had been drowned by a reportedly bewitched crocodile the previous year.

A list containing instructions for blessing a new seine net (or seine netting area) was obtained which mentioned the role of a *Chipupila* to speak some words and bless the net. The list consisted mostly of the parts of many local trees that would be needed for the blessing.

The *Chipupila* is required to stay in the fishing areas almost year-round. Some *Chipupilas* are more enterprising in their investments, with one of them owning his own fishing outfit and selling his fish directly to the Copperbelt and DRC border markets. Some fishermen feared that this could cause conflicts of interests with the *Chipupila's* duties.

Problems with the *Chipupilas* included corruption, with them allocating areas to, and protecting the interests of, the highest bidder. This became a problem during 2012, when immigrant fishermen rented fishing areas without consultation with the area chief or local fishermen. There were also boundary disputes between groups of *Chipupilas*. These complex disputes were partly motivated by attempts by one group to gain control over the tribute of another's area. The root of one conflict in particular was that many decades ago one group was given temporary access to another group's area after lions had been causing problems in the first group's area. The group that had moved never went back, and were now trying to claim rights to parts of the area and formalise a boundary. A 70-year-old fisherman interviewed (from a *Chipupila* family) stated that he hoped to see the conflict resolved before he died: this highlighted the seriousness of the long-standing dispute to the affected groups.

Fishing camps

A group engaging in fishing were referred to locally as a 'company'. A fishing company consisted of a gear or fishing ground owner, and his family and assistants. Weir fishing was a family affair as the wife and children of the fishermen were brought to the camps too. Foreign groups of fishermen using the area and groups utilising seine nets were almost always groups of men.

Fishing camps in the swamp floodplains around Chikuni were generally clustered around slightly higher-lying areas of land that remained dry at the peak of the floods. The number of dwellings in a camp varied from four to twenty, with one island (Chona Island) having 40 huts. The camps inside the Lukulu Delta were densely clustered on islands. Huts were commonly built on a levelled-off termite mound, which gives it sufficient elevation above the high water mark (Figure 4.1a). Dry season camps used by seine net fishermen were temporary and could be constructed anywhere. These were usually clustered around pools suitable for seine netting.

Fishing huts were constructed from a wide variety of materials, including wood, grass, clay plastic sheeting and tarpaulins. There was a seasonal difference in the construction of shelters, with wet-season huts having better constructed roofs and dry-season shelters mostly providing shelter from wind. Some immigrant seine net fishermen from deeper inside the swamp were excellent hut-builders. The *Unga* people from deeper inside the swamps are renowned for building fishing huts even where there is no dry land, by using cut vegetation to build up a floating platform.

A fishing hut generally had a floor space of 3x7 m. The roof was low, being 1.5-2 m high at the gable. There was usually only a single entrance, which was low (< 1 m high). A cooking fire covered by an iron smoking grid was positioned in the middle of the floor, with sleeping areas covered by mosquito netting against the sides of the hut. Belongings taken out to the camps were basic, but luxuries included radios and their associated power source (photovoltaic solar panel and batteries). Outside the hut there was always a raised grass-mat fish drying rack, a flat sitting and working area, and a wood pile.

The fire and smoking rack were crucial parts of the hut. Almost all fish larger than 15 cm were smoke-dried. The key equipment needed for this process was the sun-drying rack, the indoor fire, a metal grid above the fire (either in a drum or as a grid over the fire), and a reed mat hung a metre above the fire where hot-smoked fish were stored. This storage rack was an important feature, taking up a considerable amount of space inside the hut (Figure 4.1b). Smoking kilns made of metal fuel drums were popular, as they save considerably on the amount of firewood used. It is thought that this technology was first introduced by a fisheries development project on the Elephant Marsh system in Malawi (Tweddle et al. 1978).

Figure 4.1: Examples of fishing huts and water craft used in the Bangweulu Wetlands study area: a) Woodland fishing hut built on a large termite mound; b) Hut interior with smoking fire and rack with stored smoked catfish; c) Wooden dugout canoe with catch; d) Fibreglass banana boat with wildlife scout team, showing large payload capacity. Photos: a-b) Carl Huchzermeyer, c-d) Morgan Trimble.

Division of labour

A hard-working fisherman had a full day, checking his gillnets and longlines at dawn. This could take two to three hours depending on how much gear he had set and the size of the catch. If he was fishing in weirs with baskets or net traps, he could expect to add another two hours onto his morning rounds. Late morning and early afternoons were spent mending fishing gear, resting and attending to business. In the late afternoon gears were checked again and reset. Seine netting teams hauled their nets at dawn, over midday when it was hot, and again in the evening. If many hauls were made through the night, the day was reserved for resting.

Women and children also played an important role in fishing: their job was to gut and scale fish, tend to fish that was smoking and maintain the fishing household. Men living in the swamps without their wives processed the fish themselves. Women were never seen mending or setting fishing gear, apart from drag baskets (*ulwanga*). The children in the camp assisted with all of the chores, and learned about fishing by emulating the baskets, weirs and drying racks made by adults. Almost everybody could paddle a canoe.

Fishing calendar

The important seasons and events on the Bangweulu Wetlands fishing grounds have been summarized by month in Table 4.1. In general, fishing activities peaked while floodwaters receded off the plain in March- June, which was the main season in which fish weirs were used. In the dry season, a smaller proportion of fishermen remained in the fishing grounds, utilising seine nets to fish in the remaining pools of water. Gillnets and longlines were used throughout the year. Fish spawned at the start of the floods (December-January), with the young growing on the plains and forming the basis of catches during the drawdown (March-June). Remaining pools of water held fish to recolonize the floodplains in the following wet season.

Table 4.1: Fishing calendar for the Bangweulu Wetlands fishery activities, environmental conditions and fish biology, by month. (*Denotes the government-legislated fish ban).

Month	Weather	Water levels	Local fishing methods	Intensity	Migrant fishing	Fish biology
January*	Warm, heavy rain	Major rise	*Chilambo* (spearing spawning fish)	Low- farming and rain	-	Spawning, disperse
February*	Warm, light rain	Stable to slight rise	Gillnets and hooks	Low- mostly subsistence, longline catch good	Seining begins in channels	Juveniles disperse
March	Cool, heavy rain	Rise, rain water floods higher areas	Gillnets and hooks	Low- weir maintenance, subsistence catch	Seining intense, gillnets	Juvenile growth
April	Warm, rain ends	Stable, rain water dries	Weirs- *sola* funnel nets, gillnets	Low- awaiting fish movement	Seining, gillnets	Juvenile growth
May	Warm, wind begins	Receding, shallow floodplains dry	Weirs- funnel nets and *mono* basket traps	High- fish moving, focus on weirs	Left area	Migration, high mortality
June	Cool, windy	Recedes slowly	Weirs- basket traps, seining	High- weirs drying	-	Migration, slow growth
July	Cold, windy	Recedes slowly	Seining	Low- water cold	-	Slow growth, little movement
August	Cool, windy	Recedes slowly, deeper plains dry	Seining	Medium- water cold	-	Slow growth, little movement
September	Warm, windy	Recedes faster, channels still deep	Seining	High- water warm	-	Growth, gonads start developing
October	Hot, calm	Recedes faster, channels shallow	Seining, gillnets, poison, spearing	High- water warm, fish concentrated	-	Gonads ripening, movements
November	Hot, cloudy	Recedes faster, channels low	Seining, gillnets, poison, spearing	Medium- little open water	-	Gonads ripening, movements
December*	Hot, rain begins	Lowest levels, slight rise at end	Seining, gillnets, poison, spearing	Low- little open water, farming starts	-	Gonads ripe, some spawning

Fishing methods

Water craft

The wooden dugout canoe (*ubwato*) is a crucial fishing tool in Bangweulu, and every fisherman owned at least one (Figure 4.1c). These were usually made by the fishermen themselves. The dugouts were made from a variety of tree species, most commonly *Pterocarpus angolensis* (kiaat/mukwa), *Parinari curateifollia*, *Syzigium caudatum* (waterberry), *Diospyros mespilliformis*, *Vitex* cf. *doniana* and a few others, each with differing levels of durability. Dugouts were mostly cut in tall forest-woodland away from the swamps, in time to retrieve them at the rainfall peak. A wooden bailing scoop (*ulwipo*), a raffia palm (*Raffia farnifera*) or cultivated bamboo pole for pushing the dugout through shallow water and a long-bladed wooden paddle carved from the wood of mukwa (*Pterocarpus angolensis*) or saninga (*Faurea* sp.) trees were essential for using the canoes.

Most dugouts were 3-5 m long, and 30-60 cm wide at the widest point on the base. Large (60-80 cm wide), stable dugouts employed for seining from a boat were scarce because these had to be acquired from sellers bringing canoes from forests higher up the Chambeshi River. Fibreglass 'banana boats' (Figure 4.1d) were more commonly used for businesses such as hiring out to fish traders or transport services to the swamp islands. They are not as manoeuvrable as dugout canoes, and were therefore rarely used to deploy fishing gear except for seine nets.

Fish weirs ('amaamba')

The use of weirs and barriers to intercept migrating fish is a common feature in floodplain fisheries globally (Welcomme 1979) and they are the iconic fishing method of the Bangweulu Swamps. An aerial view of the floodplains reveals the extent of these structures (Figure 4.2a). Fish weirs were used throughout the Bangweulu system. Weirs were used in diverse habitats ranging from drainage streams, where small fish weirs and barriers were made across streams and dambos (drainage lines with grassy wetlands in the woodlands) for subsistence fishing, to deep floodplains deep in the swamps (Brelsford 1946, Chanda 1998).

The traditional authority governs the ownership of fishing weirs and the allocation of fishing rights in the areas of water that drain through a fish weir. Fish weirs were inherited, owned and operated by individual fishermen and their families, overseen by the *Chipupilas* (traditional spiritual and fishing leaders).

Longer fish weirs (1-2 km in length) around Chikuni had multiple owners. Every owner assisted with the construction and maintenance of a section of fish weir, and the gaps left in a fish weir for trap placement were individually owned.

The typical fish weir was a low levee made of turfs cut from the surrounding grassy topsoil, or in deeper areas from muddy peat, roots and vegetation supported by reed stakes (Figure 4.2b). Grass and vegetation regrew rapidly over the turfs, protecting against erosion. The turfs were gathered from 1 to 2 m on either side of the weir, and were packed up to a height of 0.7 to 1.5 m depending on the water depth. The base of the weir was about 1 m wide. Once the weir has been used for a season, it would have reduced considerably as the turfs compacted, and maintenance in subsequent years would mostly involve patching areas that had been trampled by wildlife or subsided below the water level. New weirs were constructed in the dry season.

Fish weirs impeded canoe transport, and thus it was common courtesy for there to be a boating gap in each fish weir. Various innovations such as reed mats or grain bag barriers that blocked fish from passing, but allowed boats to pass over, were observed.

Fish weirs were left open for water and fish to pass through when the flood plains began to fill at the start of the rains from December to February. Fishermen recognised that this was an important time for fish spawning, and that juvenile fish need access to the shallow flooded areas to feed and grow. Also, the fish weirs could not yet be 'closed' at peak flows at the end of the rains, from February to the beginning of March, or they would be breached. When the first indications of reduced flows were detected, the fish weirs were 'closed' and fishing commenced. Catches were observed to be very low in the first few weeks after the floodwaters began to recede, yet fishermen had to still painstakingly maintain their weirs to prevent escapes. Once fish began to move *en masse*, catches increased. Fishermen said that the cue to fish movement was a strong south-east wind signalling the end of the rainy season, called *apumbwe*. The fish weirs were fished for as long as there was still water for fish to move through. While catches from weirs are at their peak, little effort was put into other fishing methods. The floodplain weir season was from March to June (Table 4.1).

Basket traps ('mono')

This widespread gear consisted of a conical grass or reed basket with a valve at the front, and was set into fish weirs as floodwaters receded (Figure 4.2c). Most fishermen wove their own baskets, and were capable of constructing up to three basket traps in a full day. Materials used were the side shoots of *Phragmites* reeds, or straws of thick *Hyparrhenia*-type grasses. The straws were bound together in a mat with bark fibre, which had been traded from woodland areas where suitable trees grew. Sometimes a very strong sedge (local name: *lutindi* or *insubwa*) from certain swamp areas was also used to bind baskets. This mat was then placed around two hoops made from pliable branches, and the end of the cone bound with fibre. A valve woven from the same materials was inserted at the open end of the cone. Fishermen matched the size of their baskets to the depth of water they expected to fish. Hoop diameter varied from 70cm at the largest to 30cm in a very small basket. The most common hoop diameter was 40-60cm, corresponding to a total basket length of 100-120cm.

Most fish baskets lasted only one season. Old and new baskets that needed to be stored (or transported) had the inside rings and valves removed, allowing them to be folded flat.

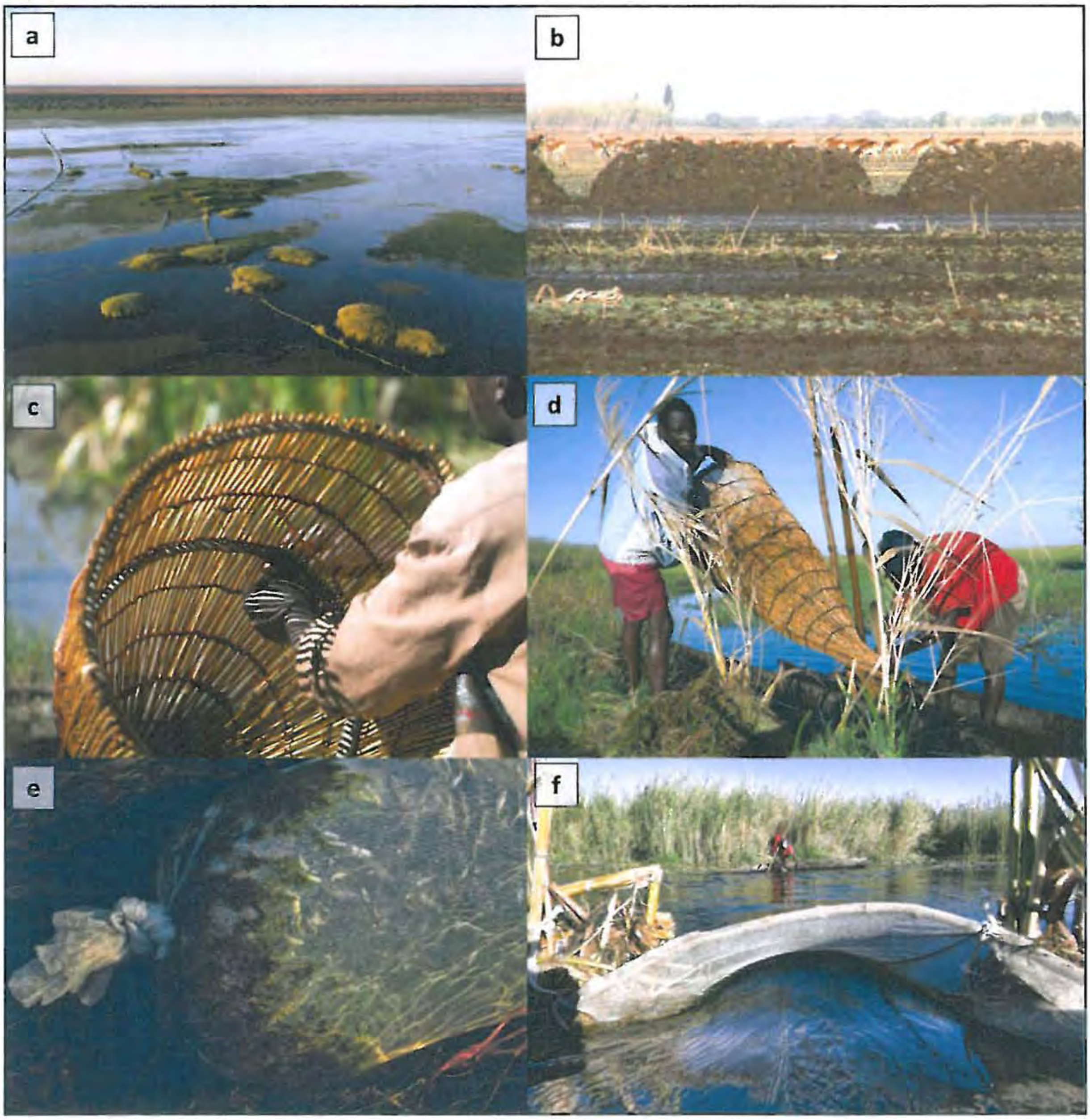

Figure 4.2: Components of the fish weir fishery: a) Aerial view of earth fish weirs over the plain; b) Newly constructed fish weir with gaps for setting traps; c) a basket trap (*mono*) being woven, before insertion of the valve; d) emptying the catch out of a basket trap; e) a mosquito-meshfunnel net's 'cod end'; f) checking a funnel net (*sola*); note the distance between the entrance hoop and the cod end held by the fisherman. Photos a) Lorenz Fischer, b) Carl Huchzermeyer, c-f) Morgan Trimble.

The *mono* basket traps were set into gaps in the fish weirs at a depth so that part of the opening of the basket always remained above water, and care was taken to close any gaps below the basket with mud and turf. Often, the basket was covered with grass and aquatic vegetation to provide shade and encourage fish to enter or to disguise baskets from predators. The baskets were set with their openings facing either up- or downstream, depending on which way the fisherman thought the fish were migrating.

Fishing baskets were checked early every morning. Each basket was lifted out of the weir and the binding removed from the narrow end of the cone. The contents of the trap were then shaken into a bucket or canoe (Figure 4.2d), after which the trap was replaced.

Mosquito-mesh funnel nets ('sola')

This relatively new gear has become established during the last decade. They were set in fish weirs and acted as passive trawls, 'sifting' out anything from the water moving through the weir. They were most effective when there was considerable water current moving through weirs, and have possibly brought forward the date at which weir fishing commences.

The primary material used for producing these nets was mosquito bed-nets. A long, narrow tube not unlike a windsock was made from the net. The opening was held open by a hoop made from a pliable branch, and the end of the net was closed with an overhand knot (Figure 4.2e). The typical dimensions were an entrance hoop diameter of 50-150 cm and a length of up to six metres (Figure 4.2f).

The nets were placed into gaps in the weirs. The long length of netting allowed enough mesh free of debris for water to pass through. The 'cod end' of the net could become swollen with fish and debris until bursting point and nets required frequent cleaning. Fish died and often spoiled in the nets. Pressure from fish traders for a less damaged fish product resulted in some fishermen using innovations such as making enlarged, bulbous cod-ends or having the main tube of the *sola* net feed into a separate, box-like 'fish pen'. These 'box-nets' were becoming increasingly common, and also functioned as a type of non-return trap when water velocities were lower (Figure 4.3e). Apart from regular cleaning of debris, frequent stitching of torn holes in the nets was also required.

Another variation of the funnel net was a 'wing-net' observed from the air set across narrow channels (Figure 4.3f). Here, netting was used to make a barrier (the 'wings') with a single long tube in the middle for the fish. The make-up is similar to the 'wing-traps' used in Southeast Asian river deltas described by (Welcomme 1979).

Gill nets ('umsumbu')

This gear, the most important modern commercial gear used in floodplains (Welcomme 1979), was widely used in the Bangweulu system. Small mesh sizes (25 mm, 38 mm and 51 mm stretched-mesh) were popular and reflected the small size classes and species of fish that make up the bulk of the fish fauna of this system.

The type of gillnet used was almost exclusively multifilament nylon gillnets. Monofilament nylon gillnets ('glass nets' in Bangweulu), increasingly common in other African systems, were very rarely encountered during 2011, but in 2012 they had become very popular, with most fishermen owning at least one of these nets.

Multifilament mesh sizes ranged from a minimum of 1 inch stretched mesh (25 mm), through 1 ¼ inch (32 mm), 1 ½ inch (38 mm), 2 inch (51 mm) and 2 ½ inch (64 mm), to a maximum of 3 inch (76 mm), and very rarely 3 ½ inch (89 mm) stretched mesh. Monofilament nets brought in by traders from the border with Tanzania were only available in larger mesh sizes: 2 ½ inch (64 mm), 3 inch (76 mm), 3 ½ inch (89 mm) and 4 inch (102 mm) stretched mesh.

The nets were hung with an even (50%) hanging ratio from a nylon cord and attached with nylon gillnet twine. The nets were made up by the fisherman while seated, with the feet being used to stretch the mesh to the correct spacing. Twine jigs were made from two bicycle spokes. Only every fourth or fifth netting square was attached to the float and bottom lines, and this was done to make the net feel 'softer' to any fish encountering it.

Floats were traditionally made from the large cork thorns of a local tree (*Kalunguti*-unidentified), now largely replaced by plastic sandal foam. Sinkers for the bottom line were made from balls of baked anthill clay. The nets were cleaned daily by shaking off debris, and were regularly removed from the water to dry in the sun (Figure 4.3a). Holes in the nets were not regularly repaired due to the ease of replacing a net. A net's average lifespan was reported to be two seasons, depending on how heavily it had been used. Theft of a gillnet, or even removal of a fish from a net, was considered a very serious offence and many fishermen used charms to reinforce this custom.

Gillnets were usually set from a dugout canoe (Figure 4.3b), but also by foot in shallow areas. Popular setting sites included areas along fish weirs (where fish moved in the slightly deeper water created by the removal of turfs during construction), lechwe paths, among water lilies and on the edges of channels against vegetation. Nets were set both parallel and perpendicular to the current. If weights were not used, then the netting was often supported by submerged vegetation.

The most important season for gillnets was between February and May, and again from October to December (Table 4.1). During these times water temperatures were warmer, and the fish more active, while from June to September lower water temperatures resulted in reduced fish movement and lower catch. Gillnets were set to fish both during the day and during the night, and were usually checked once a day, early in the morning.

In some areas fish were chased out of thick channel vegetation into gillnets (*kutumpula* or *kusakila* fishing) by splashing the water with a specially modified pole with a cup-shaped end, an example of which was seen in a fishing camp. This activity was not observed in the Chikuni area during this study. In recent years, driven gillnet fishing was reportedly a common noise heard by guests from Shoebill Island camp (Frank Willems, Kasanka Trust Limited, *pers. comm.*) near Chikuni, but this labour intensive practice appears to have become less important now. Some older, more experienced fishermen were reportedly able to set their nets under papyrus mats through a laborious process of pushing the net along via a series of holes chopped into the papyrus.

Hooks and longlines ('iindobane')

The most common deployment of fishing hooks was in the form of longlines (Figure 4.3c: showing a longline neatly bunched together and folded while not in use). These consisted of 40- 50m lengths of nylon cord with hook snoods at intervals of 1.2-1.5 m. The main line was stretched between reed stems pegged into the plain or channel at 10 m intervals. The line was often kept above the water level, with the snoods hanging down into the water. The snoods consisted of a 40-60 cm length of nylon cord knotted to the main line on one end and to the hook on the other. The hook knot was tied onto the hook shank below the eye, enabling the hooked fish to twist without winding up the line. Hooks came in various sizes (standard j-hook shape with a single barb, shank lengths 1-5cm).

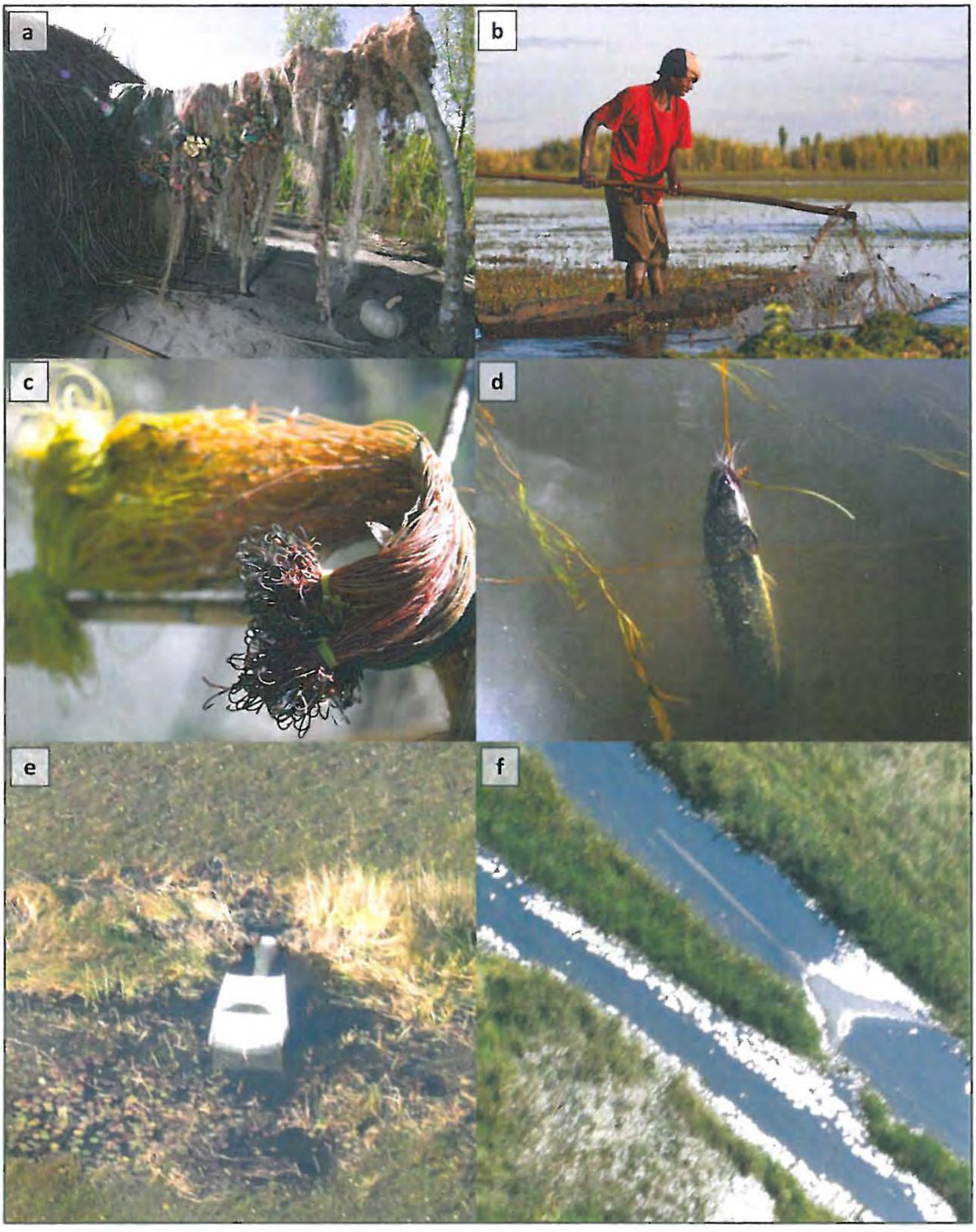

Figure 4.3: Gillnets, longlines and modified funnel nets used in the study area: a) gillnets hanging on a traditional net frame; b) a gillnet being checked from a canoe; c) a longline, carefully folded for ease of setting without tangling; d) a*Clarias* catfish hooked on a longline with the hook just below the water surface; e) aerial view of a 'box-net' *sola*; f) aerial view of a 'wing-net' *sola*. Photos: a-c) Morgan Trimble, d-f) Carl Huchzermeyer.

There were many variations to this form of setting hooks. Longlines were sometimes attached directly to vegetation, and shorter lines could be set inside very dense vegetation thickets. Sometimes a snood or two were attached to a thick section of papyrus stem, and a couple of these would be deployed across a pool with minimal flow, where they drifted untethered but frequently checked by the fisher. In the dry season, Clariid catfishes used 'breathing holes' (30-70 cm diameter gaps in the floating *imitafu* grass mats), and hooks were used here too.

The hooks were baited with a variety of baits, most importantly earthworms, but also small (1 cm^3) pieces of large water snail, washing soap bar, fish and scarab beetle larvae. Two different earthworm species were used: a large black earthworm found in damp topsoil, and a thinner, semi- aquatic earthworm found in floating mats of vegetation. Once all of the hooks were baited, the lines were lowered into the water. This was done late in the evening, to prevent small diurnal species from removing the bait. Catfish would take the bait near the surface, and become hooked as they turned around to return to the bottom (Figure 4.3d).

The lines were checked at dawn. The fish were almost always speared before being lifted into the boat to unhook. The spear would sever the spinal cord and immobilize the fish.

The catch on longlines consisted almost exclusively of catfishes in the genus *Clarias*, and this gear was capable of holding fish up to 8 kg (the maximum size observed during the study).

Seine nets ('mukwawo')

Seine nets were an important gear used to fish deeper channels and pools. Nets used in the study area varied in length from 35 to 60 m and needed a team of five to eight fishermen to operate. They were used almost to the exclusion of other gears from June to November, and during 2012 there was a large increase in wet-season seine netting by immigrant fishermen.

The most common netting material used by local fishermen was mosquito nets stitched together, hereafter referred to as 'mosquito seine nets' (Figure 4.4a). Occasionally pieces of shade cloth or sardine netting from Lake Tanganyika were also incorporated. The nets were sewn together in the village by a tailor. An approximately 1-inch (25 mm stretched-mesh) multifilament seine-netting material ('six ply' or 'nine ply') was sometimes purchased at great cost (Table 4.2) from netting originating in Tanzania. This was used to make 'coarse-mesh' seine nets, used by more successful groups of fishermen and especially by immigrant fishermen from deeper in the swamps (Figure 4.4b). This netting was strong and durable.

The nets had a shallow 'cod-end', and if constructed of mosquito nets they contained many folds where the netting had been bunched together. This was called *indumba* and the fishermen explained that the fish swimming against these folds in the 'pocket' would remain inside the cod end trying to push their way out. The centre of the net was marked with a large buoy.

The two 'wings' were made from the netting panels, and were attached to a pole on each end. Each end of the pole was attached to the main drag line made from strong rope. The net's depth at the cod end was 5-7 m and the wings were 1-2 m deep. The drag produced by the fine mosquito netting limited the size of mosquito seine nets to 50 m, while coarse-mesh seine nets were mainly limited by the amount of netting a fisher could afford to buy. Nets remained small enough to be bundled and transported on the back of a bicycle or in a narrow dugout canoe.

Large floats were used to keep the net on the surface. These consisted of large pieces of sandal foam, plastic bottles and sometimes pieces of papyrus leaf-stem. They were placed at intervals of about one metre. Weights consisted of large baked clay balls or pieces of brick or concrete rubble held to the bottom line by a cloth bag. Comparatively few weights were used, spaced every 2-3 m, to ease hauling.

The use of seine nets was largely dependent on the availability of shallow (1-2.5 m deep) pools and lagoons. Once a pool had been identified, much of the aquatic vegetation, especially water lilies, was cleared from the pool. This was done using sickles tied to paddling poles, and immigrant groups used a large home-made scythe.

Seine nets were set along one edge of a lagoon and left there for a period of 20 minutes to two hours before being hauled in. This allowed fish to resume their natural movements through and around the lagoon. The seine net could be hauled either from dugout canoes or from the bank. The larger mesh-size seine nets had a more rapid haul rate. As a result, most of the nets seen in use during the early part of the seining season (May to June 2011, and March to May 2012) were of this type, with mosquito seine nets becoming increasingly common as the dry season progressed. Fish became more concentrated with decreasing water levels, which increased the effectiveness of the mosquito seine nets.

Dry season seine netting was commonly done during the night, though daytime seining was also important. Lunar conditions reportedly had an effect on catches, with catches of mormyrids being highest on dark nights. This group of fishes were reportedly sensitive to disturbance, and the careful approach needed to make hauls of these fish was frequently stressed by the fishermen. A seine net was usually hauled between four and six times a night, at intervals of one to four hours. Daytime hauls varied from two to eight hauls, usually over midday. The number of hauls made were higher when catches were higher, capitalising on days with favourable conditions for fish movement e.g. warm, calm days and dark, moonless nights.

Spearing ('Chilambo' and 'ukusopa')

Spears were important for fishing at two times of the year: when water levels were very low in November and December, and during the catfish spawning run (*Chilambo*) in late December or early January.

Every fisherman carried a spear throughout the season, mostly for removing catfish from longlines. These were tipped with varying sizes of metal rod or wire, sharpened to a point with serrations cut into the metal shaft to serve as barbs. This was mounted with melted plastic and nylon cord binding into a handle of reed or thin piece of bamboo.

A few pools on the floodplain were well known for retaining large numbers of catfish as the water receded. One of these visited in early November 2011 was 100 m in diameter and surrounded by thick floating grass mats. A temporary encampment of approximately 60 people was using a combination of seine netting and spearing the margins (*ukusopa*) to fish the pool. Spearing was done by thrusting spears blindly through the floating mud until contact was made with a fish. Then a second spear was thrust down in case the first spear had not secured the fish. Fishing was done until the pool was depleted of fish.

Areas adjacent to the Lukulu Delta were known for their *Chilambo* catfish spawning runs. Spawning aggregations of adult *Clarias* catfishes and the mormyrid *Marcusenius macrolepidotus* reportedly moved into shallow, newly flooded parts of the plain while floodwaters were rising in late December and early January. The author was not in the field during the 2011 spawning event. Despite occurring during the countrywide fishing ban, it remained an important date on the fishing calendar. Numbers of fish were very easily speared in the shallow water, and some of the specimens were reportedly large (2-6 kg).

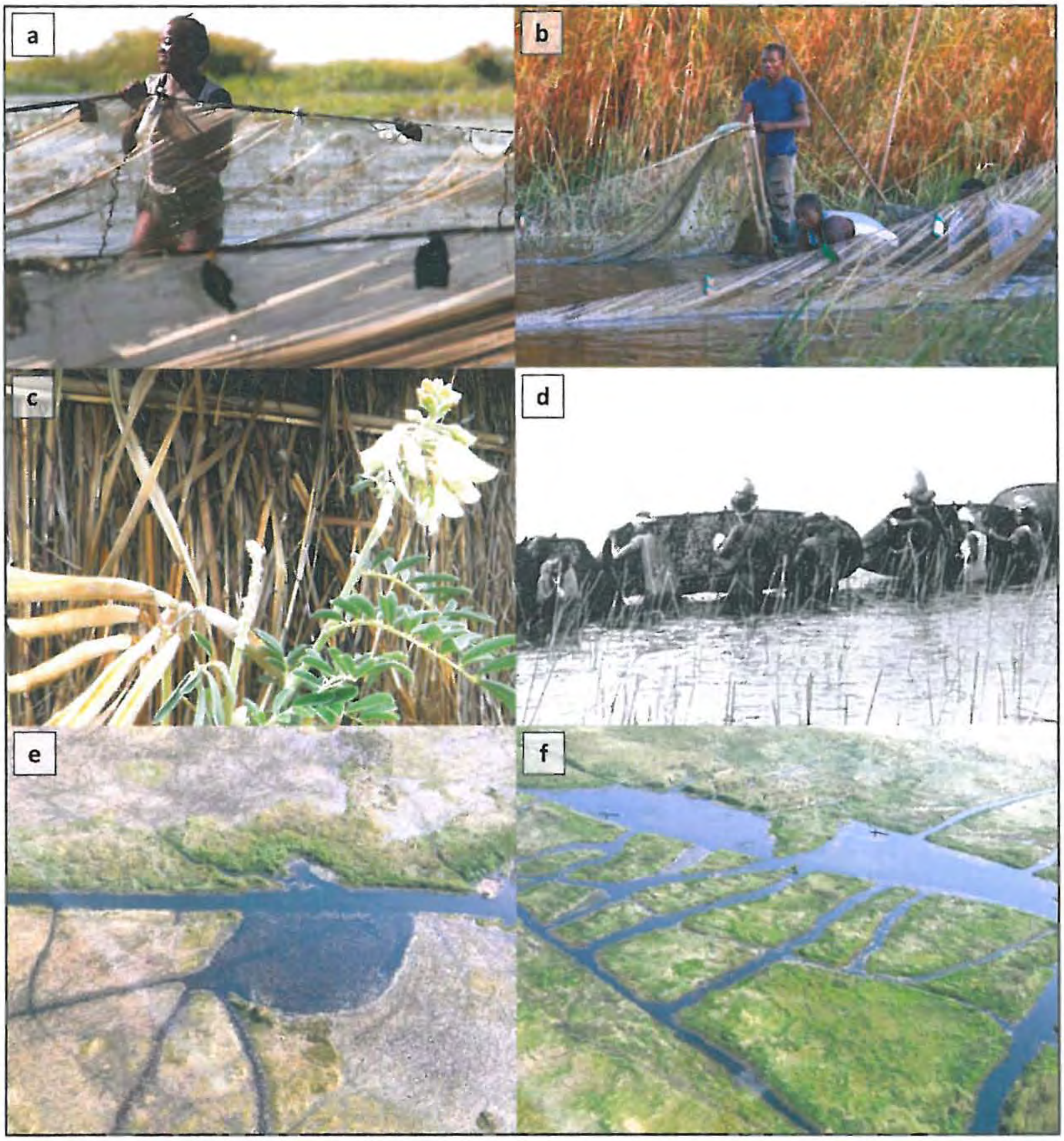

Figure 4.4: a) A seine net made from mosquito netting being hauled in, with the sides held high to prevent fish jumping out; b) a coarse-mesh seine net in use by a group of immigrant fishermen; c) *Tephrosia vogelii*, a useful cultivated legume used as a piscicide; d) *Ulwanga* drag baskets used in a large drive in fairly open water (from Debenham 1952); e) Aerial photograph of a clearing in swamp vegetation made for seine netting; f) Aerial photograph of 'feeder' channels around a seine netting pool. Photos: a-b) Morgan Trimble, c, e-f) Carl Huchzermeyer.

Piscicide poisons

In Bangweulu a large number of trees and shrubs were known to have piscicidal properties, though only a few were reportedly used. The most popular fish poison was a cultivated leguminous plant: *Tephrosia vogelii* (Figure 4.4c). It was common in fields, where it was grown primarily as a fish poison but also because of its pesticide and nitrogen-fixing properties (Mike Bingham, independent consultant, *pers. comm.*).

Fish poison was prepared by pounding leafy parts of the plant into a fibrous mass. This was put into baskets, which were washed around in the water, releasing the toxic compounds. Fish poisoning was mostly done in isolated woodland pools and swamp backwaters cut off from the main water bodies where fish had limited space to escape the contaminated water. Fish poisoning was primarily an activity of the late dry season, when fish were concentrated in the least amount of water.

The method appeared to be widely practiced, but at a low intensity. Its importance had reportedly decreased in the delta areas around Chikuni. Here only two or three poisoning parties were organised, and catches were low. In Lavushi Manda National Park evidence was found that this method was widely used along the upper Lukulu River in the dry season.

Drag baskets ('ulwanga')

Another gear rarely seen in use was the lift- or drag basket, *ulwanga*. This large, rigid basket was used exclusively by women and children, and was reportedly still popular in some areas. It was rarely seen in use around Chikuni. The baskets would be shoved into densely vegetated water, with the opening towards the fisher. She would stamp her feet, frightening fish out into the basket, which was lifted about ten seconds after it was put down. The catch was varied, but near Chikuni it consisted of small climbing perches and mormyrids. Debenham (1952) shows a photograph of part of a line of women using a very large version of these baskets (Figure 4.4d) in open water. This strategy wasn't used in the study site.

Digging

During years when water levels become very low (not in 2011), fish reportedly become stranded in large areas of deeper, grassy floodplain north of Chikuni. When these areas dried, fish were trapped under dense vegetation mats in shallow depressions. People found these refuges by watching bird activity, and if the vegetation was hauled out fish could be caught in great numbers. Fish were caught by hand and spear and people were said to be "digging for fish".

Costs of gears

The prices obtained for various gears are presented in Table 4.2. These were mostly for modern materials. Traditional materials were usually collected by the fishermen themselves or obtained by trade, barter or sale from people living in the higher-lying woodland areas.

Table 4.2. Local prices of various fishing gears and materials in the Bangweulu Wetlands area (exchange rate (09/2012): 1 ZMK to 0.0002 USD).

Item	Price	Notes
Large wooden dugout canoe	USD 193.00	
Fibreglass banana boat	USD 1544.00	
Mosquito bed-net	USD 3.00	Makes one funnel net
Multifilament gillnets	USD 1.20	Per 100 m bundle, 50 m hung
Monofilament gillnets	USD 40.00	Per 200 m bundle, 100 m hung
Sandal foam	USD 3.00	For 5-7 gillnets
Nylon cord	USD 0.80	50 m bundle
Hooks	USD 4.00	Box of 100
Seine net tailor service	USD 9.00	Net of 15-20 mosquito nets
Mosquito seine net	USD 45.00	Net of 15 mosquito nets
Coarse-mesh seine material	USD 4.00	Per meter (1 m x 2 m wide)
Coarse-mesh seine net	USD 200.00	50 m net

Interactions with wildlife

With Bangweulu Wetlands being a conservation area, any observed or reported interaction between fishing activities and wildlife were recorded. These were:

- Flocks of pelicans were welcomed as their hunting activities could drive fish through traps in weirs, increasing the catch.
- Scavenging from funnel nets by birds was discouraged by surrounding them with reed barriers.
- Gillnet catches were sometimes damaged by otters which often consumed only the head of a fish.
- Crocodiles and hippos could drag nets away, and in some areas scarecrows were made to discourage the passage of animals through the netting ground.
- There were reports of pythons and water monitor lizards becoming entangled in gillnets, though usually in the uncommon, larger (> 3 inch/76 mm) mesh sizes.
- Longlines reportedly caught terrapins in the main channel of the Lukulu River at the neck of the delta near the village. A juvenile crocodile is also known to have been caught albeit "*a long time in the past*". The nylon lines spanned across the surface of the water pose a hazard to low- flying birds, and ornithologists think this may play a role in discouraging African Skimmer (*Rynchops flavirostris*) birds from utilising the area (David Ngwenyama, Zambian Ornithological Society, *pers. comm.*). A hand-reared shoebill chick swallowed a hooked catfish, fortunately without injury. Occasionally lechwe antelopes and hippos dragged a longline around.
- During 2011 there were two reports of a hippo breaking through a seine net while it was being retrieved. Elephants also shredded a seine net left lying outside a vacant hut.
- Nylon cord snares set for water birds were found near most fishing camps.

4.4. DISCUSSION

The fishing activities and methods used in Bangweulu are typical for a floodplain fishery (Welcomme 1979). Many fishing methods such as fish weirs, longlines and gillnets are shared with similar floodplain fisheries in the region, such as the Zambezi River floodplains in western Zambia (Bell-Cross 1971) and the Shire River floodplains in Malawi (Tweddle et al. 1978). The dispersed nature of the fishing grounds, migratory activities and reliance upon water craft are common to many floodplain systems, where fluctuating water levels cause the shoreline of these shallow systems to move over great distances (Tweddle et al. 1978, Welcomme 1979).

Overall, no fishing methods had a high impact on the environment. The construction of fish weirs and the clearing of seine netting pools were the only methods with a semi-permanent impact on the landscape, though it could be argued that these activities add habitat complexity. Gears made from modern materials such as nylon longlines, mosquito-mesh funnel nets and seine nets have a visual impact, especially for tourists. The application of fish poison mostly occurred in seasonal pools and other restricted bodies of water, where its impact would be minimal (Welcomme 1979). However, the use of poisons in flowing streams and in important dry-season fish refuges such as the Lukulu Delta should be discouraged as the effects of the poison could extend downstream and cause mortalities in a greater area of water than intended by the fishers.

Changes in the fishery

There is no doubt that in the past, fishermen were not able to exploit the full potential of the fish stock available. Their main limitation was in their fishing gears, which were limited in availability and laborious to make (Jul-Larsen et al. 2003). Gillnets used to be woven from root bark fibres of the Ng'ansa tree, *Brachystegia boehmii* (Lusenga 2011). It took considerable skill to knot these nets, and being made of a natural fibre, they were less durable than modern nets. Hooks were made by village blacksmiths in the shape of a modern 'circle' hook (Brelsford 1946). An old fisherman interviewed stated that seine nets, already adopted at an early date by the *Unga* in the main swamp, were more durable if woven from fibres taken from old tyres, also documented by (Brelsford 1946).

Interviews with fishermen revealed that there has been a shift from subsistence fishing to commercial fishing within the last two to three decades. Young fishermen in their mid-twenties recall their fathers fishing largely for home consumption and local trade, and elderly *Chipupilas* interviewed confirmed that the fishing was '*not for business*' and that there were '*many new things in fishing*'. Elderly fishermen noting these changes did not express any views on how the resource would respond. Fishing groups largely consisted of a father and one or two of his older sons or nephews as his apprentices. Fishing was reportedly done with less gear, and the impression was that fishing trips had been shorter in duration. Once the amount of fish needed had been caught, they would return to their villages to continue their farming activities.

This contrasted with the fishing that occurred deeper in the swamps, where Brelsford (1946) described the shift from subsistence to commercial fishing occurring on a considerable scale already in the 1940's. Access to the market is one of the most important factors influencing commercialisation of floodplain fisheries (Mortimer 1965). The remoteness of the Chikuni area, with limited access to the main roads and the main swamp channels, may have slowed the development of the commercial aspect of fishing there. The roads have improved in recent years, especially with infrastructural input by Bangweulu Wetlands, easing access to traders.

While Brelsford (1946) stresses the popularity of driven gillnet fishing (*ukusakila*), which was a popular method around the country and elsewhere (Mortimer 1965, Kolding and van

Zwieten 2011), it was rarely used around the study site. The importance of this method in the deeper swamp areas is described in detail by Ichikawa (1985), while Imai (1998) shows a decrease in active gillnetting methods and an increase in seine nettings for the periods 1983-1993. Whether this trend has continued throughout the system is not known, though indications are that seine netting continues to rise in popularity.

The fishing in the study area changed considerably between 2011 and 2012. The greatest change in gear was the widespread adoption of monofilament gillnets. In 2011 there was only one fisherman with 5 nets using this gear. In 2012 almost every fishing group had at least one of these nets, and some groups had as many as 10 nets.

On a flight over parts of the swamp to the north of the study site in 2012, there was strong evidence of the modification of pools for seine netting. Narrow channels had been significantly widened in parts by removal of vegetation (Figure 4.4e). Many of these pools had 'feeder' channels cut towards them, possibly in an attempt to guide fish towards the pool (Figure 4.4f). In this way, it could be hypothesised that the surrounding, thickly vegetated swamp acts as a source for fish, which are captured and removed at the seining pool.

Welcomme (1979) shows that in some floodplains in West Africa and South East Asia, fishermen have taken the modification of pool environments even further by digging ponds into the floodplains. These deeper environments retain fish after most of the plain is dry and can yield large catches. In Bangweulu, weirs and the maintenance of pools for seine netting can be viewed as attempts at managing water bodies for increased fish catch (Welcomme 1979).

Immigrant fishermen

The flooded season during 2012 saw a strong influx of fishermen from the main Bangweulu Swamps (Figure 4.5). These were mostly full-time fishermen of the *Unga* tribe, and originated from areas such as Nsalushi Island (Chief Nsamba) near the Chambeshi Delta on the east of the Basin, to the Lake Bangweulu at Samfya, in the west. The majority of groups had come from the chiefdom of Kasoma Lunga, well outside of the Bangweulu Wetlands boundary.

These groups used seine nets, often of the strong 'coarse-mesh' type, and monofilament gillnets. For some of the people from the lake, these were not the gears they were accustomed to using, with one group only recently having changed from the light-attraction fishery on the lake for the kapenta-like '*chisense*' (*Neobola moeruensis*).

The immigrant fishermen customarily move about during the flooded season, seeking areas shallow enough to fish. Nobody was completely clear as to why so many of them had come during 2012 but questionnaires confirmed that it was a combination of factors. There had been heavy rainfall and flooding in the Lunga area of the swamp, rendering most of their fishing areas unsuitable for seine netting. Others stated that they had heard from traders and two or three groups who had come to fish the year before, that there were still good numbers of larger cichlids to be caught in the channels. The large majority of these fishermen had never been to the Chikuni area previously.

The immigrant fishermen were generous, friendly and inquisitive. Being new in the area, they were curious about the wildlife. Their friendly attitude was no doubt because they were fishing in another's area, and they had no reason not to cooperate with the fish research activities.

The locals were very concerned having seen the amounts of fish being caught by the immigrant fishermen. During March to May, the local resident fishermen were all using their fish weirs, and resented other groups having a 'head start' on the seine net fishing. There were very real fears that there would not be enough fish left in the channels for many of the local fishermen who would only return for fishing during the dry season. By June the immigrant fishermen had mostly left back to their home areas of their own accord, despite attempts by the traditional authority to remove them.

The recent exploitation of the deeper channel habitats using seine nets and the targeting of larger fishes (> 20 cm) using monofilament gillnets, are possibly the last major changes in the fishery around Chikuni, with no major size or species component of the fish community remaining unexploited.

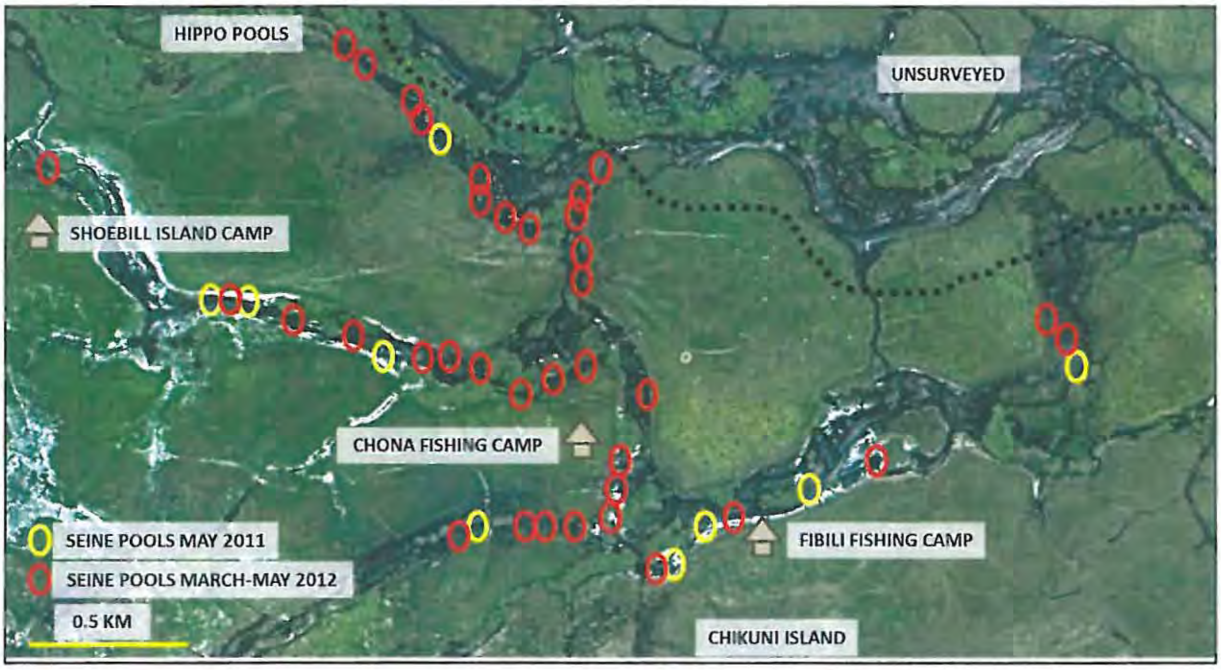

Figure 4.5: Map of the delta edge near Chikuni, in the core study area in Bangweulu Wetlands, highlighting the proliferation of seine netting between 2011 and 2012. Each pool represents a group of fishermen, as most seining groups must pay for the pool they use. By July 2012 almost all the pools were vacant again. (Imagery: ©Google Earth 2009).

Future research

The traditional regulation of resource access rights through the traditional authority and fishing chiefs (*Chipupilas*) represents a significant opportunity in managing the Bangweulu Wetlands fishery. The observations about traditional mechanisms made during this study were brief and could be influenced by errors in interpretation. Therefore this aspect needs further research.

CHAPTER 5

Catch Composition

5.1 INTRODUCTION

Comprehensive information on fisheries is required to aid decision-making about the biological, economic and social sustainability of the resource (Bayley 1988, Welcomme 1999). Fisheries scientists strive to describe the functioning of fish populations, and how these respond to different variables, such as predation by man's fishing activities (King 1995). While research into sustainable yields from industrial, single-species, single-gear fisheries with long-term data sets is most advanced, the complex artisanal, multi-species, multi-gear fisheries found in the developing world, and typical of African inland waters, still receive far less scientific attention (Bayley 1988, Weyl 1998, Welcomme 1999). Most predictions of fisheries population dynamics assume a hypothetical equilibrium state with biological and environmental stability (Bayley 1988). However, floodplain habitats as found in Bangweulu Wetlands are not stable systems (Welcomme 1979, Bayley 1995, Kolding et al. 2003). Pulsed systems, such as floodplains, are extremely variable, with cycles of water level, nutrient availability and fluctuations in interspecific interactions like competition and predation (Junk et al. 1989). Floodplain fisheries also use a diverse set of fishing gears to harvest a broad range of species, representing fishermen's attempts at stabilizing or maximising their economy in a highly variable environment (Welcomme and Hagborg 1977). This complexity in environmental and human effects prevents assessment of the fish population by traditional models, but some general rules deduced from the environment can still be applied (Welcomme 1999). Where reliable, long-term data sets are absent, as is the case with Bangweulu Wetlands, preliminary information for decision-making can be obtained by describing the fish production and yield of an area, and biological data such as species composition and growth rates (Bruton and Jackson 1983). This information can then be used to make useful comparisons with similar systems (Welcomme 1999).

The aim of this chapter was to establish a baseline of key biological (size, species composition) and fisheries (gears and effort) parameters describing the catch, which allow some generalisations about the fisheries ecology to be made. In most studies of African inland fisheries, the most important factors to collect data on are catch and effort, used to estimate fish yield per unit area (Bruton and Jackson 1983, Bayley 1988). These values can be compared between systems, but any comparison must also take into account differences in both the abiotic, biotic and human environments (Jul-Larsen 2003). Once established, baseline data can be further refined to gain a more detailed understanding of the system, and can also be used to monitor future changes (Welcomme 1999).

The specific objectives of this chapter were to:

1) Determine the species composition of the different gears used in the fishery.

2) Assess the size structure of the main target species in the catch.

3) Establish estimates of catch-per-unit-effort (CPUE) of fishing gears and compare these with other floodplain fisheries.

4) Estimate daily and annual catch of a typical fishing group using the catch assessment and results of a socio-economic survey.

5) Compare seasonal catch and gear use values to the information obtained by interviews presented in the 'Fishing Calendar' (Chapter 4).

6) Attempt to derive an estimate of fish harvested per unit area in the floodplain such that a total yield for the study site can be projected.

5.2 METHODS

As described in Chapter 4, fishermen operated as two main types of fishing group: a family unit owning a section of a weir, or in the case of seine netting, a net owner and his assistants. Fishermen were interviewed on return from checking their gears in the morning. The catch was then sorted according to gear and thereafter into the separate species. During the weir-fishing season, fishermen were asked in advance to use a pile of waterweed to separate the catch of fish from baskets and funnel nets. Fish caught by hooks and gillnets were easy to distinguish by their injuries. As it was sometimes not possible to distinguish which fish were from monofilament gillnets or from different mesh sizes of multifilament net, these catches were grouped under a general gillnet category for the analysis.

The catch from each gear was weighed collectively to the nearest 20 g and then separated into different species components. Each species component was weighed separately (also to the nearest 20 g), or if they were very small species and few in number, with a more accurate scale to the nearest gram. A sample of the catch was also measured for length, with species groups not attaining at least 3 cm in length being excluded. Fishermen were then asked how many gear units the catches had come from, and all the data was recorded in notebooks and later entered into the Pasgear 2 database (Kolding and Skålevik 2010).

Catch composition

The catches of each gear were analysed in Pasgear to examine the relative contributions of each species. This was expressed as the percentage number (%NO), percentage weight (%W), percentage frequency (%F) and an index of relative importance (%IRI) for each species. Pasgear calculates %IRI of each species *i* as:

$$\%IRI_i = \frac{(\%W_i + \%N_i) * \%F_i}{\sum_{j=1}^{s}(\%W_j + \%N_j) * \%F_j} * 100$$

where $\%W_i$, $\%N_i$, and $\%F_i$ are the weight, numerical abundance and commonness (frequency of occurrence) of species i in a particular gear, and $\%W_j$, $\%N_j$, and $\%F_j$ are the weight, number and commonness of each species for the total number of species S in all the gears (Kolding and Skålevik 2010).

Size composition

Length measurements were expressed as length-frequencies of species in the total catch, as well as for groups in each gear. All fish with forked tails (e.g. cyprinids, characids, mormyrids and some catfishes) were measured in cm fork-length (FL) and fish with truncate or rounded tails (e.g. clariids, cichlids) were measured in cm total-length (TL).

Catch per unit effort

The number of gears or hauls used for a landing, given by the fisherman, was used to quantify the relative effort used to make a catch. The dimensions of typical gears are given in Chapter 4. Total lengths of gillnets vary due to the different mesh-sizes used, and cutting and combining of nets done by fishermen. As they did not land with their nets, a standard length of 50 m per net (approximate length of a standard 100 m net when purchased, once hung) was used in the analyses. Standardised CPUE was calculated as:

$$CPUE = Catch * (\frac{Effort_{standard}}{Effort_{observed}})$$

where *catch* is the total weight (g) of all species caught in that gear for that landing, *standard effort* is the standard unit for a particular gear, and *observed effort* is the total gear units reported by the fisherman (e.g. number of baskets, number of hauls). Standard units for the gears were catch per trap or per net for basket traps and funnel nets, catch per 50 m net for gillnets, catch per 100 hooks for longlines, and catch per 5 hauls for the two seine net categories.

Fish production

The average of individual landings was used to estimate the average daily catch per fishing group. Days with no fishing (due to errands, drinking, poor weather or family business), and therefore no catch were not been estimated nor factored into calculations of CPUE, production or yield. Therefore estimates must be viewed as maxima. These values were compared to production estimates gained from data collected during a socio-economic survey (African Parks 2011b), where fishermen expressed their seasonal production as grain bags of dry fish. The average number of bags from the interview was multiplied by 70kg (the weight of a typical grain bag of dry fish) and converted to fresh weight by the conversion factor 3.9 (see Chapter 6 for explanation). This wet fish production value was divided by 210 days, in order to arrive at a daily catch estimate for a seven month season.

Seasonality

The year was divided into a wet (December to May) and dry (June to November) season. Microsoft Excel 2010 was used to perform a Student's t-test ($p < 0.05$) to check whether there was a significant difference between the two season's catches (daily total landings), after confirming equality of variances with an F-test. CPUE from individual gears was also separated into the two seasons and the results compared to patterns described in the Fishing Calendar (Chapter 4). A non-parametric Mann-Whitney-Wilcoxon test on ranks ($p < 0.05$) was used to test for significance between mean gillnet CPUE for dry and wet seasons. This test was chosen due to a non-normal sample distribution and small sample size.

Yield

The number of fishing groups on one fishing camp (Chona Island) from which most catch-measurements came was multiplied by the total daily production of a fishing group multiplied by the three month fishing peak in that area. This total seasonal catch of all the inhabitants was divided by the approximate 130 ha (1.3 km x 1.3 km square) area around the island that they used for fishing, which gives a yield in kg/ha/season.

5.3 RESULTS

In total, 87 total daily catches were examined. The total daily catch was defined as the catch from all gears brought in by one fishing group on a particular day. As a landing frequently consisted of catches taken from multiple gears, the total number of gear-catches, defined as the portion of the catch in a landing attributable to a particular gear, was 160. The number of gear-catches for which length measurements were taken was 44. The total number of fish counted, weighed or measured in this study was 116 841 individuals.

Catch composition

Every gear type examined caught multiple fish species. A total of 23 fish species were harvested. Small *Barbus* and *Aplocheilichthys* species were designated only by genus, and a further category, 'tiny species and fry ('lila')' was used for any unidentified fish below 20 mm in length (Figure 5.1). The relative importance of the different species to the total catch from all gears is shown in Figure 5.1, where the species are ranked according to their IRI. The three most important species in the total harvest were *Clarias gariepinus*, *Tilapia rendalli* and *Marcusenius macrolepidotus*. These species had a high % weight contribution to the ranking (24.5%, 24% and 18% respectively, 67% together), while the category, 'tiny species and fry', was ranked fourth most important by IRI with a high % number (43%) but low (3%) contribution to the weight of the catch (Figure 5.1). The contribution by weight of each of the remaining species was less than 10% (Figure 5.1).

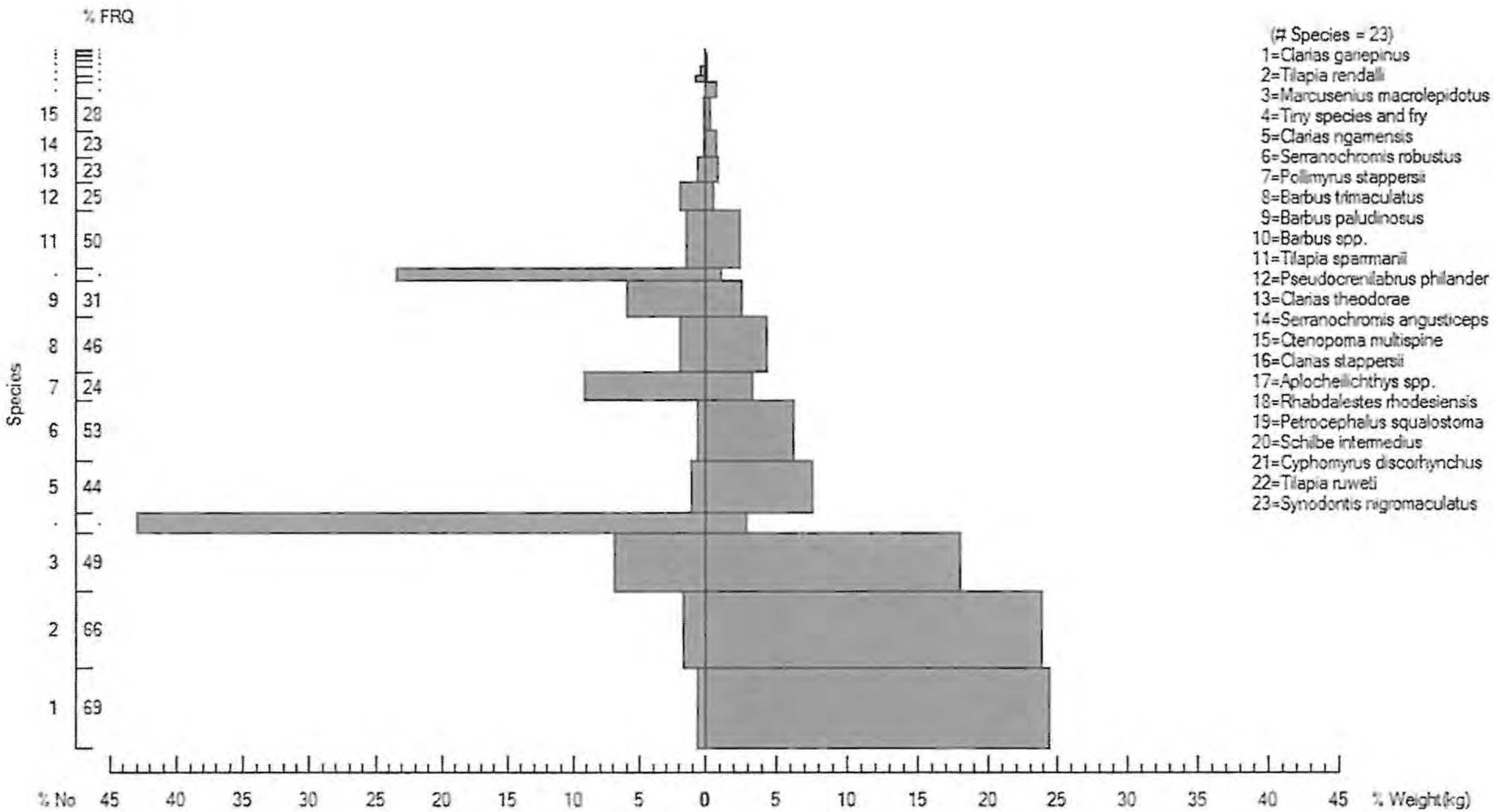

Figure 5.1: Importance of different species to the catches examined in Bangweulu Wetlands. The histogram ranks species (1 highest, 23 lowest) according to their index of relative importance (IRI= area of rectangle), with the length of the rectangle being determined by the species' % number and % weight in the total catch, and the height of the rectangle from the species' % frequency in catches.

Relative contributions of the different species to the catch by gear are provided in Table 5.1. The greatest number of species were caught in basket traps (21 species) and funnel nets (22 species), while gillnets (15 species), mosquito seine nets (13 species) and coarse-mesh seine nets (12 species) caught an intermediate number, and longlines (7 species) caught the least number of species (Table 5.1).

The most important fish species by number in the fine-mesh gears were *Pollimyrus stappersii* (55%) in basket traps, small *Barbus* and 'tiny species and fry' (40% and 33%) in funnel nets, and 'tiny species and fry' (83%) in mosquito seine nets. In gillnets and coarse-mesh seine nets, *T. rendalli* (24%) and *M. macrolepidotus* (46%) were most important respectively. In longline catches, *C. gariepinus* made up 78% of the catch by numbers.

The greatest percentage weight contributions were made by *P. stappersii* (20%) in basket traps, *M. macrolepidotus* (48%) in funnel nets, *C. gariepinus* (86%) on longlines and *T. rendalli* in gillnets (29%), mosquito seine nets (34%) and coarse-mesh seine nets (57%) (Table 5.1). The number of species contributing more than 10% to the weight of the catch was 5 (of 21 species) for basket traps, 2 (of 22) for funnel nets, 4 (of 15) for gillnets, 2 (of 7) for longlines, 4 (of 13) for mosquito seine nets and 2 (of 12) for coarse-mesh seine nets (Table 5.1).

The most common species in catches, represented by their percentage frequency of occurrence (% F), were *P. stappersii* and *Clarias ngamensis* (both 84%) for basket traps, *Barbus paludinosus* and *C. gariepinus* (both 84%) for funnel nets, *C. gariepinus* (96%) on longlines, and *T. rendalli* in gillnets (86%), mosquito seine nets (100%) and coarse-mesh seine nets (100%).

Table 5.1: Catch composition in percentage number (% N), percentage weight (% W), percentage frequency (% F) and percentage index of relative importance (% IRI) of all 23 species caught in different gears examined in Bangweulu Wetlands between April 2011 and May 2012 (n = the number of examined catches per gear). Group categories are given in bold. An asterisk (*) marks 9 species that commonly exceed 15 cm TL/FL.

	Basket trap (n = 22)				Funnel net (n = 30)				Gillnet (n = 59)				Longline (n = 27)				Mosquito seine (n = 13)				Coarse-mesh seine (n = 9)			
Species	% N	% W	% F	% IRI	% N	% W	% F	% IRI	% N	% W	% F	% IRI	% N	% W	% F	% IRI	% N	% W	% F	% IRI	% N	% W	% F	% IRI
Small barbs and '*lila*'																								
Barbus spp.	0.2	0	11	0	40	7	56	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tiny species and fry	1.1	0.1	5.3	0	33	5.4	72	19	-	-	-	-	-	-	-	-	83	13	62	42	-	-	-	-
Rhabdalestes rhodesiensis	0	0	5.3	0	0.6	0.3	44	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aplocheilichthys spp.	-	-	-	-	1.2	0.2	28	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Climbing perch																								
Ctenopoma multispine	0.7	0.2	32	0.2	0.2	0.2	40	0.1	2.4	0.8	39	1	-	-	-	-	-	-	-	-	0.6	0.3	44	0.3
Medium barbs																								
Barbus paludinosus	11	4.5	74	7.3	4.6	4.7	84	5.5	5.3	0.8	1.8	0.1	-	-	-	-	7.6	7.6	54	5.8	1.5	0.2	44	0.6
Barbus trimaculatus	5.2	7.1	63	5.1	0.2	0.6	52	0.3	8.4	2.3	46	3.9	0.5	0	3.6	0	2.6	11	77	7.6	23	7.4	89	22
Small mormyrids																								
Cyphomyrus discorhynchus	-	-	-	-	0	0	4	0	-	-	-	-	-	-	-	-	-	-	-	-	1	0.2	11	0.1
Petrocephalus catastoma	0.1	0.1	16	0	0.1	0.2	28	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pollimyrus castelnaui	55	20	84	41	7.2	8.9	76	8.6	-	-	-	-	-	-	-	-	0.2	0.2	7.7	0	-	-	-	-
***Mintesa* (medium mormyrid)**																								
*Marcusenius macrolepidotus**	9	11	79	10	8.1	48	80	31	14	14	49	11	-	-	-	-	1.3	8.1	77	5.1	46	27	11	6.6
Clariid catfishes																								
*Clarias gariepinus**	0.6	11	74	5.6	0.4	10	84	6.2	5.2	23	53	12	78	86	96	92	0.2	13	77	7.1	0.9	3.3	22	0.8
*Clarias stappersii**	0.2	2.8	37	0.7	0	0	20	0	0.2	0.7	7	0	2.3	1.4	14	0.3	0	0.3	7.7	0	-	-	-	-
*Clarias theodorae**	1.5	6.1	68	3.4	0.8	1.1	64	0.9	0	0	1.8	0	1.8	0.3	14	0.2	-	-	-	-	-	-	-	-
*Clarias ngamensis**	2.6	17	84	11	1.3	9.7	80	6.2	1.4	7	21	1.4	17	12	43	7.3	0	1.6	31	0.3	0.7	1.8	33	0.7

Other catfishes																								
Schilbe intermedius	0	0.1	16	0	0	0	4	0	0.1	0.1	3.5	0	-	-	-	-	-	-	-	-	-	-	-	-
*Synodontis nigromaculatus**	0	0	5.3	0	-	-	-	-	0	0.1	1.8	0	-	-	-	-	-	-	-	-	-	-	-	-
Large cichlids																								
*Serranochromis angusticeps**	0.5	1.7	58	0.8	0	0	12	0	1.7	1.5	26	0.7	-	-	-	-	0	0.7	23	0.1	0.2	0.1	22	0.1
*Serranochromis robustus**	1.2	1.8	63	1.2	0	0.3	32	0.1	21	17	75	23	0.5	0.4	3.6	0	0.1	4.3	77	2.4	1.2	2.4	67	2
*Tilapia rendalli**	3.5	13	79	8.3	0.3	1.5	52	0.6	24	29	86	37	0.5	0.1	3.6	0	1.2	34	100	25	22	57	100	65
Small cichlids																								
Tilapia ruweti	0.1	0.1	16	0	0	0	4	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tilapia sparrmanii	2.3	1.7	63	1.6	0.5	1.2	40	0.5	16	4.4	60	10	-	-	-	-	2	4.8	92	4.4	2.5	0.8	78	2.1
Pseudocrenilabrus philander	5.7	2.2	79	4	1.9	0.8	72	1.4	0	0	1.8	0	-	-	-	-	1.3	0.9	15	0.2	0.1	0	11	0

The greatest contribution to % IRI was made by *P. stappersii* (41%) in basket traps, *M. macrolepidotus* (31%) in funnel nets, *T. rendalli* (37%) in gillnets, *C. gariepinus* (92%) in longline catches, 'tiny species and fry' (42%) in mosquito seine nets and *T. rendalli* (65%) in coarse-mesh seine nets. The number of species contributing more than 5% to the % IRI was 7 (of 21) for basket traps, 7 (of 22) for funnel nets, 5 (of 15) for gillnets, 2 (of 7) for longlines, 6 (of 13) for mosquito seine nets and 3 (of 12) for coarse-mesh seine nets.

Longlines were the only species-selective gear, catching almost only catfishes of the genus *Clarias* (98% IRI). Of the clariids caught, one species, *C. gariepinus*, made up 92% of the percentage IRI and 86% of the percentage weight.

Length composition

A total of 5031 individual fishes of 15 species were measured, from 44 gear-landings. Fish species smaller than 3 cm TL/FL were not measured (*Aplocheilichthys* spp., small *Barbus* spp. and 'tiny species and fry/lila'), and a number of species rare in catches (*Tilapia ruweti*, *Schilbe intermedius*, *Petrocephalus squalostoma*, *Rhabdalestes rhodesiensis* and *Synodontis nigromaculatus*) were also not measured (Figure 5.2). The average size of all species from all gears measured was 11.82 ± 6.7 cm TL/FL (standard deviation), with the species with the largest average size being *C. gariepinus* (28.6 ± 11.6 cm TL) and the smallest *Pseudocrenilabrus philander* (3.9 ± 1.4 cm TL).

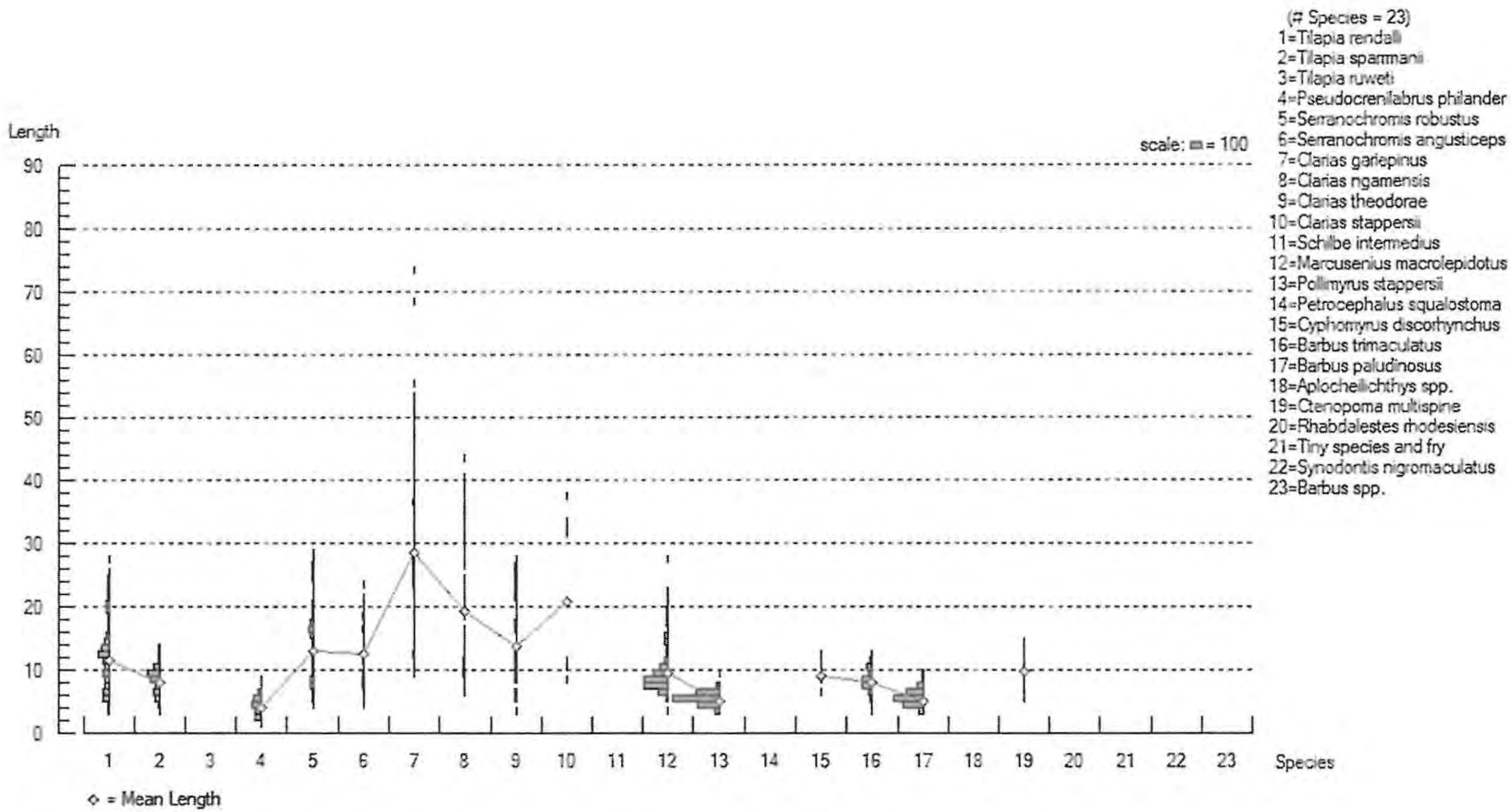

Figure 5.2: Length-frequency histogram (cm TL/FL) for all species in the catch assessment in Bangweulu Wetlands, indicating the average length for each species (number of gear-specific landings where lengths were measured = 44).

Longlines, gillnets and coarse-mesh seine nets caught fish with the largest average length (35.3 ± 10.5 cm, 21.8 ± 7.5 cm and 14.2 ± 6.1 cm TL/FL respectively), while the other gears harvested fish with average lengths less than 8 cm (Table 5.2). All of the gears were capable of catching fish of a much greater length, with a single species, *C. gariepinus*, attaining the largest length for all gears (Table 5.2). The largest fish were caught on longlines (maximum length 73 cm TL), while the smallest maximum length (26 cm TL/FL) was recorded from mosquito seine nets (Table 5.2).

Table 5.2: Total numbers and lengths of all fish species from catches of different gears in Bangweulu Wetlands (n = 44 landings).

	Bastket trap	Funnel net	Gillnet	Longline	Mosquito Seine	Coarse-mesh seine
No. fish	2213	1033	865	116	463	341
Average length(cm TL/FL)	7.4	5.6	21.8	35.3	6.7	14.2
St. dev. (cm TL/FL)	4.2	2.8	7.5	10.5	2.4	6.1
Max. length (cm TL/FL)	44	31	47	73	26	37
Largest species	*C. gariepinus*	*C. gariepinus*	*C. gariepinus*	*C. gariepinus*	*C. gariepinus*	*C. gariepinus, C. ngamensis*

Cumulative length-frequencies of species revealed the relative contribution of different sizes of fishes to the catches from different gears (Figure 5.3). The majority of fish caught from the three gears with the finest mesh (basket traps, funnel nets and mosquito seine nets) were between 4 and 10 cm TL/FL in length. Gillnets, longlines and coarse-mesh seine nets caught a wider size-range of fish (Figure 5.3).

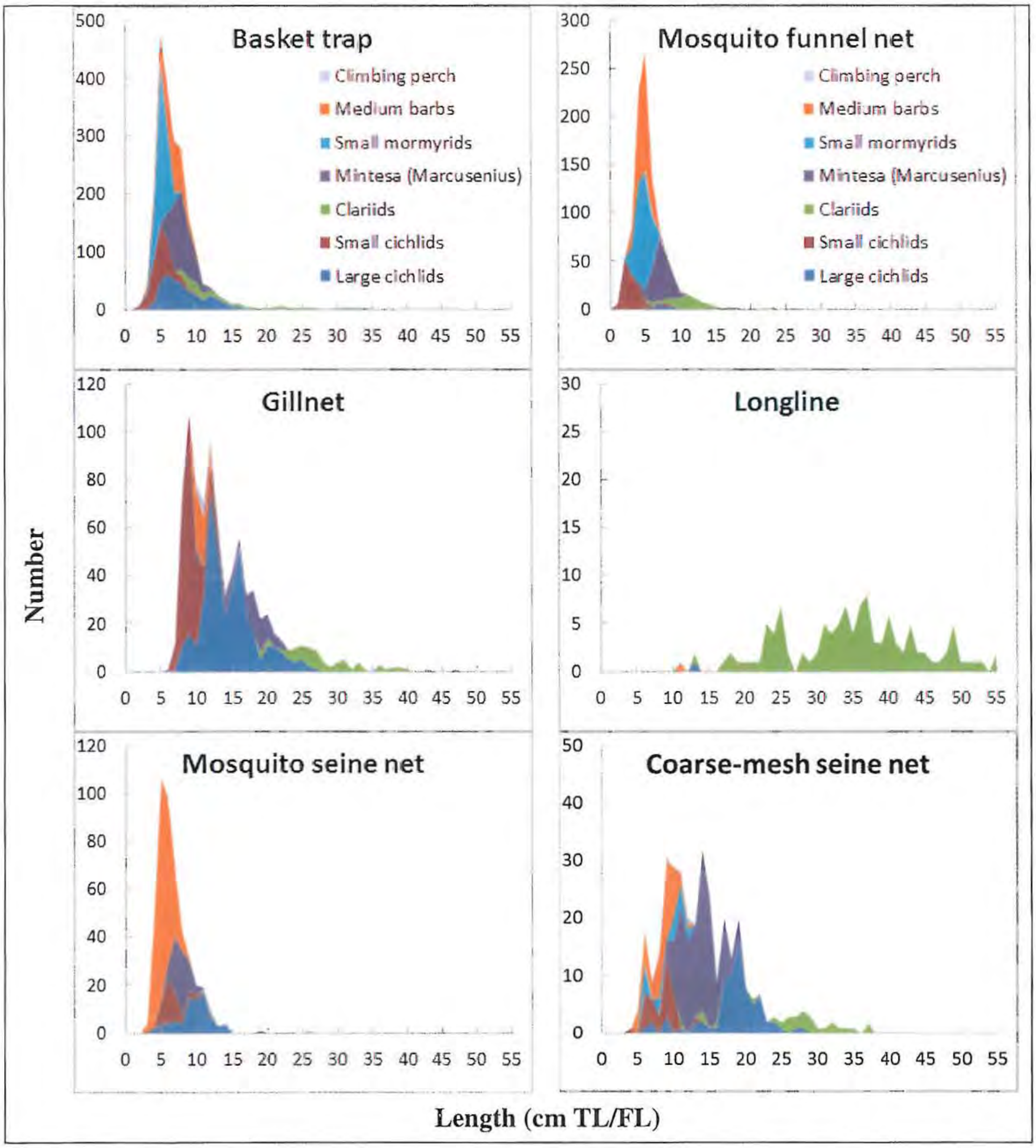

Figure 5.3: Cumulative length-frequencies for species groups in catchesin Bangweulu Wetlands (n = 44 gear-specific landings). Very small fishes (<3cm) were not measured. Climbing perch, clariids and cichlids were measured to total length (TL) and barbs and mormyrids were measured to fork length (FL). Two *Clarias gariepinus* (Longline: 68cm and 73cm TL) were left out to scale the axis.

Some gears (basket traps, funnel nets and mosquito seine nets) caught smaller size classes of particular species than the larger mesh gears (gillnets, longlines and coarse-mesh seine nets). This pattern was visible for *M. macrolepidotus* and clariid catfishes. Basket traps and funnel nets caught *M. macrolepidotus* of 5-12 cm FL, while gillnets and coarse-mesh seine nets caught the 12-23 cm FL size class of this species. In the case of gillnets, the full size range of large cichlids was harvested, though small cichlid species were more important than the smallest size classes of large cichlid species (Figure 5.3). The number of juveniles of larger species such as *M. macrolepidotus*, clariids and large cichlids caught in the smaller mesh gears was lower than the catch of small species (small mormyrids, small cichlids and medium barbs). Longlines were the only gear type that selected for comparatively large fish, with no fish below 10 cm TL/FL in length recorded (Figure 5.3).

Catch per unit effort

Standardised CPUE for each gear is presented in Table 5.3, and the average numbers of gear units or hauls used to make a landing are given in Table 5.4.

Mosquito seine nets and gillnets were the predominant gears used in the dry season, while all gears were used in the wet season (Table 5.3). Basket traps and funnel nets were used exclusively during the wet season. Gillnets were used throughout the year, though there was a significant difference ($p < 0.05$) between dry season and wet season CPUE. Sample sizes for the remaining gears were too small to test for significant differences.

Table 5.3: Standardised catch per unit effort (CPUE) (kg per landing) for different gears from 87 landings measured between April 2011 and May 2012 in the Bangweulu Wetlands fishery.

Gear	**Basket trap**	**Funnel net**	**Gillnet**	**Longline**	**Mosquito seine net**	**Coarse-mesh seine net**
Standard unit	1 trap	1 net	50 m net	100 hooks	1 haul	1 haul
Dry season:						
Avg. (kg)	-	-	0.66	9.33	1.67	1.13
St. dev. (kg)	-	-	0.44	12.13	0.84	0
No. landings	-	-	8	3	11	1
Wet season:						
Avg. (kg)	0.36	2.73	0.28	2.73	2.43	7.59
St. dev. (kg)	0.31	4.62	0.45	5.13	2.61	6.30
No. landings	22	30	48	24	2	8
Total:						
Avg. (kg)	0.36	2.73	0.33	3.46	1.79	6.87
St. dev. (kg)	0.31	4.62	0.46	6.25	1.11	6.27
No. landings	22	30	56	27	13	9

Table 5.4: Average number of gears or hauls used by a fishing group (n = 87 landings).

	Basket trap (traps)	**Funnel net** (nets)	**Gillnet** (50 m nets)	**Longline** (hooks)	**Mosquito seine** (hauls)	**Coarse-mesh seine** (hauls)
Average	9	2	15	192	6	3
St. Dev.	4	1	9	134	6	3
No. landings	22	30	56	27	13	9

Fishing patterns and overall production

The average total weight of the 87 landings examined in the study was 7.82 kg/fishing group/day, with a standard deviation of 7.47 kg. There was no significant difference ($p = 0.46$) between the average daily dry season catch (7.93 ± 5.39 kg; $n = 16$ landings) and the average daily wet season catch (7.80 ± 7.89 kg; $n = 71$ landings).

Most fishermen indicated that they fished a seven-month season (African Parks 2011b), so that the total seasonal catch of a fishing group was estimated as:

$$7.82\ kg * 210\ days = 1.64\ t.$$

From the socio-economic survey (African Parks 2011b), 57 respondents estimated their seasonal dry fish output, expressed as bags of dry fish (70 kg), to be on average 7 bags, with a standard deviation of 5 bags. Therefore, using the dry fish/fresh fish conversion factor of 3.9 (Chapter 6), this amounted to a seasonal (7 months) production of 1.9 tons and an average daily catch of 9.1 kg/unit/day.

Yield

The approximate area (130 ha) used for fishing by the inhabitants of Chona Island fishing camp is shown in Figure 5.4. The camp contained 40 fishing groups during the three-month peak (March-May 2012) in weir fishing in the area. The area selected contained both shallow plains where fish weirs were used, and deeper pools where seine nets, gillnets and longlines were used.

Each fishing group caught an average of 7.819 kg/day during this three month season, then the yield/ha is calculated as:

$$7.82 * 40 = 313\ kg\ per\ day$$

$$313\ kg * 90\ days = 28148\ kg\ over\ three\ months$$

$$\frac{28148\ kg}{130\ ha} = 217 kg\ per\ hectare$$

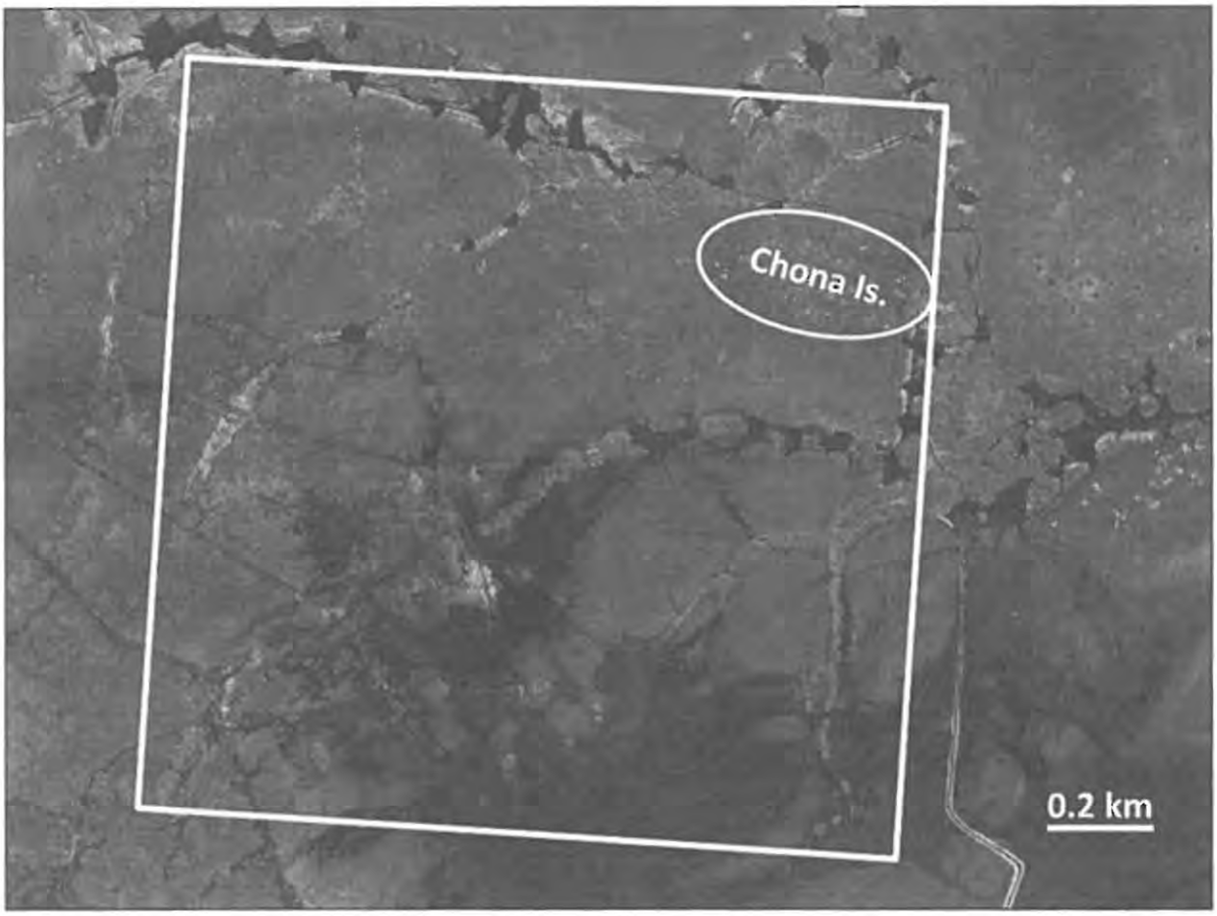

Figure 5.4: The approximate 130 ha area used by 40 fishing groups inhabiting Chona Island fishing camp. The areas to the south and west, and the channels to the east, are used by two other camps. The area to the north is an area of dry land.

5.4 DISCUSSION

Species- and size composition

Every gear used in the Bangweulu Wetlands floodplain fishery harvested multiple fish species, and between them, a very wide range of fish species were caught (a minimum of 23 species, Figure 5.1). The most important species in the present study were *Clarias gariepinus*, *Tilapia rendalli* and *Marcusenius macrolepidotus* (Figure 5.1). While African floodplain fisheries are known to harvest a wide range of fish species, with dominant species often varying between systems, many genera and ecological groups remain prevalent throughout (Welcomme 1979).

The catches of the Bangweulu Wetlands floodplain fishery appear to hold some similarities with other central and southern African floodplain fisheries. In one study, catches on the Lower-Shire floodplains in Malawi were composed of 39 species, with 90% of the catch being made up of *C. gariepinus*, *C. ngamensis*, *M. macrolepidotus*, *Oreochromis mossambicus* and *Eutropius/Schilbe deppresirostris* (Willoughby and Tweddle 1977). In another study, the gillnet catch of the Kafue Flats floodplain fishery was composed primarily of *C. gariepinus*, *Schilbe intermedius*, two *Serranochromis* species and *M. macrolepidotus* (Nyimbili 2006). In the Okavango Delta, Bokhutlo (2011) found that *S. intermedius*, *C. gariepinus*, *M. macrolepidotus*, *Hydrocynus vittatus* and *Brycinus lateralis* were the most important species in experimental gillnet catches.

On the Barotse Floodplains of the Zambezi River in south-western Zambia, Bell-Cross (1971) reported similar species being of value to the commercial fishery there as in the Bangweulu system (*Clarias*, *Tilapia* and *Serranochromis* species). Gillnet catches on the Zambezi River there were dominated by large riverine species (*H. vittatus* and *Oreochromis* species) while the lower-importance species in that fishery (< 5% by weight) such as *Clarias* sp., *Serranochromis* sp., *Tilapia* sp. and *Marcusenius* sp. feature strongly in the Bangweulu catches (Table 5.1). However, the weir fishery of the Barotse floodplains shared more similarities with the Bangweulu Wetlands fishery, with smaller cichlids, climbing perch, clariids and mormyrids being important in weir catches. There appeared to be an absence of barbs in the Zambezi weir catches (Bell-Cross 1971).

A more recent study by Peel (2012) on the floodplain-river systems of the Caprivi Strip in Namibia (Zambezi, Kwando and Kavango Rivers, and Lake Liambezi) found that catches were dominated by *S. intermedius* and the small characin *B. lateralis*, followed by *H. vittatus*, *Marcusenius altisambesi* and *Petrocephalus catastoma*. The dissimilarity of the catch composition of the Bangweulu Wetlands fishery and the gillnet catch compositions of Bell-

Cross (1971) and Peel (2012) were likely due to habitat differences where gillnet fishing focussed on large bodies of open water rather than the plain itself.

Chanda (1998), examining catches in the deeper parts of the main Bangweulu Swamps found that *M. macrolepidotus* contributed the most by weight (37% in seine nets, 23% in gillnets and 34% in basket traps). No funnel nets were in use at that time. *C. gariepinus* was the most important species in the weir catches (30% by weight), but not in gillnets and seine nets (Chanda 1998). Some differences were the high importance of larger cichlids such as *Serranochromis* spp. (10.2% by weight in weirs), possibly as a result of the deeper water habitats. The contribution of these species to the percentage weight of basket traps in the present study was only 1.5-1.8% (Table 5.1). The only small fish recorded from the swamp study by Chanda (1998) were *Ctenopoma* sp., *Tilapia sparrmanii* and *Barbus paludinosus*, where they made an important contribution to the percentage number of catches (7-13%). This was possibly a reflection of the absence of fine-meshed materials such as mosquito nets at the time, which could also explain the absence of barbs in weir catches of the Zambezi floodplains (Bell-Cross 1971).

The length-frequency histograms (Figure 5.3) highlight that all of the gears except longlines can effectively harvest small-sized species. The average size of the fishes in the catches of the study area (average length 9.2 cm ± 6.9 cm TL/FL) is an indication of the importance of small fishes in this fishery. This average length is however biased due to the relatively large size of the abundant *C. gariepinus* in catches (average 28.6 cm ± 11.6 cm TL) and the fact that the catch component of fishes less than 3 cm TL was excluded from length-measurements. Nevertheless, this reveals the importance of catches from small mesh sizes and may also reflect the size-structure of the fish community. As a general rule, about 50% of species in a freshwater fish community do not exceed 15 cm in length (Welcomme 1999). In Bangweulu Wetlands, only nine species (39%) of the 23 species caught in the fishery commonly attain lengths in excess of 15 cm TL/FL. The true figure may be lower than 39% as the fishery may be biased towards larger species, and some small species were lumped in the analysis ('small fry category').

Kolding (1989) cautions against using the catch composition as a true reflection of the fish community, as fish species vary in their susceptibility to being caught in different gears with different selectivities. In this study, only the longline gear was species selective, capturing predominantly *C. gariepinus* (78% by number) out of only seven species overall (Table 5.1). An example of variable susceptibility of species to different gears was the very high catch of the small (< 50 mm) species *Pollimyrus stappersii* (55% abundance) in basket traps, while funnel nets and mosquito seine nets, with even finer meshes, only contained 7.2% and 0.2% by number of this species respectively. The basket traps were used in shallow sections of weirs, funnel nets in deeper weirs and mosquito seine nets in open pools. However, the composition of the catches of all the methods together (Figure 5.1) should approximate the structure of the fish community. The variation in habitat and catchability of the different fish species drives fishermen to use a wide-range of gears suited to different conditions, a pattern common to most floodplain fisheries that results in the entire fish community being maximally exploited (Welcomme 1979, Welcomme 1999, Kolding and van Zwieten 2011).

Fish communities under fishing pressure respond by first showing a decline in older, often larger individuals and slower-growing, late-maturing species. As populations of larger, often predatory, fishes decline, fishermen start targeting the more abundant, smaller types of fishes that have a faster population turnover, are often lower on the food chain and already adapted to higher mortality rates (Allan et al. 2005).. This is termed 'fishing down the food chain', and though the total yield of the fishery can remain stable (or even rise as small species benefit from the absence of large predatory species), 'fishing down' can be considered a type of overfishing with its main impact being on the biodiversity and ecological structure of the community (Allan et al. 2005). In the absence of historical data on the fish community, it is impossible to distinguish how much effect the fishing pressure has had on the present fish community. With the study site lying on the very margins of the floodplains, it is expected that the fish able to survive this temporary environment would be small, short-lived and have a high biological turnover rate (Chapter 3). The small average size of the species in the fishery, and the small number of large fishes over 30 cm in length (Figure 5.3) could be due to heavy fishing pressure, the harsh ecological conditions, or both. Comparisons with studies in the deeper Bangweulu Swamps (Chanda 1998, Kolding et al. 2003), where catches contained larger fish species and more predators (e.g. *H. vittatus*), also need to take into account that those areas of swamp differ in habitat, and that far less of the deeper swamp area dries out during the dry season. In the study area, the high abundance of the predator *C. gariepinus* and the importance of *T. rendalli* in catches, both of which attain more than 5-10 years of age in other systems (Bokhutlo 2011, Peel 2012), possibly indicates a healthy state of the fishery. Larger individuals of these two species are limited to the deeper delta habitats, and the general small size of most species in the study area may therefore be due to shallow habitat rather than 'fishing down'. While Peel (2012) found no cichlids to contribute more than 20% by weight in any of the Zambezian systems he examined (all of which had a greater diversity of cichlids), *T. rendalli* was the second most important species in the present study, contributing 24% by weight to the total catch (Figure 5.1). Therefore, *C. gariepinus*, *T. rendalli* and *M. macrolepidotus*, the three most important species in the fishery, can be viewed as key indicator species that must be monitored into the future, as excessive fishing pressure on them in their dry season refuges would lead to a reduction in the larger size classes of older fish. However, differences in flood cycles (high and low years) would also have an impact on the population structures of these fish, therefore long-term monitoring should take into account flood level measurements.

Catch per unit effort

CPUE has been calculated for the Bangweulu Swamps fishery, especially for gillnets and is presented in Imai (1998) and Kolding et al. (2003). CPUE estimates for the Bangweulu Swamps from experimental fleets were 1.51-1.71 kg/50 m set for monofilament gillnets, and 1.59 kg/50 m set for multifilament gillnets, with an overall mean CPUE of 0.86 kg/net/setting based on catch survey data (Kolding et al. 2003[1]). Values for other African inland waters quoted in the same study vary between 0.63 kg/50 m net and 8.53 kg/50 m net (Kolding et al. 2003). The values obtained in our study area were low, being 0.334 kg/50 m gillnet (Table 5.3). Imai (1998[2]) reports a CPUE of 0.89 kg-1.12 kg/50 m net for stationary gillnet fishing in the Bangweulu Swamps, but showed that fishermen actively chasing fish into nets could make larger catches. On the Kafue Flats, CPUE declined from 5 kg/net in 1986 to 0.2 kg/net in 2005 (Nyimbili 2006) and in the water bodies of the Caprivi Strip in Namibia, Peel (2012) found a high CPUE of 4.3-10.3 kg/net, depending on the system.

For seine nets, Imai (1988) reported daily catches from seine nets being 20.7 kg-25.9 kg/day. In Bangweulu Wetlands an approximate number of hauls made during the day was five, though this varied depending on conditions and catch (Table 5.3 and Chapter 4). Therefore, catches were 8.93 kg/5 hauls for mosquito seine nets and 34.36 kg/5 hauls for coarse-mesh seine nets. The latter category surpasses the values reported by Imai (1998). No comparable CPUE estimates for longlines, gillnets or funnel nets were found in the literature.

The region's fisheries show a high degree of variability in CPUE, especially those reported for gillnets. CPUE is not considered a good indicator of the state of a fishery in floodplains (Welcomme and Hagborg 1977) because CPUE is prone to fluctuate with intra- and inter-

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[1] Kolding et al. 2003- reported CPUE: Bangweulu Swamps: Multifilament gillnet 1.43 kg/45 m, monofilament gillnet 1.36-1.54 kg/45 m, gillnet from yield back-calculation 0.86 kg/net; African average: gillnet 0.57-7.68 kg/45 m.

[2] Imai 1988- reported CPUE: Gillnet 1.77-2.23 kg/100 m.

annual changes in fish populations in response to flooding. Therefore it is difficult to draw inference about effort levels and the health of the fish stock based on CPUE in floodplain environments (Jul-Larsen 2003).

Seasonal patterns

Despite the apparent seasonal fluctuation in CPUE for some gears (Table 5.3) there was no seasonal change in total catches for a fishing group as people shifted areas and gears in response to the environment undergoing immense change from flooded to dry. As is typical of many inland fisheries, resource users vary along a continuum of full-time fishermen to farmers who only fish at peak times (in this case the weir fishery from March to May) (Welcomme 1999). A socio-economic survey conducted in the study site highlighted that some groups shift between up to three camps, while the minimum duration of a fishing season was 4 months (African Parks 2011b). The drying of floodplains resulted in an apparent reduction in numbers of people fishing in the area, most returning to farming activities (Chapter 4).

Estimates of CPUE presented in Table 5.3 show that there were seasonal changes in catch for the different gears. The two fish weir gears, basket traps and funnel nets, were only used during the wet season when there was water on the floodplain. Gillnet catches were also significantly different ($P < 0.05$) between the two seasons. This seasonal difference in catches for gillnets corresponds to the 'Fishing Calendar' (Chapter 4), where key informants stated the period September-November as being important for gillnets. Kolding et al. (2003) showed that deeper in the Bangweulu Swamps, there was a significant inverse correlation ($r = - 0.65$) between water level and gillnet CPUE, with greater catches being made during the low-water season when fish become concentrated.

Sample sizes were insufficiently large to test for monthly patterns of resource use, and therefore the 'Fishing Calendar' (Chapter 4) gives a better overview of fishing activities based on the detailed indigenous knowledge of key informants. In general, the flooded season was a weir-fishing season, with seine nets predominating in the dry season.

Total production and yield

The average weight of a day's catch for a unit, calculated from the catch measurements, was 7.8 ± 7.9 kg/fishing group/day. This was similar to the socio-economic survey estimate of 9.1 kg/unit/day obtained by back-calculating from fishermen's estimates of dry fish production. Kolding et al. (2003) provide estimates of average daily catch for gillnet fishermen (6.9-8.6 kg/fisher/day) and seine net fishermen (4.4-5.5 kg/fisher/day; after division of catch between group members). Ichikawa (1985) showed that fishing groups utilising a variety of methods in the main Bangweulu Swamps fishery were able to maintain average daily catches of 9.9 kg/fishing group/day. Therefore the estimate obtained from the socio-economic survey is consistent with catch-survey estimates of daily yield.

Jul-Larsen et al. (2003) shows that most African inland fisheries maintain annual catch rates of approximately 3 tons per fisherman. For a seven month season, Jul-Larsen et al.'s (2003) figure is 1.74 t, which corresponds to the yields per fisherman of 1.64 t (catch assessment) and 1.9 t (socio-economic survey) obtained during this study. Therefore the fishery in Bangweulu Wetlands produces catch yields typical of an African inland artisanal fishery.

The spatial yield estimate of 217 kg/ha/3 months is towards the upper limit of estimated yields (72-200 kg/ha) for floodplain rivers given by Welcomme (1976). Toews and Griffith (1979) estimated a yield of 10-35 kg/ha for Lake Bangweulu, which is known to have a far lower productivity than the adjacent swamps (Brelsford 1946, Jackson 2000). This contrasts with the high productivity estimate of the floodplain margins of the present study area, lending support to the theory that productivity could be driven by the large spatial interaction that floodwaters have with the terrestrial environment (Karenge and Kolding 1995, Kolding and van Zwieten 2006, Kolding and van Zwieten 2012). The terrestrial nutrient input is likely enriched by the grazing activities of the black lechwe herds. This lends support to the importance of conserving herbivore biomass in Bangweulu Wetlands. However, further investigations into the yield of the area depend on accurate estimates of the total fishing population of Bangweulu Wetlands and the size of the areas used for fishing.

Conclusion and future research

This study has yielded sufficient insight into the area's fishery to conclude that it is a multi-species fishery, utilising a range of gears to maximise catch and maintain steady catch rates throughout the season. Fish yield per unit area should be viewed as a first-estimate until better-resolution estimates of spatial use by fishermen are obtained. Future investigations should also attempt to quantify the number of days during a fishing season when zero catch is made, be it due to weather or a lack of effort by the fisherman. Obtaining a fishery-independent yield estimate, through controlled experimental fishing, may be advantageous due to the high variation in fishing effort, both between individual fishermen and between groups with differing levels of involvement in other livelihood strategies such as farming.

An understanding of the age structure of key fishery species for the area is required to gain further insight into the fisheries biology of targeted species (Bruton and Jackson 1983). For example, assessments of age structure in the fish population of Bangweulu Wetlands could yield insight into the ages attained by the larger species in the fishery, and reveal whether sufficient escapement from fishing, predation and unfavourable environmental conditions occurs for fishes to attain more than 2-3 years of age.

In future, should any areas be closed to fishing for tourism objectives, the value of these closed areas as fish refuges could be evaluated by comparing standard experimental CPUE and length-frequencies of larger fish species between fished- and unfished areas, allowing management to identify key exploitation indicators in line with conserving the biodiversity and ecological function of the area (Allan et al. 2005). However, any fisheries monitoring in the area must always be interpreted in the context of the high natural fluctuations inherent in floodplain systems.

CHAPTER 6

Catch Processing and Trade

6.1 INTRODUCTION

Zambia consumes in excess of 100 000 tons (t) of fish each year (Mudenda et al. 2005). The national annual production of fish is only 70 000 t, of which 5000 t are produced by aquaculture (Mudenda et al. 2005). The shortfall of 30 000 t is made up for through imports. The capture fisheries are thought to be fully exploited, with a fairly stable output of 65 000 t (Mudenda et al. 2005). The limited growth in supply, coupled with a rapidly growing national population, has resulted in a reduction in per capita fish consumption. Annual per capita consumption of fish has dropped from a high of 12 kg in 1970 to 6.2 kg in 2000 (Mudenda et al. 2005). In the same period the population grew from 4.2 million (1970) to 66.7 million (2000). This trend is seen throughout the region, with Malawi's per capita annual consumption of fish declining from 7.9 kg in 1980 to 5.4 kg in 2000 (Weyl 2003). Indeed Africa was the only continent where per capita fish consumption fell: globally, consumption of fish has risen (FAO 2012). African consumption of fish is well below the global average of 18.8 kg per person per year (FAO 2012). However, in Zambia and some of its neighbours, fish contributes significantly to the protein supply, with over 20% of animal protein consumed coming from fish (FAO 2012).

A wide variety of fish species and products are consumed in the country. While there is a definite preference in the urban markets for fresh fish, supply is constrained by long distances and poor road networks to the various Zambian fishing grounds (L'Hereux 1985). In addition, many of the Zambian fishing grounds are floodplains and rivers (Bangweulu, Mweru-Luapula, Kafue, Barotse floodplains). Floodplain fishermen are by necessity dispersed over large areas, which makes the development and use of central landing points for fresh fish difficult (Tweddle et al. 1978, Welcomme 1979). Therefore dried fish are a durable and widespread product in the region.

The increase in urbanisation in southern Central Africa in the early decades of the twentieth century led to the rapid development of a market for fish products. Often linked to mining centres, such as on the Zambian and Congolese Copperbelts, this market developed around the supply of easily-transported dried fish, often from distant fishing grounds (Gordon 2003). These markets are still the most important in the region, with the Congolese market obtaining fish products from as far afield as the Namibian and Mozambican coasts (trader interviews). In the early years some European companies did much of the trading, having an initial advantage in accessing capital for transport and in large contracts to supply the mining companies (Brelsford 1946). However, these were replaced by a myriad of local small-scale traders, most of whom were women, either bolstering household income or seeking an income stream independently of their husbands (Gordon 2003).

In this chapter, the catch processing and trading patterns observed in the study area are examined in order to understand the role that the fishery plays in the livelihoods and economy of the inhabitants of Bangweulu Wetlands. Details on various fish products are presented, as well as an attempt to calculate standardised prices for comparison with the literature. Some financial scenarios surrounding trading are also explored.

6.2 METHODS

The processing of catches was observed during frequent fishing camp visits where catches were examined (Chapter 5). Various stages of the fish preserving process were observed directly, while fishermen and key informants explained the details.

Fish price data were collected through interviews with traders and by weighing fish for sale. Fresh fish bundles being peddled to traders and reserve staff had a fixed price per bundle and were weighed upon purchase. Dried fish were weighed both at the point of transaction between traders and fishermen, and during simulated transactions with traders. Traders were more willing to discuss fish prices than the fishermen. After a short interview they were requested so set up some examples of the trade units and prices of whichever fish products they had purchased. The units were described and weighed, in order to obtain an eventual price per kilogram. In addition to giving an accurate reflection of the prices paid at source, the transaction simulations also gave an indication of the market prices, as most traders were very familiar with the pricing climate of the urban markets and could quote what they expected to be paid for the same amount of fish. Sometimes units would differ between source and market, which the traders would indicate by rearranging the amounts of fish before quoting the market price. The prices per unit were converted to price per kilogram to allow comparison. According to the traders, market prices can fluctuate even within a day, depending on supply, and therefore a price range was often quoted. The average between the two values was then used for subsequent analysis. Only price data for dried fish from Bangweulu was used in analyses as few of the traders encountered had experience in selling fresh fish. Prices in Zambian Kwacha (ZMK) were converted to United States Dollars (USD). A non-parametric Kruskall-Wallis ANOVA on ranks ($p < 0.05$) was performed to test for significant price differences between categories of dried fish at source and at market.

A fish-drying experiment was run to estimate the weight lost during the curing process. Batches of fresh fish species were purchased, counted and then weighed; fish larger than 15 cm were weighed individually. Fish were processed and dried using the same techniques as the fishermen by one of the project's assistants, who was also an experienced fisherman. Care was taken not to lose any fish or confuse batches. Fish were weighed to the nearest 1 g at various stages of the drying process in order to determine when the fish was dry. The fish product was considered dry when the assistant judged the fish to be dry enough for storage. A non-parametric Kruskall-Wallis ANOVA on ranks ($p < 0.05$) was done to test for significant differences between average weights lost between different types of dried fish.

Fish traders and key informants were interviewed on the costs involved with a fish buying trip. These included fixed costs irrespective of amount of fish purchased (e.g. price of transport per person), variable costs (e.g. price of transport per bag of dry fish). Total expenditure was subtracted from gross income upon sale (based on market price) to calculate profit scenarios for varying numbers of bags purchased. A simplified value for return on investment (Wikipedia 2012) was calculated as:

$$Return\ on\ investment = \left(\frac{final\ investment - initial\ investment}{initial\ investment}\right) * 100$$

where the value for 'final investment' is total costs (excluding purchase price) subtracted from gross income after sale, and the initial investment is the amount spent on purchasing the product. Thus:

$$Return\ on\ investment = \left(\frac{((fish\ sale - costs) - fish\ purchase)}{fish\ purchase}\right) * 100$$

The return on investment values for varying numbers of bags traded were compared with available return-on-investment estimates for various industries in Zambia, as well as the national inflation rate.

6.3 RESULTS

Catch processing

While men were responsible for catching the fish, the women and children of the family (if they were present in the camp) cleaned, sorted and prepared the catch (Figure 6.1a).

Four broad categories of fish products were available in the fishery: fresh fish, sundried fish, smoked fish, and salted fish. Fresh fish were sold by species groups as bunches (400-800 g) of cichlids (*Tilapia* spp. and *Serranochromis* spp.), catfish (*Clarias* spp.) and the mormyrid 'mintesa', *Marcusenius macrolepidotus*. These bundles were sold to traders, people in the village, and employees of Bangweulu Wetlands or the tourist lodge.

Most fish smaller than 15 cm TL were sundried on grass drying mats over a reed frame 1.5 m above the ground (Figure 6.1b). Fish that were smaller than 8 cm TL were dried whole without gutting or scaling. The fish, which took between 1.5-3 days to dry, were separated into three main categories for trade: *baby lila* (a mixture of very small fish < 40 mm TL), *kasepa* (mixed fish 40-80 mm TL/FL) and *uluya* (a mixture of oily species containing a high proportion of mormyrids).

Fish that were smoked were catfish, mormyrids and cichlids larger than 15 cm in length. Fish that required smoking were gutted, scaled (if necessary) and then placed in the sun for 1-4 hours. This firmed up the flesh, after which fish were packed onto a wire smoking rack. At first a hot fire was used, almost cooking the fish, after which the fire was allowed to cool. The entire smoking process took between five and 12 hours, after which the fish were placed onto a rack hanging higher above the fire (Chapter 4). Freshly smoked fish retained some moisture and were still a little soft if squeezed, termed *motomoya*. Once they had been in the dry air above the fire for a further two days they were completely dry, and could reportedly be kept for a few months. The smoked products were called *muta* (large catfish) (Figure 6.1c), *popa* (small catfish), *mintesa* (mormyrids) and *ilikota* (smoked cichlids).

There was apparently a rising demand for salted fish from traders, especially for the DRC market. Most fishermen preferred the wood-smoking process, and so salting was done mostly by the traders themselves after purchasing bundles of fresh fish. The fish were split open and packed into a plastic drum, alternating layers of fish and coarse salt. After 24 hours of brining they were laid on drying mats in the sun.

Dried fish were brittle, and the market demanded that fish be whole. Therefore, great care was taken to minimise losses, and this determined how fish were packaged for transport. Small, sundried fishes could be packed into '90 kg' grain bags, with an average weight of 70 kg. Both large and small catfish could also be transported in bags like these, with approximately the same weight. The dried mormyrids (*mintesa*) were more brittle, and these were packed in 'bundles' (Figure 6.1d). The wood hoops and netting of the bundles acted as frames, and offered more support to the fish being transported. Most other fish could also be packaged in bundles, and bundles made with grass lining had already been in use before bags became common (Brelsford 1946).

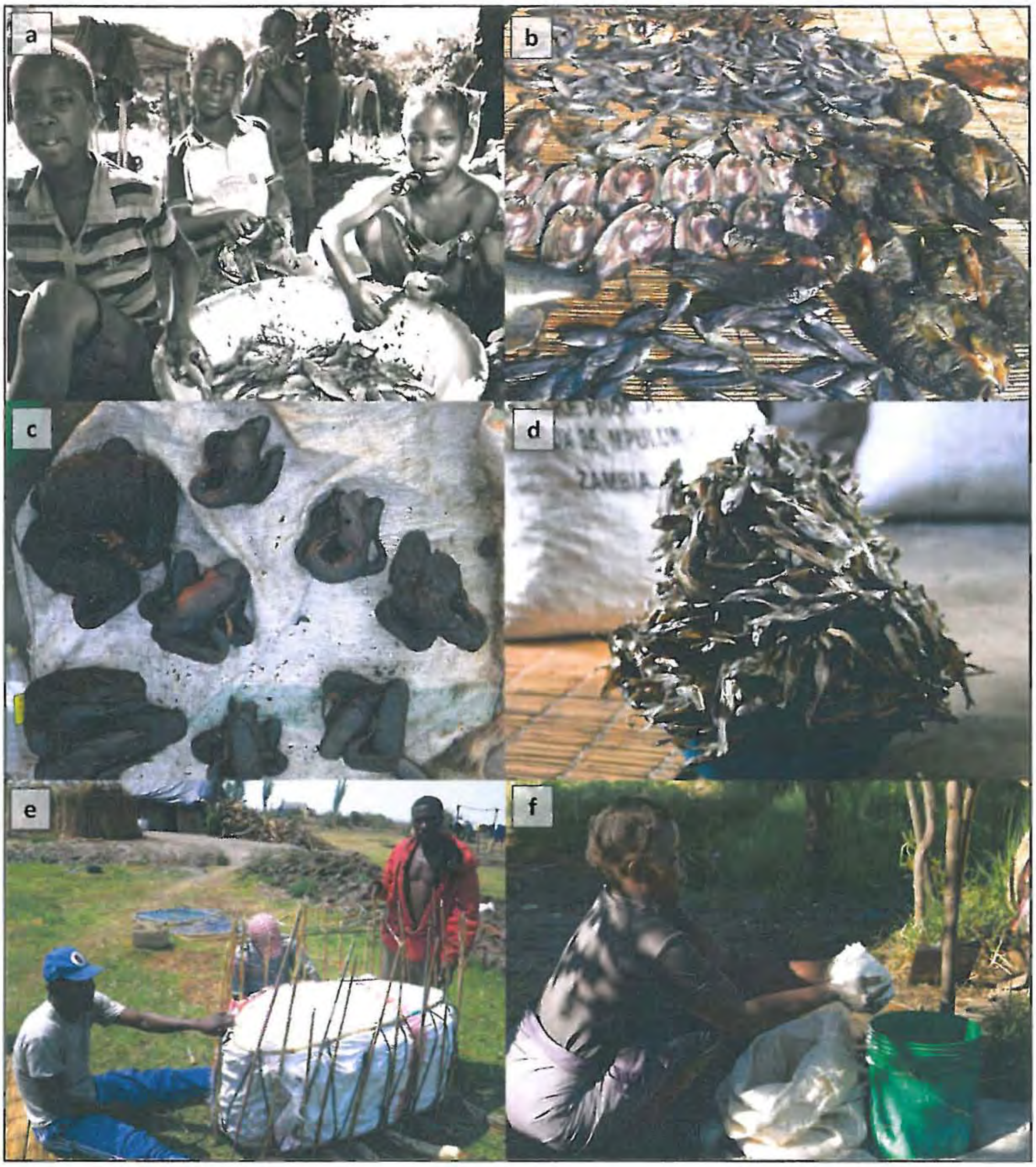

Figure 6.1: Aspects of fish processing and trade in Bangweulu Wetlands: a) Children scaling fish; b) Fish on drying mat; c) Smoked, dried *muta* (large catfish); d) 'Pail' trade unit of small sundried fishes (approx. 1.5 kg dry); e) Bundles being prepared for transport; f)Staple starch (maize or cassava meal) sale. Photos a, e-f) Morgan Trimble, b-d) Carl Huchzermeyer.

Marketing and Trade

Fish from the floodplain fishery around the study site were disposed of in three main ways: subsistence consumption, local trade in exchange for staple food and other products, and sale into the formal markets. The various channels that fish products moved through are presented in Figure 6.2.

a) Subsistence consumption

The subsistence catch is any part that is not kept for sale or trade and is consumed by the fisherman and his family (Berkes 1988). This aspect of catch disposal was important in that a significant portion of the catch was consumed and not traded, especially during reported times of low catches, such as during the peak of the floods in February and March, and in the cold winter months of July and August (Chapter 4). Dried fish taken home for relatives or for periods spent in the village doing other activities could also be considered part of the subsistence catch. The amounts consumed by a family must vary according to supply, species and the trade situation, and was not quantified during the study. Anecdotes obtained from key informants and attempts at purchasing research samples revealed that fishermen would often refuse to sell fish if there was not a surplus, and even when there was a surplus they retained the best fish for themselves.

b) Local trade

The local trade in fish was also very important, and was linked to subsistence and food security (Figure 6.2). Farmers from the mainland had always traded meal with fishermen from the swamps (Brelsford 1946). In the Chikuni study area, farmers from Chiundaponde came by bicycle to Muwele village and the fishing camps to sell maize meal (Figure 6.1e). They then used the income to buy fish. Bartering used to be common, but now cash was preferred. The price for cassava and maize meal was higher on the floodplains (USD 0.45/ l) than on the mainland (USD 0.35/ l), especially at the end of the dry season when reserves were running low. Much of the traffic on the road from Chikuni to Chiundaponde consisted of bicycles carrying a bag of meal and a small 4 litre bucket used for measuring.

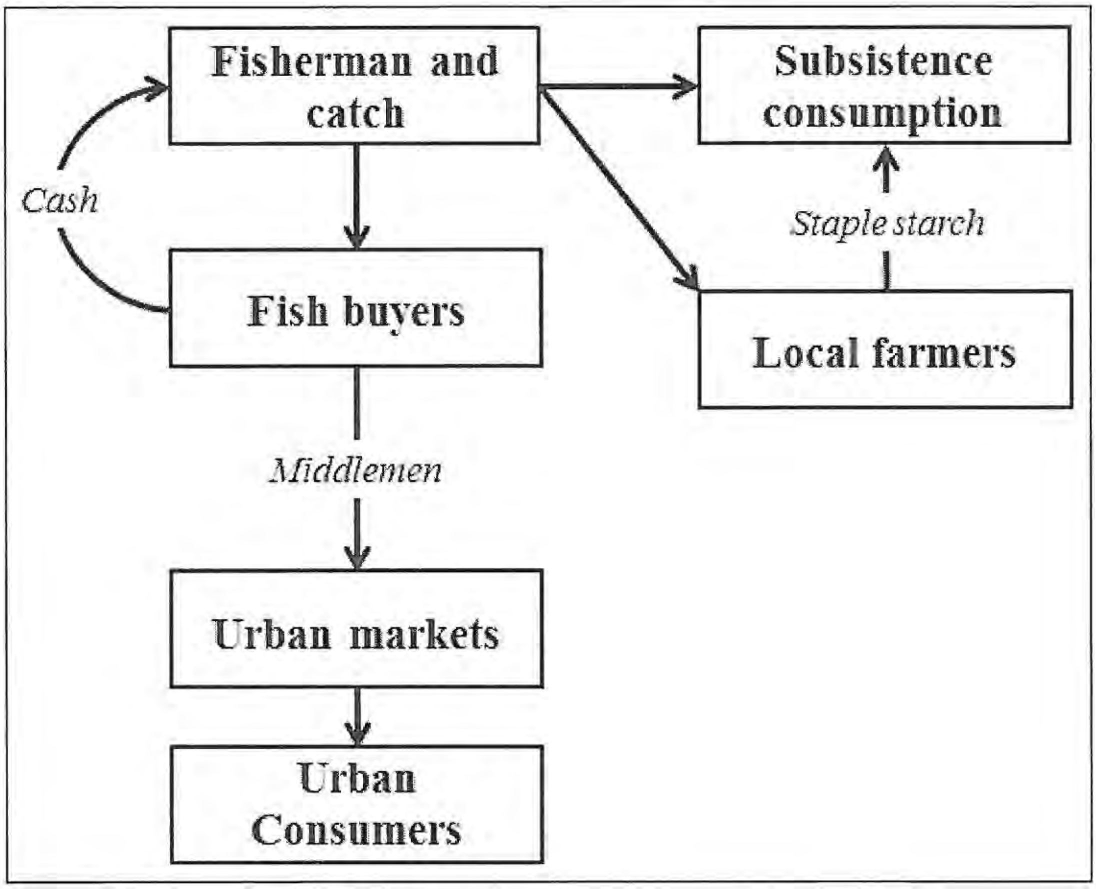

Figure 6.2: Flow diagram showing how a catch from Bangweulu Wetlands can be used either for subsistence consumption, traded for staple food or sold to traders who transport the catch to urban areas.

c) Formal trade

There were always some fish available in the fishing camps at any time of the year. However, traders were aware of the peak seasons. As trade in these parts was almost exclusively in dried fish, the time taken to find fish for purchase was less critical, and traders usually made tours of the different fishing camps. Traders arrived by water in rented fibreglass banana boats from "Tuta Bridge" over the Luapula River, from March until May. From May until December most came by road, and were based at Muwele Village where they lived in 'depots'; local huts rented out for storage and accommodation. The traders were usually women who came from towns, bought fish, and transported it for sale in urban markets (Figure 6.2 and Figure 6.3). Their access to capital was usually through a spouse's salary. For buying trips to fishing camps, a trader had to rent a boat with paddler/guide during the wet season and bicycle and vehicle transport in the dry season. Traders coming by boat usually brought goods into the swamps, and these 'floating shops' sold everything from matrasses and bicycles to medicine and clothes. Transactions were usually in cash, with limited bartering also taking place. Traders bought any fish that was for sale, and if these were not completely dry yet the traders would continue the curing process themselves. The majority of traders took their fish to sell at the Kasumbalesa border post between Zambia and the Democratic Republic of Congo (DRC) and the cities of the Zambian Copperbelt.

Prices for units of fish were determined by the amount, size and quality of fish. A large variety of units were used for measuring, although a large pile in a shallow dish ('pail') was most common (Figure 6.1f). The prices of different types of fish (smoked clariid catfishes, smoked mormyrids, smoked cichlids and sundried small, mixed species) at source and at market are presented in Table 6.1. No significant differences (Kruskal-Wallis ANOVA, $p < 0.05$) were found between different types of dried fish in either the source or market price categories. Therefore an average value for dried fish at source (3.14 ± 1.34 USD/kg) and market (6.14 ± 2.54 USD/kg) was obtained for subsequent analyses.

Table 6.1: Dried fish prices for different types of fish at source and at market (n = number of batches weighed; Exchange rate: 1 ZMK = 0.0002 USD).

		Waterside price			*Urban market price*		
Species	**Product**	**USD/kg**	**Stdev**	**n**	**USD/kg**	**Stdev**	**n**
Clariids	Smoked	2.63	0.71	22	6.08	2.54	22
Mormyrids	Smoked	3.91	0.92	5	7.51	2.67	6
Cichlids	Smoked	4.58	1.50	3	7.13	2.22	2
Small species	Sundried	3.54	2.25	7	4.35	1.81	5
	Average (total):	3.14	1.34	(37)	6.14	2.54	(35)

The results of the dried fish experiment are presented in Table 6.2. The same fish types were examined as were common in the trade (smoked clariid catfishes, smoked mormyrids, smoked cichlids and sundried small, mixed species). No significant differences (Kruskal-Wallis ANOVA, $p < 0.05$) were found between the percentage weight lost between fish categories. Therefore, an average value (25.4%) for dried fish was used to calculate a conversion factor of 100/25.4 = 3.9, used for subsequent analyses (also in Chapter 5).

Table 6.2: Results of fish drying experiments, for different species and products (n = number of batches of each species weighed).

Species	Product	% fresh weight	Stdev	n
Clariids	Smoked	26.8	3.8	4
Mormyrids	Smoked	25.8	4.5	2
Cichlids	Smoked	26.9	4.9	2
Small species	Sundried	25.8	4.5	3
	Average (total):	25.7	3.9	(11)

Using the conversion factor, the average values of dried fish converted to fresh weight were USD 0.81/kg fresh weight at source and USD 1.57/kg fresh weight at market.

Importance of fishing and trade to the local economy

The fish traders visiting the area supported a number of auxiliary industries. These included transport services to the area, escorted transport to fishing camps and accommodation. Routes for fish buying trips (by land or by water) and expenditures on different costs by traders are presented in Figure 6.3.

The fishermen also supported secondary economic activities by spending their money following sales of their catch. Approximately ten small shops in Muwele Village stocked a large variety of basic goods, as well as more luxury items such as new clothes and bottled beverages. There were a number of traditional breweries, and heavy drinking frequently followed sales of fish.

In addition to the very important fish-for-meal trade, inhabitants of the woodland farming areas benefitted from the fishermen by selling natural fishing materials to them, most importantly bark fibre for weaving traps and grass drying mats (Chapter 4).

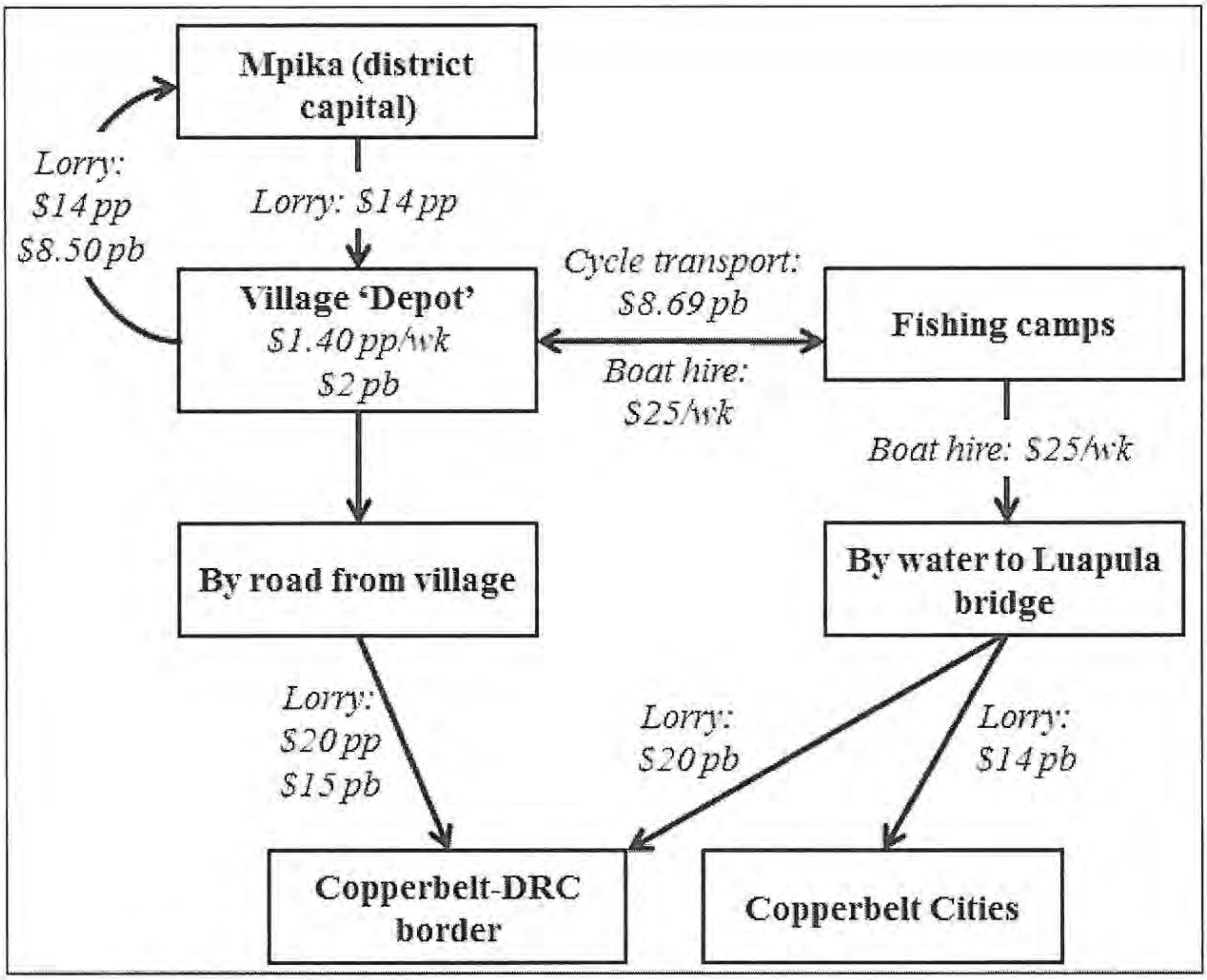

Figure 6.3: Flow diagram showing trade routes and costs (pp = per person; pb = per 70 kg bag) associated with a fish buying trip (wk = 7-day week), including transport by land and by water, as well as road transport costs to the two main urban markets for dried fish originating in the Bangweulu area (All values in USD; exchange rate: 1 ZMK = 0.0002 USD).

Trade scenarios

The majority of traders interviewed were dry-season traders from the town of Mpika, who were based in Muwele Village. Therefore the following scenario examines the costs and potential profits of a typical fish buying trip based out of Mpika (Table 6.3). One trip could take two to three weeks, depending on transport arrangements and the availability of fish for purchase. Expenditure and income was calculated per bag (70 kg) of dried fish, using the average source and market prices in Table 6.1. One bag of dried fish is sufficient to cover costs and turn a profit (Table 6.3). Traders rarely purchased more than six bags due to transport limitations. Return on investment (yield) varied from 51% for one bag traded to 80% for six bags.

Table 6.3: Balance sheet for a week-long fish buying trip to Bangweulu Wetlands originating in Mpika and ending at the Copperbelt markets, indicating changes in costs and profits for scenarios where a trader purchases 1, 2, 4 or 6 bags of fish (all values in USD; exchange rate: 1 ZMK = 0.0002 USD).

Fixed costs (per trader):	1 bag	2 bags	4 bags	6 bags
Transport: Mpika-Muwele	14.00	14.00	14.00	14.00
Depot room: 1 week	1.40	1.40	1.40	1.40
Boat hire: 1 week	25.00	25.00	25.00	25.00
Transport: Muwele-DRC border	15.00	15.00	15.00	15.00
Transport: DRC border-Mpika	20.00	20.00	20.00	20.00
Subtotal:	75.40	75.40	75.40	75.40
Variable costs (per 70 kg bag):				
Depot storage: 1 week	2.00	4.00	8.00	12.00
Transport to DRC border	20.00	40.00	80.00	120.00
Subtotal:	22.00	44.00	88.00	132.00
Total costs:	**97.40**	**119.40**	**163.40**	**207.40**
Fish purchase (USD 3.14/kg):	219.8	439.60	879.20	1318.80
Total expenditure:	317.20	559.00	1042.60	1526.20
Gross Income (USD 6.14/kg):	**429.8**	**859.6**	**1719.2**	**2578.8**
Profit (USD):	112.60	300.60	676.60	1052.60
Yield on investment (%)	**51**	**68**	**77**	**80**

6.2 DISCUSSION

Formal fish marketing in the Bangweulu Wetlands area can be considered well developed. Historically factors constraining Zambian fish marketing were ready supply of fish, access roads and open waterways and facilities for traders to use (Mortimer et al. 1965). None of these factors posed a challenge in the study area. Recent improvements in road infrastructure will likely bolster the trade further.

During the times of Brelsford's (1946) study, fishermen from Bangweulu took their own fish to market. This meant extended absences from their fishing areas (Brelsford 1946). However, with traders coming into the fishing grounds and touring fishing camps, fishermen can spend more time producing fish. The dispersed nature of floodplain fisheries inhibits the development of centralised landing sites (Tweddle et al. 1978, Welcomme 1979), necessitating the camp visits by traders and thereby creating opportunities for bicycle and boat transport providers.

Subsistence consumption of fish, as well as the fish-for-meal trade with mainland farmers ensures a stable food and protein supply in the chiefdom, as fishermen have access to staple starches and high-quality fish protein reaches remote agricultural villages. The price charged for meal in the fishing grounds was USD 0.45/l[3], while the national price of USD 0.35/kg (Mayaka 2012). Many of the farmers trading meal came from villages up to 70 km away, highlighting the penetration that fish protein has in the periphery of the Bangweulu basin.

The average urban market value for dried fish was USD 6.14 ± 2.54. This corresponds to a fresh-weight value of USD 1.57/kg. The official price for dried Kapenta (*Limnothrissa miodon*) from Lake Kariba was reported to be USD 12.70/kg (Mayaka 2012). Fresh fish prices on the urban markets were reportedly USD 2.00/kg for fresh cichlids (Mudenda et al.

[3] Price was obtained for meal measured in 4l buckets, no weight was obtained.

2005) and USD 3.54/kg for fresh cichlids from an aquaculture facility (D. Huchzermeyer, Sterkspruit Veterinary Clinic: aquaculture consulting, *pers. comm.*). The value of groundnuts (an important source of vegetable protein) was given as USD 1.20/kg for groundnuts (Hossain and Green 2011), and the national staple starch, maize meal, was valued at USD 0.35/kg (Mayaka 2012). Therefore dried fish from Bangweulu were an affordable source of food when compared to other products, particularly as a protein source for lower-income classes. However, urban Zambians of most income classes purchase dried fish as an integral part of their cuisine despite the availability of fresh fish from aquaculture (D. Huchzermeyer, *pers. comm.*).Therefore, floodplain fisheries such as Bangweulu, with their wide range of fish species and products, contribute to the economy, nutrition and food-security of a broad cross-section of society.

Most traders purchased two to four bags, representing a yield of 68-77% (Table 6.3) for a two to three week trading cycle. Returns-on-investment for small-scale pond aquaculture in Zambia have been estimated as 53-68% (Mudenda et al. 2005), slightly less favourable than fish trading. The Zambia High Commission United Kingdom (2009) states that investment in various Zambian industries can yield 40-70% returns on investment. In 2012, Zambia's national average inflation rate was 6.4% (Mayaka 2012). In this study, the number of buying trips *per annum* and other sources of income for traders were not determined. However, investment in fish trading appears on the background of present calculations comparable to other economic opportunities in Zambia. Further research should examine the reasons why fish traders choose this investment option over any other alternative opportunities available to them.

Access to capital appears to be a major factor in determining who can trade fish, and may explain why most formal traders are urban spouses of salaried persons, usually public servants. Despite the good yields on investment, traders claimed that the market was prone to fluctuation. The trade is likely also constrained by transport limitations and a high investment in time to purchase fish and negotiate transport.

The data collected yield only the most rudimentary insight into the highly complex small-scale trading strategies employed in rural Zambia. The diversity of trade pathways available to fishermen, and the wide range of auxiliary industries supported by traders indicate that it is likely that the Bangweulu Wetlands fishery and its associated activities are an important and far-reaching livelihoods activity. Like elsewhere in the Bangweulu basin, farming is primarily a subsistence activity, while fishing ranges from subsistence to commercial (Imai 1985). With much of the human population being connected to and benefitted from the fishing activities in some form, the fishery in Bangweulu Wetlands is a good example of how small-scale, artisanal inland fisheries contribute to social security in remote and rural areas where access to the formal economy is limited (Bayley 1988, Kolding and van Zwieten 2011).

CHAPTER 7

Conclusions and Management Recommendations

7.1 THE FISHERIES ECOSYSTEM

The floodplain fishery in Bangweulu Wetlands is a typical small-scale fishery, relying on a multi-species harvest by utilising a variety of low-technology fishing gears, and playing a central role in the informal economy and local food security (Bayley 1988, Kolding and van Zwieten 2011). By utilising fish biota that are well-adapted to the unstable floodplain environment, and which frequently form the basis of fisheries in similar environments elsewhere (e.g. floodplains of the Kafue, Zambezi and Shire Rivers), the fishery is likely to remain healthy as long as key ecological processes in the highly productive floodplain environment are conserved.

The natural environment

Bangweulu Wetland's peripheral and shallow floodplains differ from the better-studied swamp and floodplain-river-channel fisheries of the Bangweulu Swamps and elsewhere (Chapter 2). The shallow and highly seasonal floodplains mostly dry out after a few months of flooding, and fish species are adapted to this (Chapter 4). A few dry-season refuge environments, such as the Lukulu Delta, retain sufficient stocks to recolonize the floodplains during the annual flooding season (Jan-March), when the warm, shallow, nutrient-rich and well-oxygenated waters provide ideal nursery grounds allowing for rapid growth and little risk of predation. This situation is reversed when the waters recede, leading to rapidly increasing mortality due to: external factors such as drying water-bodies, internal density-dependent factors such as competition, predation and parasitism, and fishing by humans. The adaptations and response of the fish stock to this type of pulsed floodplain environment is summarised in Table 7.1.

Table 7.1. Comparison of the characteristics of fish stocks between stable and unstable African freshwater systems (adapted from Jul-Larsen et al. 2003).

Constant (non-seasonal) systems →		**Pulsed (seasonal) systems**
Stable environment with internal energy pathways		*Unstable environment with strong pulses of nutrients*
Large, deep lakes like Tanganyika and Malawi		Floodplains, shallow lakes, wind-mixed (disturbed) zones of large, deep lakes
Fish resource character	**Constant systems**	**Pulsed systems**
Species diversity	Higher	Lower
Trophic diversity	Higher, specialists	Lower, generalists
Migrations	Short, territorial	Long, lateral and longitudinal
Spawning	Continuous	Seasonal
Fecundity	Low, parental care	High, little parental care
Growth to maturity	Slow	Fast (1-2 years)
Natural mortality	Stable, constant	Fluctuating, periodic
Biomass	High	Low
Productivity	Low	High
Regenerative capacity	Low, fragile	High, resilient
Susceptibility to high fishing	High	Low
Inter-annual fluctuations	Low	High

Fish abundance depends on extent of flooding during the wet season, as well as on the extent of areas remaining inundated as refuges during the dry season (Welcomme and Hagborg 1977). This pattern is well-recognized by the fishermen, who stated that flood level and timing had a greater effect on the fish stocks than fishing pressures, and that it also resulted in differences in harvest between years of differing flood levels. Therefore changes to the hydrological regime are the greatest threat to the floodplain ecology and its associated fishery.

Floodplains count among the most biologically diverse environments on earth (Ward et al. 1999). This diversity is due to the overlap between species with adaptations for amphibious, aquatic and terrestrial life-histories, as well as important migratory components, all making use of the wide range of habitats that become available across time and space as waters advance and recede (Ward et al. 1999, Junk et al. 2006). Globally, floodplains are under threat and in most developed countries there have been significant alterations to the flood regimes of floodplain rivers (Bayley 1995, Ward and Tockner 2001). Improved appreciation of the ecological and economic value of healthy floodplains has led to significant interest in studying the largely-pristine floodplains and wetlands of developing countries, even as a reference point for restoration efforts in the developed world (Bayley 1995, Ward and Tockner 2001). Other key ecological drivers apart from flooding also need to be studied; especially the role of nutrient cycling which also has a direct bearing on fisheries ecology (Bruton and Jackson 1983).

Floodplains have a high potential for nutrient exchange between the aquatic and terrestrial environment, especially due to the advance and retreat of these zones of interaction (Junk et al. 1989, Bayley 1995). Nutrients released from newly flooded soil and plant matter are rapidly utilised by actively growing plants (Welcomme 1976). The grazing action of herbivores ensures that a portion of the nutrients held by plants are re-released into the water column (Mosepele et al. 2009). Various minerals dissolve from submerged grass and herbivore dung, especially phosphates, nitrates and potassium, all important nutrients in the aquatic food chain (McLachlan 1971). As the most abundant large herbivore on the Bangweulu floodplains, it has been proposed that the endemic semi-aquatic black lechwe antelopes play an important role in this form of nutrient-cycling (Grimsdell and Bell 1975). The migratory behaviour of lechwe following water levels, and their seasonal aggregations on shallow grazing lawn floodplains possibly results in lechwe acting as a type of 'nutrient-pump' by retrieving nutrients over a wide area and concentrating them on the grazing lawns. These areas of shallow plain are adjacent to the Lukulu Delta, and act as important spawning and nursery areas for fish. The combination of the Lukulu Delta as a dry-season fish refuge, the large numbers of herbivores concentrated in this area and the shallow-plain fish nurseries make this an ideal place to study these trophic interactions.

It is imperative that the rich and sensitive floodplain environments are better understood, so that they can be better protected from developments (damming of tributaries, draining wetlands for agriculture etc.) that will negatively impact on their functioning (Bruton and Jackson 1983). This requires landscape-level management of the ecosystem, made challenging by the diverse and often conflicting resource users such as agriculture, fisheries and industry (Welcomme 1976, Welcomme 1979). For example, in the Kafue floodplains system the construction of hydroelectric schemes that regulate the seasonal flooding have been shown to have had a detrimental effect on fish catches there (Nyimbili 2006). The conservation activities of Bangweulu Wetlands need to extend beyond the borders of the park, so that catchment-level impacts can be detected and mitigated against. As long as key ecological processes such as flooding and nutrient cycling are conserved, the natural, fisheries and human ecology of the basin should remain in a good state of health (Bruton and Jackson 1983, Welcomme 1999).

The human environment

Small-scale, artisanal inland fisheries such as that found in Bangweulu use low-cost, low-technology methods that require minimal capital expenditure but are capable of employing very large numbers of fishermen (Bayley 1988, Kolding and van Zwieten 2011). Much of the fishing activity on floodplains is highly seasonal, representing a continuum between livelihood activities ranging from farmers that engage in seasonal fishing (e.g. many of Bangweulu's fish weir users) to migratory, full-time commercial fishermen (e.g. seine net fishermen in Bangweulu) (Welcomme 1999). Artisanal multi-species fisheries are capable of absorbing higher effort numbers than single-species fisheries, and through their high labour input and energy efficiency are capable of harvesting marginal fish resources not economically accessible to more industrialised fisheries (Welcomme and Hagborg 1977, Bayley 1988, Kolding and van Zwieten 2011). Artisanal inland and floodplain fisheries therefore act as a valuable social security system (Bayley 1988, Kolding and van Zwieten 2011).

The marketing system for dried fish is also informal and diverse (Chapter 6). Catches contribute significantly to the protein consumption of not only the fishermen, but also of the mainland farmers who come from further afield to trade staple starch meal for fish (Chapter 6). The supply of cheap dried fish also contributes to the protein security of lower-income urban classes. Therefore the dried fish trade has wide-reaching implications for food security on both a local and regional level. The fish trade provides employment and spin-off opportunities for local entrepreneurs providing boat hire or accommodation services, and also contributes to the import of various commodities into the remote villages. The dispersed nature of the floodplain fisheries means that there are no centralised fish landing sites, and traders must therefore visit individual fishing camps (Bayley 1988). This allows fishermen to spend more time fishing, improving their overall productivity.

The fishery in Bangweulu uses a wide range of fishing gears (Chapter 4) to harvest a wide range of fish species (Chapter 5). By diversifying the harvest patterns, fishermen are able to stabilise their catches in a variable environment (Welcomme and Hagborg 1977). This often involves the use of fishing gears considered illegal in terms fisheries legislation, such as fine-mesh nets and weirs that capture juvenile fish (Kolding and van Zwieten 2011). The unsuitability of fishing regulations to floodplain fisheries has often resulted in conflict, including in Bangweulu Wetlands.

A high degree of resistance to fisheries research initially encountered among fishermen was instructive: the mistrust between the community and the fishing authorities, but probably even more with the wildlife authorities, was well entrenched. Being a relatively marginal and remote fishing ground, a law-enforcement presence by the Department of Fisheries had never been maintained in this area. However, the fishermen were well aware of the attempts at resource management from other fishing areas (especially Lake Bangweulu and the fish-checkpoint on the Tuta Bridge over the Luapula River). Additionally, the conservation projects of the WWF and later Bangweulu Wetlands both highlighted fisheries regulation in their conservation manifestoes. Therefore the local community, already at odds with the authorities due to numerous arrests for poaching, began to see the conservation activities as a threat to their main remaining livelihood option: fishing.

The theory of the 'tragedy of the commons' (Hardin 1968) is still highly pervasive in the minds of tourists, managers and government officials witnessing rural resource use on customary land in Zambia. The theory states that a group of people, especially in a population increasing rapidly in number that is utilising a commonly-owned resource will exploit it unsustainably until its regenerative capacity is undermined. While the challenges of day-to-day survival can lead to very intense exploitation regimes, it is now generally held that common property users nonetheless develop conservation practices that protect the socio-economic and biological sustainability of the resource (Jul-Larsen et al. 2003, Kolding and van Zwieten 2011). These can be very subtle 'unspoken' rules, influenced strongly by cultural and ethnic nuances, and building on an intimate knowledge of the environment (Imai 1998). In the case of Bangweulu Wetlands, the control of fishing grounds by traditional authorities, the *Chipupilas*, means that the fishery is neither open-access, nor lacking in mechanisms to limit effort and conflicts between fishermen (Chapter 4).

With the Bangweulu floodplains still in an ecologically intact state, the fish resource should be able to continue to support a considerable fishery into the future with minimal but locally-adapted regulations. Most floodplain fisheries depend largely upon seasonal harvests of juveniles returning off floodplains (such as in the fish weirs), and this harvest method has been shown to be highly efficient, resulting in high catches for local residents who often don't have access to the resource elsewhere or at a different time, and to have a minimal impact on the productivity of the resource (Welcomme and Hagborg 1977). Methods such as weirs and basket traps were shown to have a minimal impact on stocks of larger commercially-valuable species, despite official assumptions to the contrary (Bell-Cross 1971). The harvest of a wide range of species and sizes, caught with a variety of gears in numerous habitats, has a lower ecological impact than targeting only a particular component of the fish community, such as large predators (Kolding et al. 2003, Kolding and van Zwieten 2011). Finally, the harsh living conditions of the floodplains, and the inherent variability in catches and environmental conditions will in itself limit effort in the fishery, as long as alternative livelihood options (such as farming) are available (Jul-Larsen et al. 2003). Therefore, the floodplain fishery of Bangweulu Wetlands is most-likely sustainable and is likely to remain in such a state into the foreseeable future. Nevertheless, it would be prudent to put a locally-adapted management framework in place that will serve to strengthen relations between resource users and conservation authorities.

7.2 MANAGEMENT RECOMMENDATIONS

The following set of management recommendations are based on the results of this study, discussions with Bangweulu Wetlands management as well as collaborative discussions around field visits by Dr Olaf Weyl (South African Institute for Aquatic Biodiversity) and Prof. Jeppe Kolding (University of Bergen). The recommendations aim to maintain the *status quo* in the fishery and prevent an influx of non-local fishermen by strengthening traditional resource-rights access mechanisms. An area-specific set of fishing by-laws would legitimise fishing practices suited to floodplains but which are currently considered illegal in the national regulations (e.g. weirs and fine-meshed gears such as baskets and small-mesh gillnets). Strong communication channels between park authorities and fishing groups will serve to minimise conflicts between conservation, tourism and fishing goals.

1) It is recommended that the park management of Bangweulu Wetlands recognises the value of the fishery as an important ecosystem service, and that both ecological and social sustainability are taken into account in any management intervention. Given the high level of dependence upon the fish resource and the potential for conflict, it will be crucial that any successful, sustainable resource management action be supported by the local community and traditional authority.
2) The fish community is highly adapted to the unstable floodplain environment, making it robust and resilient to the effects of fishing pressure. From a fisheries perspective, there is no need to reduce fishing effort or alter fishing methods in any areas.
3) Fisheries management should aim to maintain the *status quo* of the fishery, while remaining vigilant to any changes in gear, method or effort that could alter the current sustainable harvest pattern. The fishing community needs to understand that park management recognises and supports their fishing strategies as a legitimate and sustainable livelihoods activity. A strengthening in trust between the communities and park management will result in greater support for conservation activities by the community.
4) A better understanding of the local resource-access mechanisms needs to be obtained. Any Fisheries Management Plan (FMP) for the area needs to ensure access rights are limited to the local communities inside the park. Determining the boundaries of different customary fishing areas as well as developing mechanisms to promote fishing by resident fishermen only (e.g. closed season for wet-season seining, mostly done by immigrant fishermen) will guard against the resource and its derived benefits being exported by groups from outside the conservation area.

5) The FMP should retain the conservation and tourism goals of the park and ensure that a set of behavioural and conservation rules are accepted by the fishermen. These should address attitudes towards tourists, behaviour towards threatened species such as shoebills and aesthetic problems such as litter in fishing camps.
6) Certain fishing methods and fishing areas have a high visual impact, primarily the use of mosquito-mesh funnel nets and temporary, rainy-season fishing camps built on the shallow parts of the plain. These are both crucial to harvesting the transient fish resource moving over the floodplain. Without an understanding of floodplain ecology, these methods could be interpreted by tourists as destructive. Therefore it is imperative that tourist guides are able to give tourists insight into the fisheries ecology of the area, and that informative materials such as information boards or pamphlets summarising human activities in the area are provided to tourists upon entry into the park.
7) A Fisheries Management Forum (FMF) should be established to assist in the development and implementation of the FMP. This forum should be made up of representatives of Bangweulu Wetland's management staff and community development facilitators, the chief's authority, key fisheries leaders, government Fisheries Department officials and possibly other stakeholders such as transport providers or village shop owners. Initial management interventions should be positive, and once trust and buy-in into the management plan and forum has been built, more controversial initiatives (e.g. certain closed areas) can be pursued. Implementation of the FMP should initially focus on a small core area such as Chikuni as a pilot project, with later adoption of successful strategies elsewhere.
8) The FMP should outline a set of locally-adapted fisheries bylaws. These would recognise methods used in floodplain fisheries and currently considered illegal (e.g.

small-mesh gillnets, mosquito nets and weirs) as legitimate harvest strategies. The annual, three-month-long fishing ban, though unpopular, should be retained to prevent permanent settlement in wildlife areas. Modifications and exemptions could be made, such as allowing subsistence fishing near villages and possibly bringing the ban forward by a month (from December to November) to cover the vulnerable dry-season period and to allow earlier access to the flooded plains in February.

9) The small-scale trading system currently in place is highly efficient and intricate, engaging many highly skilled traders with multiple and far-reaching spin-off benefits that maximise the local benefits obtained from the fish resource. Any formalised intervention such as building centralised fish markets or controlling marketing channels should be carefully considered and discouraged if likely to disturb the intricate local trading scene.

10) Finally, it is recommended that a dedicated fisheries coordinator post be created by Bangweulu Wetlands. The incumbent should have a fisheries background, experience in working with communities and sufficient background skills to guide the development of the FMP, steer the FMF, and have the ability to engage the various stakeholders and lobby for the creation of a legislated Fisheries Management Area (FMA) for Bangweulu Wetlands with its own set of locally-adapted regulations.

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