"Fish rescue us from hunger": The contribution of aquatic resources to household food security on the Rufiji River floodplain, Tanzania

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Abstract

Inland fisheries are essential to nutrition and food security in developing countries but remain undervalued. Worldwide, studies of aquatic resource consumption are rare.

We use data from a monthly survey of 40 households over one year in a Tanzanian village, combined with qualitative methods, to analyse consumption of animal aquatic resources across wealth, seasons, fishing vs. non-fishing and male- vs. female-headed households. We find that local freshwater fish are the most frequent source of animal protein, consumed on 57% of survey days. Wealth matters, with better-off households eating fish more often and in larger daily quantities on average. Middle-ranked households catch and sell fish more often, but all households double their consumption on average on days they catch rather than purchase fish. Female-headed households rely on gifts to increase consumption. Our results emphasise the need to preserve the livelihood functions of inland fisheries in the face of increasing threats.

Introduction

Wild capture fisheries are essential to food security in the developing world (Hall et al. 2013), particularly in Africa where aquaculture remains negligible and fish provide a large proportion of animal-source foods (Beveridge et al. 2013). In 2009, the region was second only to Asia in the proportion of total animal protein contributed by fish (18.5 vs. 23%; Tacon and Metian 2013). Besides their critical role in providing high-quality protein, fish also supply unique long chain fatty acids and essential micronutrients—including vitamins D and B, calcium, phosphorus, iodine, zinc, iron and selenium—that affect growth, cognitive development and overall health (Kawarazuka and Béné 2011). These micronutrients are highly bioavailable in fish and not easily obtained from other dietary sources, especially for the poor (Thilsted et al. 2016). Furthermore, fish consumption enhances the uptake of micronutrients from plant-source foods (Kawarazuka and Béné 2011). As a result, fish are increasingly incorporated in food-based nutrition interventions to combat malnutrition (Longley et al. 2014; Roos et al. 2007; Toledo and Burlingame 2006; Gibson et al. 2003).

Fish also support human food security and well-being indirectly, with income from fish sales used to purchase food, or access health and education services (Béné and Friend 2011; Kawarazuka and Béné 2010). Most rural households participate in fishing as part of a wider livelihood diversification strategy, combining different economic activities in order to manage risk and cope with shocks (Smith et al. 2005). Employment and income from fishing can increase households' resilience and prevent them slipping deeper into poverty, with this safety net role argued to be the main contribution of small-scale fisheries (SSF) (Béné et al. 2010).

Inland fisheries are particularly important for food security and human welfare in developing countries because the majority of catches are destined for direct human consumption (HLPE 2014). Yet policy makers continue to overlook this sector, with serious consequences for the well-being of millions of people (Cooke et al. 2016; Lynch et al. 2016). The characteristics of inland fisheries that make them readily accessible to users—geographically dispersed, small scale and requiring simple technology to exploit—frustrate easy data collection, monitoring and management (Welcomme et al. 2010; Mills et al. 2011). More information is required on the food and livelihood role of inland fisheries, as part of a wider move towards recognising the importance of SSF to food security and poverty alleviation (HLPE 2014).

Knowledge gaps around the contribution of fish to food security include missing information on fish consumption patterns below the national level, and their disaggregation across income groups, within households, by season and by species

(Thilsted et al. 2016; Garaway et al. 2013). Disaggregation matters in order to link fisheries policy to issues of human welfare and social justice, by answering the questions: who depends most on fisheries for food and has least access to alternatives? (Hall et al. 2013). Answers are urgently needed as threats to inland waters increase, most notably from hydroelectric developments and water abstraction for agriculture and industry, compounded by climate change (Welcomme et al. 2010).

A recent review found that data on the relation between household wealth and fish consumption were limited and inconsistent (Béné et al. 2016). There is evidence of differences in fish consumption driven by participation, with fishing households consuming more fish than non-fishing households (Gomna and Rana 2007) but alternative views exist (Fiorella et al. 2014). In SSF globally, men are the main fishers, with women more often involved in processing, trading, or fishing for home consumption (Kawarazuka and Béné 2010). These gender differences may have implications for women and children's access to fish for food and nutrition. Fish consumption is also known to vary markedly with location and season, again with important implications for vulnerable people's access, but quantification of this variability remains rare (Garaway et al. 2013).

With respect to species, small, low market value fish are easily overlooked in surveys but can be those most important to the poor (Kawarazuka and Béné 2011). Small fishes can be purchased in small quantities and for less cash in comparison to larger fish or other animal-source foods. They also exhibit higher 'divisibility', being easier to share out among household members than larger fish (Belton and Thilsted 2014). Finally, small fishes are easier to preserve (Thilsted et al. 1997) and can be eaten whole, with the consumption of bones, head and viscera increasing potential nutrient contribution (Thilsted et al. 2016).

In Africa, the range and nutritional profiles of locally consumed fish species remain poorly known (Béné et al. 2016; Gomna and Rana 2007) and that of other aquatic animals (OAA) even less so. Frogs, molluscs, crustaceans, snails and other freshwater animals contribute significantly to household nutrition in South East Asia (Garaway et al. 2013; Hortle 2007; Meusch et al. 2003). Given recent reviews outlining the contribution wild biodiversity makes to local food security and nutrition even while underlining the paucity of studies available on the subject (Powell et al. 2015; Penafiel et al. 2011), understanding the importance of OAA besides fish in other regions, including Africa, is critical.

In this paper, we provide the first description and quantification of aquatic resource (AR) use among rural African households over one year and across different groups (i.e., wealth, fisher/non-fisher, male/female household heads). The analysis is based on a monthly survey of AR use among 40 households in one village on the Rufiji River floodplain, Tanzania, where 'use' refers to all catches, consumption and sales and 'AR' include all fish and OAA. The survey data are supplemented with observations the lead author made over 15 months residing in the village. We focus here on the direct contribution of aquatic animals as food, as neither the role of fish as a source of income nor the use of aquatic plants were systematically quantified by the survey (but see Moreau 2014). Also, as this study was carried out at a household level we do not attempt to measure food security, defined as occurring when all members of a household have reliable access to food in sufficient quantity and quality to maintain an active and healthy lifestyle. This was beyond the scope of this study, given the complexities involved in its measurement (Hadley and Crooks 2012), though we do highlight issues of food access, a key pillar of food security, throughout.

The paper is organised as follows. After describing the study area, methods and survey sample, we give an overview of the AR species used locally, and explain food fish preferences. Next, we analyse consumption patterns for all households disaggregated by wealth, fishing versus non-fishing households, and wet versus dry seasons. We then consider the relationship between gender, wealth and participation in fishing, fish sales and gift exchanges before discussing our findings.

Study Area

Geography and climate

The study site is located in Rufiji District, within the Pwani Region of the United Republic of Tanzania (Figure 1). The region is one of Tanzania's poorest, ranking 15th out of 21 on the UNDP's Human Development Index (UNDP 2015).The area has a tropical, semi-arid climate. Rainfall is highly variable, but generally displays two peaks with the short rains (*vuli*) in October-November and the long rains (*masika*) from March to May (Hamerlynck et al. 2010). The agricultural year yields a maize harvest in February-March, and a rice harvest in May-June. The Rufiji River, the largest in East Africa, bisects the district from west to east. A vast floodplain occupies the river valley bottom, characterised by a mosaic of former river channels, levees and shallow depressions, and eight permanent lakes (Hamerlynck et al. 2011). The coincidence of the annual peak flood (usually in April) with heavy rains marks the wet season.

The flood pulse and local fisheries

The timing, duration and level of flooding on the Rufiji River are highly variable from year to year (Duvail and Hamerlynck 2007). When water levels exceed a certain threshold, riverine water flows into the permanent lakes, allowing exchange of suspended matter and biological material, including fishes (Hamerlynck et al. 2010). Fishing occurs year round, but with strong seasonal changes in effort corresponding to flooding patterns. Most fishing activity is concentrated in the permanent lakes over the dry season, with fishing on the floodplain targetting fish migrations through the channels on the rising or falling flood, or those fish left stranded in drying ponds (Hamerlynck et al. 2011).

The study village

The study village, Ruwe, is on Lake Ruwe, a permanent waterbody on the northern river terrace (Figure 2). The village was officially founded in 1968 through government mandate when all floodplain inhabitants in Rufiji District were resettled on the river terraces following a prolonged flood (Bantje 1980; Hoag 2003). Those who refused were threatened, jailed, or in some cases had their houses burnt down. Although ostensibly undertaken to protect the population from future floods, the move served the purpose of advancing President Nyerere's vision for a new model of African socialism ('*Ujamaa*') built around traditions of family togetherness. Central to this model was the establishment of cooperative villages in which people farmed communally (Hoag and Öhman 2008). Growth of such voluntary settlements—or *ujamaa* villages—as called for in the 1967 Arusha Declaration had been slow, and the forced villagization in Rufiji became a model for resettlement programs in other parts of Tanzania (Briggs 1979, Hoag 2003).

To this day, no one is officially allowed to live on the floodplain, with households typically maintaining a permanent home in the village—where soils are poor and agriculture rainfall-dependent—and a field house on the floodplain. At times of peak agricultural activity all or part of the household, usually headed by the wife, move to the field house. The village (population 2293, based on a 2007 census by the first author) is divided into three administrative hamlets, each dominated by certain clans. The Ndengereko are the main ethnic group in the study area, but more than ten groups are represented in Ruwe. Most people practice Islam, co-existent with a belief in spirits.

In the study year (2008), Lake Ruwe reconnected to the river for the first time since 2002, recharging fish numbers and increasing fishing opportunities (Hamerlynck et al. 2011).

Methods

Data were collected through questionnaires, interviews, participant observation (including 15 months living with a Ruwe host family) and conversations with fishers, traders, leaders and others around Lake Ruwe.

Household aquatic resource use survey (HARS)

(i) Sampling

To select households for the HARS survey (conducted once a month, with 40[1] households from March 2008 to February 2009) a sampling frame was created using a village map and a list of 144 household heads, all of which had been ranked through a process of participatory wealth-ranking.[2] Households were purposively selected for inclusion in the survey by location (across the three hamlets and from field areas) and wealth category (proportionally across all wealth categories, for village-based households only). Field-based households were selected from areas located a manageable distance from the village for regular visits by foot or bicycle, and

[1] 25 for the first month only

[2] Households were classified as poor/middle/rich in exercises held with at least two groups of villagers in each hamlet, following Grandin (1998). No wealth rankings of field-based households was attempted because no groups could be assembled.

consisted of five households in a series of depressions south of the village (~1 – 2km from the central marketplace), and two more on the floodplain (~3 – 4km distant). Given the time required to find respondents, a final sample of 40 households was optimum, with each survey round taking 7-12 days to complete.

In defining household membership, informants were asked to list: all family members in the home who cooked and ate together; any other people who ate elsewhere but slept here; or who slept here but ate elsewhere.

(ii) Questionnaire survey design and administration

The questionnaire was adapted from one used in South East Asia (Garaway et al. 2013; Garaway 2005). It was translated from English to Swahili by a Tanzanian university student and modified after trialling with three non-sample households.

Based on a 24hr-recall methodology, for each round, the questionnaire collected data on: household members present at each meal for the day preceding our visit; number of guests present that day; all AR caught, bought or received as gifts (probing specifically for fish, shrimp, turtles, crocodiles and other "insects or animals that live in the water"); AR type, origin, number, size (see below) and use (i.e., percentage eaten, sold, preserved and gifted); additional food items the household had eaten on the previous day and whether consumed at breakfast, lunch and/or dinner. The survey was modified slightly for the month of Ramadan (September 2008).[3] For each household, we collected one-off information on current household members (name, age, gender and relationship to the household head), updating the list at each round as necessary.

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[3] At Ramadan, people who fasted typically ate twice in the night. The *futari* meal shortly after sunset generally consisted of a drink of *uji* followed by a stew of cassava, papaya, sweet potatoes and/or green bananas cooked, where means allowed, with coconut milk. A heavier meal, *daku*, consisting typically of rice and *mboga*, was eaten around 10-11pm.

The female household head was the usual respondent as the person preparing the meals but also because men were more often away. Household members cooked from the same pot and typically ate off one shared platter. On occasions when the respondent had eaten apart from other household members and was unsure what the others had eaten, we would 'follow' the respondent's meals, i.e., marking as 'absent' those who had eaten apart from her. If, however, she had prepared in advance the meal others ate without her, all were recorded as having eaten together since she could report on their meal.

One female and one male research assistant from the village administered the survey as a team after receiving training and conducting the two first rounds with the lead author. The lead author continued to accompany the team for a few days on most rounds in order to check for consistency, and reviewed the completed forms daily or (if away from the village) shortly following each round.

Survey households received a gift worth 0.50USD, usually tea and sugar, every other month as compensation for their time.

(iii) Under-reporting

The survey team took several steps to address under-reporting of meat consumption and earnings from fish sales. Hunting is illegal without a permit in Tanzania, and infractions carry harsh punishments. Accordingly, respondents could be expected to avoid reporting wild meat consumption. The use of local assistants and the lead author's residence in the village (and own consumption and purchases of game) helped develop trust with informants, as well as allowing interviewers to know independently when game was available in the village and to probe accordingly. We are confident in the data obtained, particularly as it aligns with figures from neighbouring communities (Hamerlynck et al. 2011).

Collecting reliable data on cash generated from fish sales was problematic owing to respondents not always knowing how much other household members had sold the fish for and/or not being able to ask the salesperson themselves. Of 23 reported sales, data are missing on 8 and potentially under-reported in other cases. Given this, cash earnings, whilst undoubtedly important when they were accrued, are only briefly reported on.

Qualitative methods

To elicit additional information on local AR uses and seasonal trends, three discussion groups (one for each hamlet) were held with 21 women drawn primarily from the survey sample. Women were asked to: name fish, aquatic animals, insects and plants used in the village for food or medicine; assign a preference score to fish species (from best to eat to worst (i.e., 1 to 3)); and indicate fishes' seasonal availability. The groups also prepared resource calendars indicating patterns in rainfall, flooding, labour demand and hunger levels.

Data analysis

Estimating fish size and weight

Scientific names were assigned based on correspondence with local names (Appendix). Respondents were asked to estimate the size of fish reported on the survey with the use of a visual aid (Garaway et al., in prep). For each species of fish named, respondents chose from among six sticks laid side by side on the ground the one which most closely approximated the total length of the fish (i.e., TL: from tip of tail to tip of snout). For fish already smoked (2.7% of 370 records) or fried (8.1%), we asked people to estimate length prior to processing.

The stick lengths were 10, 15, 20, 30, 45 and 60 cm respectively, in line with the usual size of fish caught in the area. Where people reported a range of sizes (e.g., a bunch of 10 and 15cm long fishes), we took the midpoint as the size of all fishes in that bunch. If they said a fish was "smaller than" a particular stick, estimates were revised downwards as follows: 7, 14, 17, 25, 40, and 55cm. The smallest fishes were classified as 4cm TL. We did not test how well respondents were able to estimate fish lengths, but in examining scatter plots the reported lengths for each species were found to be largely consistent across households each survey month and also with length data obtained from independent measurements at landing sites and markets.[4]

Fish length estimates were converted to weights based on either our own data (2 species) or length-weight relationships available on Fishbase (see Moreau 2014). Weights are live weights of the whole, fresh animal, prior to any pre-processing (e.g., gutting, beheading, deboning). Conversion factors from Hortle (2007) were used to convert estimated live fish weights to weights for smoked (0.43) and sun dried (0.28) fish, and from Burger (2004) for fried weights (0.61).

Estimating weights of OAA

For OAA, we asked respondents to estimate weight in kg, but this only worked if the product had been bought at the district market or in the case of a large turtle. Otherwise, informants told us how many bunches they had bought at what price, and we estimated weight based on available price/kg information drawn from

[4] The fact that people would often qualify their choice of stick, explaining that the fish was a bit smaller or larger, further suggests that they were paying attention to actual size.

other households' surveys or from a market survey running concurrently in district towns.

Estimating AR consumption rates

Consumption is calculated on an adult male equivalent (AME) basis rather than per capita in order to reflect households' different demographic composition (Deaton 1997). Given that people of different age and gender require different numbers of calories to maintain "normal" activity levels, the conversion is as follows: males ≥ 10 years old = 1 AME; females ≥ 20 years old = 0.72; females between 10 and 19 years old = 0.84; and children < 10 years old = 0.60 (Ministry of Agriculture/Michigan State University/USAid Research Team 1992).

The number of household members and guests present at meals could vary across the survey day. We therefore calculated the g of AR/AME consumed on a meal-by-meal basis, and added these together to obtain the daily consumption of AR in each household (i.e., g/d/AME). If the fish was entirely consumed at one meal, calculating the weight consumed per AME per meal was a straightforward summing up of the individual AME values for all household members and guests present at that meal. If the AR was consumed over two or three meals, we divided the total weight by the average AME value for the meals over which it was consumed. Because we did not consistently record information on guests' gender and age, we assumed all to be adult males (AME = 1) possibly leading to slight underestimates in daily consumption rates.

In averaging quantities of AR consumed we present both the mean ± SD and the median for ease of comparison with other studies, which tend to present the former statistic. However, the median is the better measure of central tendency for our dataset given the large number of surveys on which no AR were consumed (i.e., many zero-values). Even then, to counter the effect of many zero-values, we also present the average quantity of AR consumed after excluding those surveys where no consumption was reported.

Analysing consumption patterns for all foods

Food items are scored as present/absent on the survey day rather than at each meal. People almost never ate AR at breakfast, with poorer households content with watery maize porridge (*uji*) or boiled plantain, cassava or papaya. Better-off households might have sugary tea with some variety of fried dough (e.g., rice donuts, chapatis). The midday and evening meal consisted of a starch with an accompaniment or ‘relish’ (referred to as *mboga* or *kitoweo*) of vegetables, fish or meat. Although maize (eaten as *ugali*, a stiff porridge) is the mainstay of local diets, rice is the preferred food. Since one or the other was consumed at every meal, they are not considered in our analysis. Snacking was highly individual and not specifically investigated as respondents could not be expected to report on what other household members had consumed.

Remaining food items were grouped into categories for ease of analysis: AR (local freshwater and all other); cultivated vegetables including pulses; wild vegetables; domestic meat; wild meat; eggs; and fruit.

The datasets analysed during the current study are available from the corresponding author on reasonable request.

Exchange rate

Prices are given using the average interbank exchange rate from 31 January 2008 to 31 March 2009 (0.0008 TZS to 1 USD; www.oanda.com).

RESULTS

Description of HARS sample

In all, 463 questionnaires were conducted over the study period, encompassing 1295 meals across 40 households (and 41 houses).[5] Two households had dissolved by August and September respectively, dropping the sample to 38 households. The membership of individual households tended to vary on a monthly basis as people came and went; for this reason, no average demographic characteristics are given. Guests were present on 137 surveys, with 86% of these involving just one or two individuals eating with the household at any one meal.

My presence during the survey had no significant effect on whether or not respondents reported AR use ($\chi 2 = 0.271$, $p > 0.05$, df =1), but reported instances of meat consumption were too rare to test for a similar effect.

AR in local diets

(i) Freshwater animals

Nineteen local freshwater fish species were consumed in the village, based on survey data (16 species mentioned) and group discussions (three species; Table 1). Three species made up the bulk of freshwater fish records: 'kumba' (the cichlid *Oreochromis urolepis*), 'pele' (a characin, *Citharinus congicus*) and a squeaker

[5] In one polygamous household each co-wife had her own house and refused to be interviewed with the other. We were rarely able to survey them on the same date, precluding merging of survey data.

catfish, 'kogo' (*Synodontis rukwaensis*) (Table 1). Apart from 'ngocho' (a carp, *Labeo congoro*) and 'kambale' (the catfish *Clarias gariepinus*), other freshwater fish species were infrequently reported. The main targets of local commercial fisheries were *pele, kumba* and *ngocho*, and these were also the species more often purchased than caught directly by household members.

At least another 12 local freshwater aquatic and semi-aquatic animal species were in local use, with turtles (and their eggs), juvenile shrimp (probably *Macrobrachium* sp.), clams, various birds and hippopotamus eaten by villagers (Table 2). Crocodiles, associated with witchcraft, were considered fit to eat only in retaliation for an animal killing a person.

(ii) Freshwater fish preferences

Locals preferred certain fish species (Table 1), but often remarked that any fish was good enough to eat. A species was especially prized if it could be cut into large fillets or steaks, and disparaged if full of little bones. Women also explained their preferences for fattier, oily fishes (as this saved money on cooking oil) and fish that produced a tasty broth (*mchuzi*) when boiled with water, the most common cooking method. The latter consideration was particularly relevant to children, who were regularly observed to receive only fish broth poured over their *ugali* or rice once the men, followed by the women, had served themselves fish. The large catfishes, *kambale* and *mbufu* (*Bagrus meridionalis*), and white-fleshed tilapia, *kumba*, were overall favorites in these respects.

Small fishes were widely eaten, in particular *kogo* catfish, a species generally scorned by outsiders to the district and rarely seen in the town markets. Smaller fish were sold in small quantities (by the bunch) at a price that fit into households' limited daily budget for fish (typically 0.24USD/day). Only the wealthiest villagers and state-salaried teachers generally had cash available to spend more, and even then sometimes bought large fish on credit. Observation suggests that it was common practice for small fishes to be parcelled out to individual household members at meals.

Bones and viscera of smaller species were eaten, with *kogo* innards considered a delicacy. Less popular fishes (i.e., preference scores of '3') or juveniles of preferred species (mainly *pele* and *ngocho*) were often fried and eaten whole: frying preserved fish for two or three days, and also softened unpalatable tiny bones. On several occasions elderly men were observed at fishing camps receiving bycatch, consisting of tiny fishes, as gifts from returning fishermen.

Uses of AR by all households combined

The use of AR by households–that is, any instance of catching, buying or receiving AR as a gift fish or OAA—was widespread, reported on 60% of all surveys (N=463). 93% of these AR were local freshwater fishes (Figure 3). The remaining records were for one local freshwater turtle (*ndasi*, species unknown) and for OAA sourced from outside the local area: *dagaa* (small, dried herrings typically caught in Lake Victoria and a common food across Tanzania), the sundried marine fish *mbarata* (*Hilsa kelee*) and prawns from the Rufiji delta.

The primary reported use of freshwater fishes by households was for home consumption (88%), usually eaten in entirety within the past 24h (Figure 4). Households obtained fishes more often through purchases than catching fish themselves (57% vs 37%), with the remainder received as gifts. Purchased fishes were caught locally, with village-based households buying fishes in the village itself (87%)

or near their fields. Field-based households had to range more widely, buying fish in the village (31%), across the river in Utete (38%) or near their fields (31%, N=13 records).

All OAA were purchased, with the exception of the freshwater turtle (received as a gift).

Consumption of AR

(i) Frequency in comparison to other foods

In terms of frequency of consumption, local freshwater fishes were by far the most important source of animal protein, eaten on 57% of surveys vs. 5.6% for OAA and 3.3% for meat (Figure 5). Only vegetables (cultivated and wild combined) were eaten more often at meals than fish.

Respondents reported eating bushmeat on just five surveys, and domestic meat (beef, goat or chicken) on 10. Eggs were rarely eaten. Few villagers kept any livestock besides a few chickens, and there were legal restrictions on hunting (see Methods). In Ruwe, there were only three dedicated (illegal) hunters, and they sold primarily to the Dar es Salaam market. Islamic dietary restrictions further limited game options, as most villagers avoided eating wild pigs, baboons or monkeys and a few also eschewed hippopotamus and elephant.[6] Although pastoralists recently arrived to the area sold milk and meat, the cost was prohibitive for most villagers.

Nonetheless, wild game was available, particularly in the dry season when villagers flushed out animals while burning their fields. Even at peak availability (in August 2008), however, meat was expensive, selling for between 1.20 - 2.00USD/kg

[6] The Makonde people (who are generally Christian) in the area reportedly ate baboons and monkeys, however.

in the village compared to the average price for fish of 0.96USD/kg that month. As a result, villagers did not typically buy meat but instead solicited gifts from village hunters.

(ii) Quantities of AR consumed overall

Calculating the mean daily consumption over the whole data set, average consumption of freshwater fish was low but highly variable (48.9 ± 115 g/d/AME, N=463 surveys). Given a large percentage of surveys on which no AR were consumed and some surveys with extremely high consumption, the median may be a more accurate measure of central tendancy (median = 13g/d/AME, range: 0 – 1254g). Considering only those surveys where freshwater fish consumption was reported, people ate, on average, 86.3 ± 142.3 g/AME of freshwater fish (mean ± SD, N = 262 surveys). The mean consumption rate of OAA, considering only days on which these were consumed, and not including the single instance of turtle consumption, was 5.4 ± 11.5 g/d/AME (range: 0.6 – 55g/day/AME, median = 3.2g/d/AME, N=21).

Wealth-related differences in animal food consumption

(i) Freshwater fish

Rich and middle-ranked households ate freshwater fish nearly twice as often as did poor and field-based households, and in greater quantities, based on mean daily consumption values (Figure 6). The results of a Kruskal-Wallis test were significant ($H = 38.1$, $df=3$, $p<0.001$), with the mean ranks of quantity of fish consumed per day per AME significantly different among the four groups.

Richer households were more likely to report preserving fish for later consumption, and to save a greater proportion of the item (Figure 7).

(ii) OAA

Rich households consumed OAA more often than other wealth groups (on 9% of surveys), but the differences across wealth ranks were not found to be significant.

(iii) Meat

Rich and middle-ranked households were more likely to report eating meat, with seven households consuming domestic or wild meat on 13 survey days (4.7% of 278 surveys) vs. one poor village and one field household reporting domestic meat consumption on one survey day each (1.1% of 185 surveys).

AR consumption in fishing vs. non-fishing households

Participation in fishing lead to increased AR consumption for all households, regardless of wealth rank. Households that had caught their own fish, as a group, ate more fish on the survey day than those that had purchased or received fish as gifts, achieving nearly double median daily consumption rates of 64g/day/AME vs 35 g/day/AME. The distributions in the two groups were significantly different (Mann-Whitney U =8744, n1 = 75, n2 = 174, $p<0.0001$, two-tailed).

However, the difference made by direct participation in fishing was greatest for the poorest villagers, with households in the poor and field groups more than doubling their median consumption on days they fished compared to days on which fish were purchased (Figure 8). Despite this advantage, all wealth groups purchased fish more often than they fished (Figure 9). The difference was less for the middle-ranked group, however, as we explore below.

Seasonal trends in households' freshwater fish use

Fish were eaten year-round, but with important seasonal differences for different wealth groups. Only poorer households, as a group, ever failed to report eating any fish on a survey month (Figure 11). In May, and to a lesser extent in July, this situation arose from the combination of environmental conditions, with fish more difficult to catch when waters remained high, and the constrained cash position of households yet to bring in their rice harvest.

Together, more households reported consuming fish in the dry season, when the commercial lake fisheries were most active. The highest frequency of consumption was recorded on the September and October surveys (Figure 10) and highest median amount of consumption in November (157g/day/AME; Figure 11). In the wet season, production shifted to the floodplain, with field-based households consuming more fish on average than during the dry, and rich households—much more likely to purchase than to catch fish—reducing their fish consumption in line with reduced commercial availability.

The cash role of local fisheries was strongly seasonal, playing an integral part in coping with dry season food shortages. Before the harvest of the year's first maize crop, when food stores are running low or exhausted and wild plant foods are scarce, villagers experience the seasonal hunger typical of African farming communities (see Bryceson 1989). For generations, people on the floodplain have coped by catching and smoking fish to exchange for cassava flour grown by farmers on the high terraces of Rufiji (Bantje 1980). Today, fishermen continue to exchange fish for cassava, or to sell fish for cash at district markets in order to purchase food supplies. In this way, as described by one informant: "fish rescue us from hunger nearly every year".

Patterns of participation in AR use

(i) Who fishes?: Gender and wealth considerations

In total, 22 households reported catching fish on at least one survey (N=75 surveys), these being caught by 25 different individuals. The fisher was usually the male household head (83% of surveys), or a son, male grandchild or, in one instance, the brother of the female household head.

Only three women caught fish, each on a single occasion, reflecting men's dominance in local fisheries. As explained by older female informants, women fished much more often when people lived permanently on the floodplain, especially when fish were migrating. Then, a woman could combine opportunistic fishing (e.g., seining with cloth, or using basket traps, spears or hook and line) with the rest of her daily chores. Now that households moved back to the village once the harvest was in, fishing had become "a project": one had to organise a specific time to travel onto the floodplain with family or friends, with no guarantee of spotting fish.

Middle-ranked households caught fish more often than did others (Figure 8). This was driven by the presence of six 'dedicated' fishermen in this group, i.e., men who reported catching fish between five and 13 times in the study year (median = 8 surveys) and were also known to us independently of the survey as fishermen. Other male household heads who fished did so three times or less (median = 2 surveys, N = 9 individuals).

Indeed, presence of a dedicated fisherman in the household was itself linked to wealth rank. Local conceptions of wealth included a household's ability to sustain itself through work, so that those households with able-bodied male members were considered better-off. Able-bodied men, in turn, were usually involved in fishing, unless they had alternative sources of income. For other middle-ranked households, this was typically timber harvesting. For rich households, alternatives included hunting, commodities trading and transport, and/or running milling machines. Among poorer households, even where older men could still physically fish, several described struggling to generate enough surplus income (either through fishing or other livelihood activities) to invest in more efficient fishing nets, as younger men did.

(ii) Who sells fish?

Middle-ranked households were the most likely to sell a portion of their catch. Of the 16 surveys on which poor households reported catching fish, only one household, on one occasion, ever sold a portion of the catch. In contrast, the six, middle-ranked 'dedicated' fishing households sold fish on nearly a third of the days on which fish were caught. Although the frequency of fish sales was underestimated (see Methods) this bias would apply across all households, suggesting observed differences were real.

The cash role of fish was mentioned nearly as often as its food role in conversation. Typically, an informant would explain how a satisfactory catch supplied fish for the day's meal (budgeted at TSH300, or USD0.24) and a surplus to sell for the purchase of flour (maize or cassava), accompaniments (e.g., tomatoes, onions) and necessities (e.g., soap, salt, oil). On our survey, the median reported cash income from daily fish sales was 1500TSH (USD1.20, range: 0.24USD – 8USD, N=15).

(iii) Who received fish as gifts?

Gifts were very important to female-headed households' fish consumption. These households were about as likely to consume freshwater fishes as were male-headed households (58.8% of 51 surveys vs. 60.2% of 412 surveys respectively) only because they received fish as gifts more frequently (7.8 vs 2.2% of surveys). Where fishermen specified gift recipients (N=10 surveys) the majority went to their mother or maternal aunt. Fish were also commonly given by fishermen to their lovers.

DISCUSSION

These results show that a diversity of local AR—primarily freshwater fishes—were essential to household food security and nutrition in Ruwe village. Freshwater fishes were by far the most important source of animal protein, with fish consumed on more than half of survey days and much more often than either OAA or meat. Better-off households consumed fish more often and in larger quantities each day than poorer households did. However, all households ate more fish on days they caught rather than purchased fish, suggesting that no household was able to buy as much fish as it would have liked.

Meat, both wild and domestic, was clearly less available and affordable than fish, and villagers frequently complained of meat scarcity. Research in an upstream village also found fish to be eaten much more often than meat, present in 40% of daily meals vs. 1.4% (Hamerlynck et al. 2011). Consumption of non-local AR in Ruwe—namely dried *dagaa*, *mbarata* and prawns—was also very limited. Similarly, locals were adamant that no one would eat the freshwater crabs, frogs or snails commonly observed in the area, in contrast to the widespread consumption of such animals in other parts of the world (Garaway et al. 2013; Brooks 2008; Roos et al. 2007; Meusch et al. 2003). When pressed whether people ate these creatures in times of famine, villagers invariably replied: "Only fish!". As such, although amounts of fish consumed in Ruwe were within the range observed for rural African populations

(Table 3), fish may be disproportionally important here given the lack of acceptable alternative animal protein sources.

The contribution of fish to food security goes beyond protein, with small indigenous fish species eaten whole generally providing an excellent source of essential micronutrients (Kawarazuka and Béné 2010). In Ruwe, villagers ate at least nineteen local freshwater fish species, including small species consumed whole. These small species exhibited the same pro-poor aspects, such as affordabilility and divisibility, reported in other locations (Thilsted et al. 2016; Kawarazuka and Béné 2011), and were not considered an inferior food source as can sometimes be the case with low-market value fishes in Africa (Longley et al. 2014; Kabahenda et al. 2011). Identifying and promoting the consumption of the most nutritionally rich low market-value species in Rufiji could therefore be an effective way of enhancing local food security and well-being in one of the poorest regions of Tanzania. For the 5.5% of adults living with HIV in the Coast Region (NBS 2018), improving nutrition is essential in keeping healthy for longer (Friis 2006).

Food security depends not only on the availability of safe and nutritious foods, but on people's ability to access these (Hadley and Crooks 2012). We found household wealth to be a key factor determining households' access to fish and fishing opportunities in Ruwe—a result also found in the Democratic Republic of the Congo (DRC; de Merode et al. 2004) but not elsewhere (Fiorella et al. 2014; Fa et al. 2009; Gomna and Rana 2007). In the DRC, only wealthier households could afford the nets required for fishing, with access to fishing further restricted to members of a particular social group. In Ruwe, where participation in fishing was widespread, we have suggested that the underlying reason better-off households ate more fish related primarily to their cash position. Rich households simply purchased fish, whereas middle-ranked households (when compared to poorer households) were more likely to have able-bodied male members and consequently more likely to engage in cash-earning activities, including fishing.

Nonetheless, even the poorest households were able to catch fish on occasion, particularly in the less labour- and capital-intensive floodplain fisheries operating in the wet season. Maintaining access to such fishing opportunities is clearly important: all households increased their fish consumption on days they caught rather than bought fish, but disagreggating by wealth demonstrated that for poor households the amounts consumed more than doubled. In Nigeria, fishing households similarly were found to eat more fish than non-fishing households, but with no discussion of wealth-related differences (Gomna and Rana 2007, but see Fiorella et al. 2014).

The gender of the household-head was crucial to determining access to fish. Women were largely excluded from the male dominated fisheries, and their trading activities restricted to selling fried fish (see Moreau 2014). Although female-headed households were able to increase their fish consumption through the receipt of gifts, basing access to fish on good relations with fishermen could be viewed as a risky strategy (Moreau 2014). Where women did report fishing themselves on our survey the catch went to home consumption and contributed to household food security, as found for women fishing in Zambia (Merten and Haller 2008) and the Congo (Béné et al. 2009).

Besides their direct contribution to food supplies, the role of SSF in generating cash income for rural households is well-documented in the literature (Kawarazuka and Béné 2010), and was also apparent in our study from interviews and participant observation. The use of fishing as a reliable source of cash for meeting daily needs in Rufiji District is described at nearby Lake Zumbi (Paul et al. 2011) and matches the description of river fisheries in the DRC serving as a "bank in the water" (Béné et al. 2009). We found that wealth and gender mattered to fish sales, with middle-ranked, male-headed households more likely to fish and to sell a portion of their catch.

The daily cash contributions from local fisheries take on additional significance in times of food shortages, during the dry season, when fish can be exchanged for cassava or sold for cash. This safety net function of local fisheries is integral to Rufiji households' diversified livelihood strategies and is critically important in reducing their vulnerability to poverty, as also seen in other SSF communities (Béné and Friend 2011).

How much of the cash earnings from local fisheries return to the household in the form of nutritious food is a key question for achieving food security. In Lake Victoria's Nile perch fishery, fishermen often choose *not* to share the proceeds of their daily catch with their family, with dire consequences for children's nutrition (Geheb et al. 2008; see also Bryceson 1989). Women and children in Rufiji had to further contend with the cultural practice of men serving themselves first at meals, and taking the greater share of fish (see also Bantje 1982; Caplan 2003; Gomna and Rana 2007). Any future studies of the contribution of AR to food security in Rufiji or similar floodplain systems would benefit from closer investigation of such intra-household dynamics around access to food and income from fisheries.

We would further suggest methodological improvements to future surveys aiming to quantify AR consumption in light of the considerable daily and seasonal variation we observed in our study. Making more frequent visits to respondent households (e.g., daily or weekly) in periods of peak production—in terms of fish and/or labour availability, as occurs during the flood cycle—would ensure a more complete accounting of households' participation in and use of local fisheries. For instance, two of the three instances we recorded of women's fishing occurred in a single survey month (July), in the short period when fish migrating off the floodplain become easy targets for opportunistic fishing. This focused timing, however, would require researchers to be well attuned to local conditions.

Overall, all households in Ruwe benefited from local fisheries: locals had access to a diversity of nutritious fish species and opportunities to sell and exchange surplus fish in pursuit of enhanced food security. Nonetheless, by disaggregating our sample, we reveal that the poorest households, and/or those headed by women, had the least access to fishing opportunities and consequently lower levels of fish consumption. For policy-makers intent on improving the status of such vulnerable households, maintaining access to the less labour- and capital-intensive floodplain fisheries must be a priority, together with increasing women's opportunities to gain income from the fishery sector.

The continued productivity of Rufiji's fisheries, however, depends on maintaining an adequate flooding regime. Yet, like inland waters across Africa and the world, Rufiji's fisheries are threatened by climate change and proposals for upstream hydro-electric development (Hamerlynck et al. 2010). Tanzania's current government is intent on beginning construction in 2018 of a 2,100MW dam on the upper Rufiji River, at Stiegler's Gorge in the Selous Game Reserve, severely disrupting water flow (Makoye 2018). Similar plans were halted in the 1980s in recognition of the significant harm a major dam would do to downstream environments and livelihoods (Hoag and Öhman 2008). To dismiss these earlier findings and proceed without adequate social and environmental impact assessments—as the government is now doing—is to put at risk the food security and well-being of some of Tanzania's poorest citizens for uncertain gain.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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Captions for Illustrations

Figure 1. Location of Rufiji District within the Pwani (Coast) Region of the United Republic of Tanzania.

Figure 2. Location of the study village (Ruwe) on Lake Ruwe (upper map) and location of the study area within Rufiji District (lower map).

Figure 3. Frequency of different types of AR reported as used (i.e., eaten, preserved, sold and/or given away) by households (N = 396 records, where each different species on a single survey counts as a separate record).

Figure 4. Primary reported use (% of records) of local freshwater fishes brought into the home (pie chart), and of fish kept for home consumption (bar graph) (N = 370 records).

Figure 5. Frequency of consumption of different food types by households over the survey year (N = 463 surveys).

Figure 6. Frequency across surveys and mean amount of consumption per day of local freshwater fish by households across wealth groups (N=463 surveys). Sample sizes above each bar refer to the number of surveys in each group. The number of households in each group were as follows: Rich – 4, Middle – 20, Poor – 12 and Field – 5.

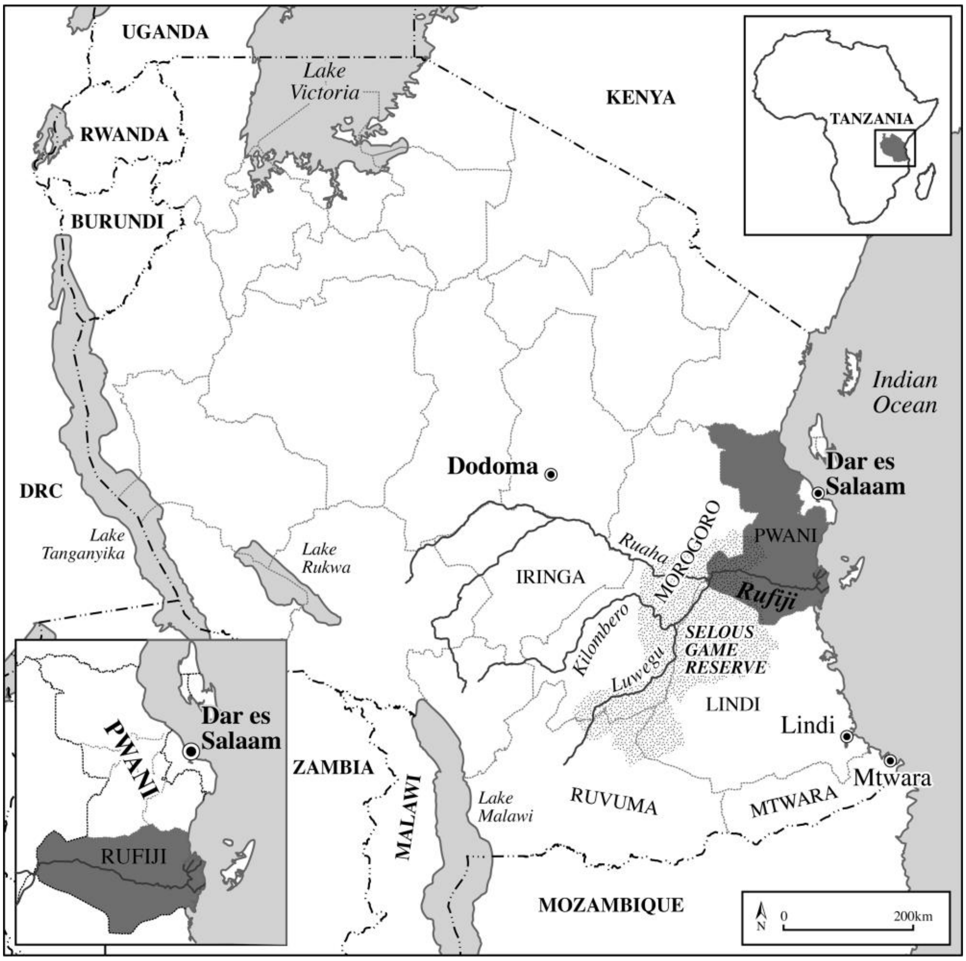
Figure 7. Differences across wealth ranks in the frequency of preserving fish and, where preserved, in the mean proportion of fish kept for later consumption (N=463 surveys).

Figure 8. On days fish were consumed (N=262 surveys), median amount of fish consumed per individual (g/d/AME) depending on mode of acquisition, by wealth group.

Figure 9. On days fish were consumed (N=262 surveys), frequency with which households in different wealth categories purchased, caught or received gifts of freshwater fish.

Figure 10. Seasonal patterns in the frequency of consumption of aquatic resources by all households combined (N = 438 surveys).

Figure 11. Mean amount of freshwater fish consumed (g/day/AME) each survey month, by all households combined and by wealth group (N=463 surveys).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MOROGORO
PWANI
Rufiji
SELOUS GAME RESERVE
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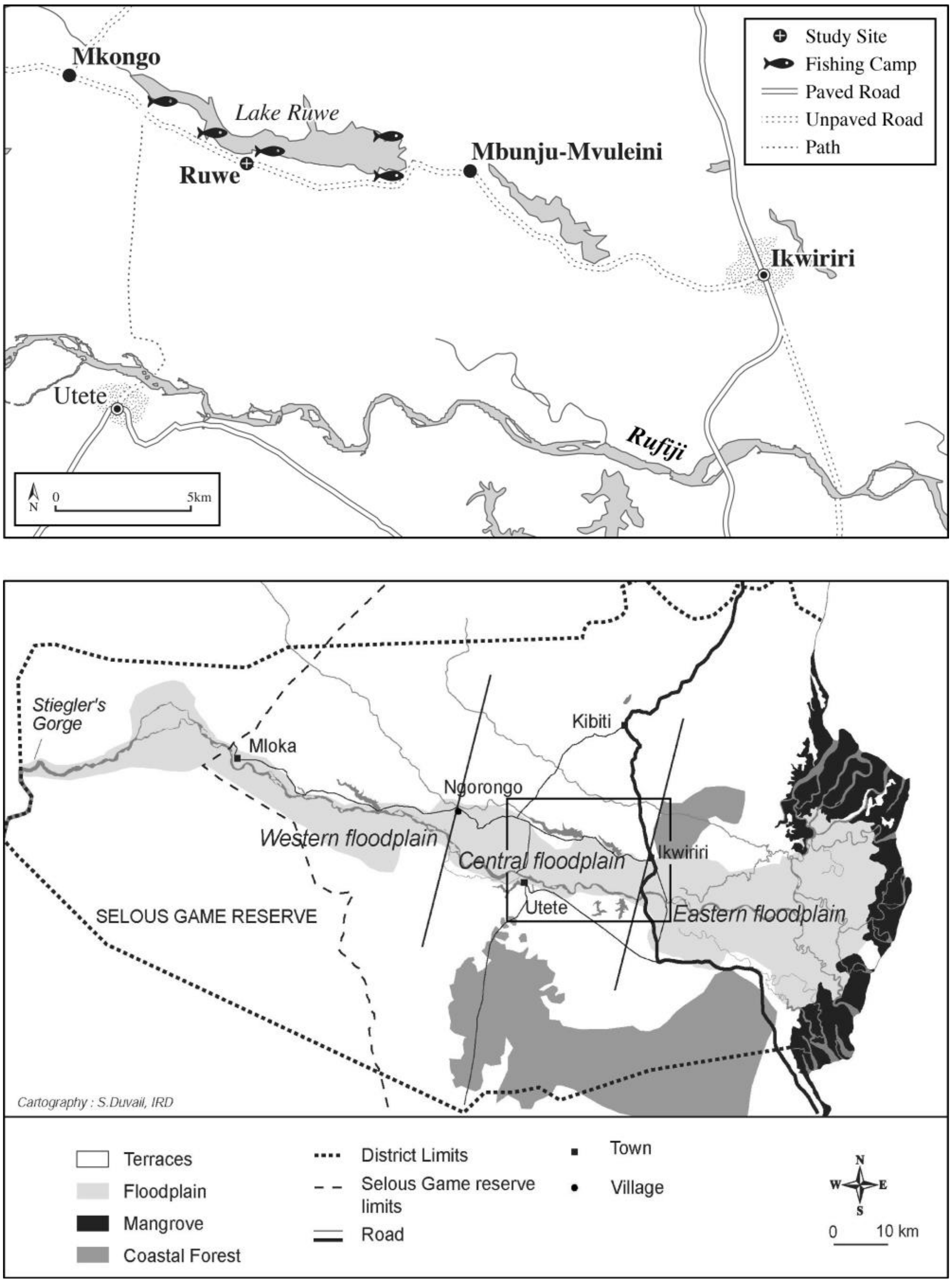
Figure 1.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Study Site
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Stiegler's Gorge
Mloka
Kibiti
Ngorongo
Western floodplain
Central floodplain
Ikwiriri
Utete
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SELOUS GAME RESERVE
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Figure 2.

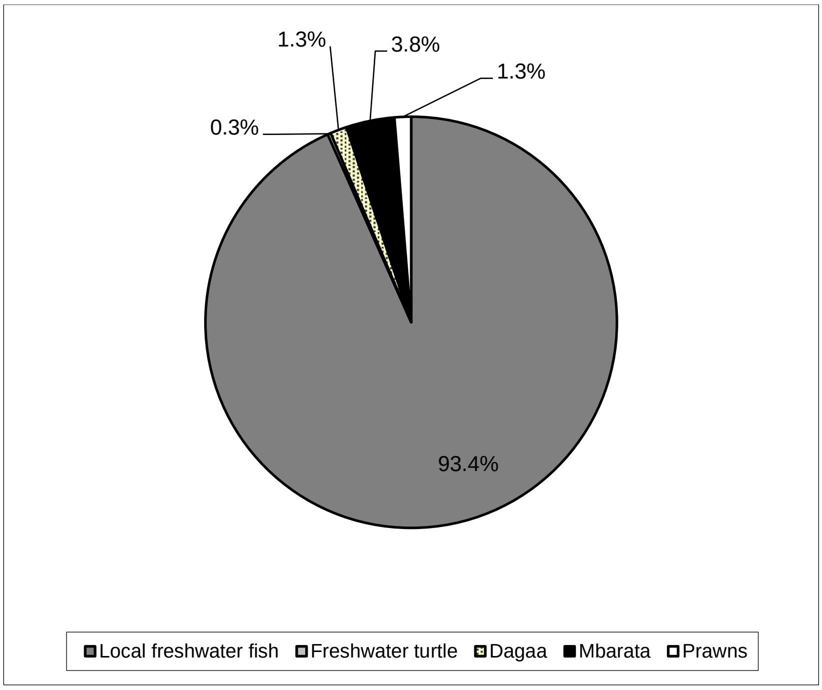


Figure 3.

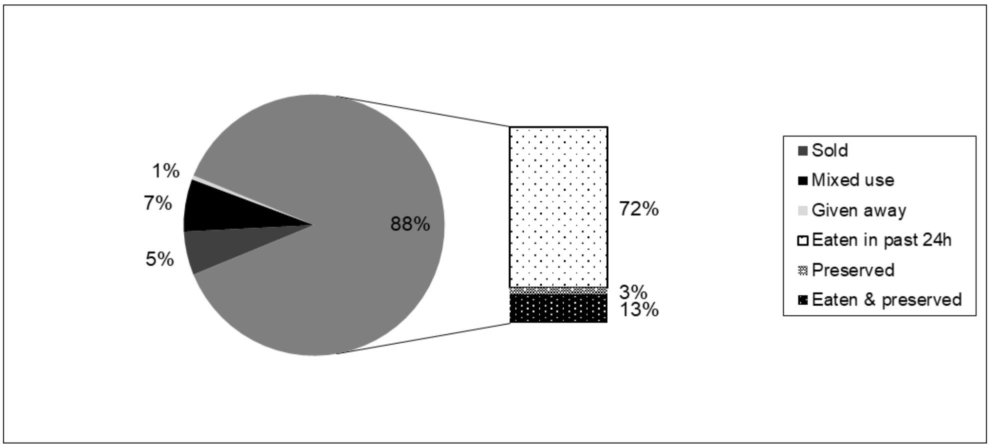
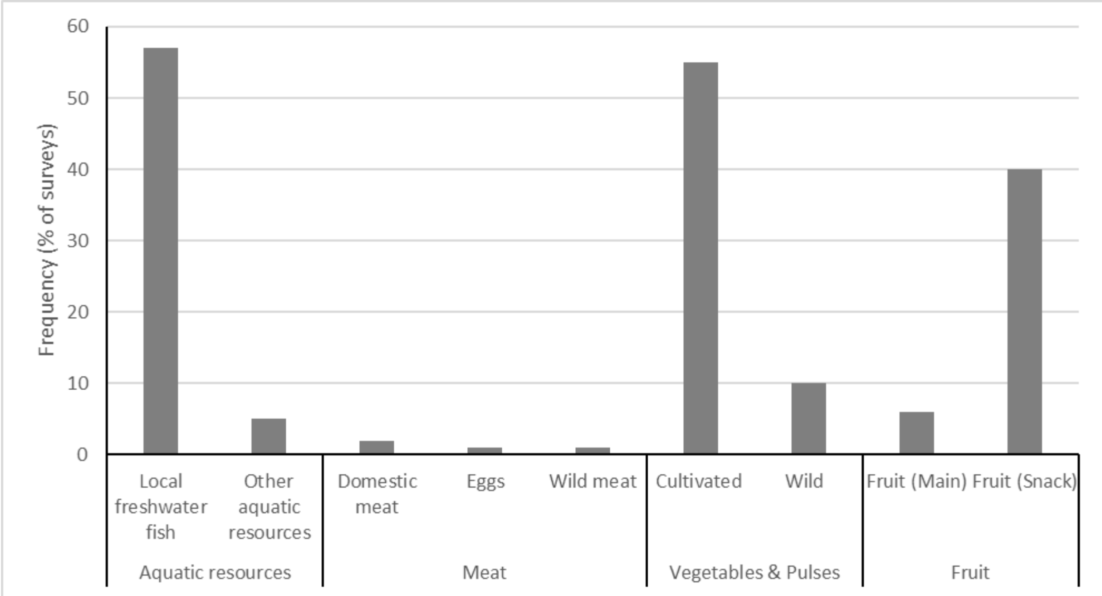


Figure 4.

☐



Note: Fruit are split to reflect whether they were eaten as a main course or as a snack; snacks are likely under-reported, see Methods.

Figure 5.

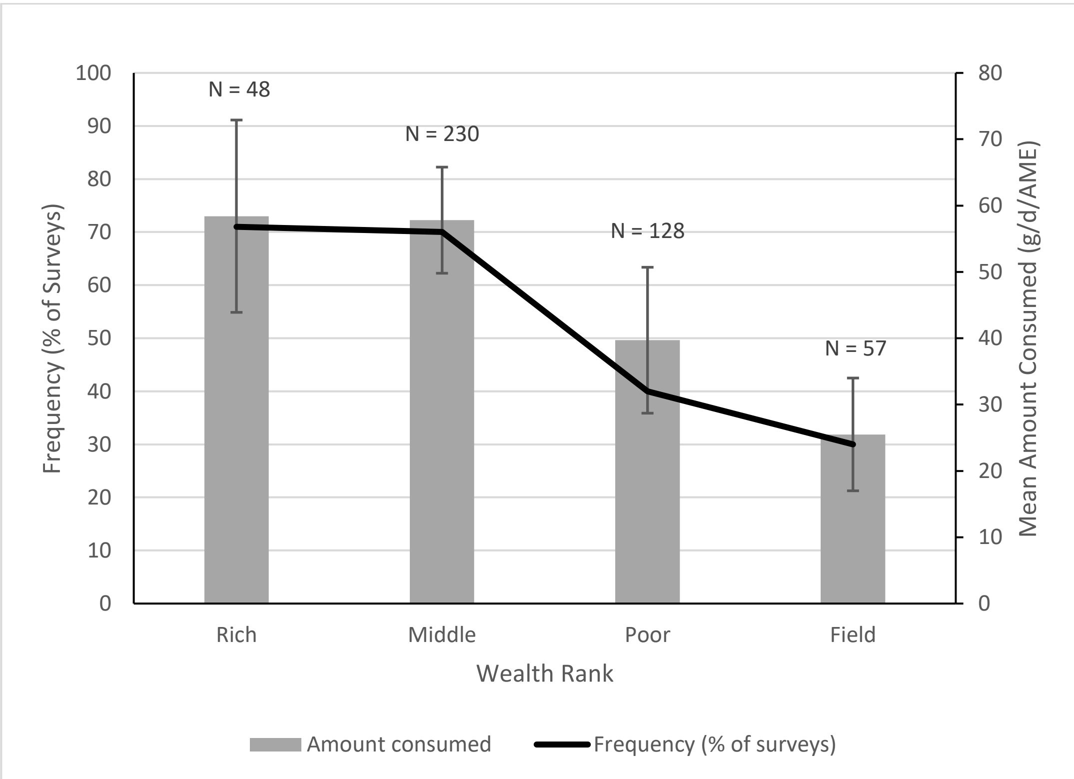


Figure 6.

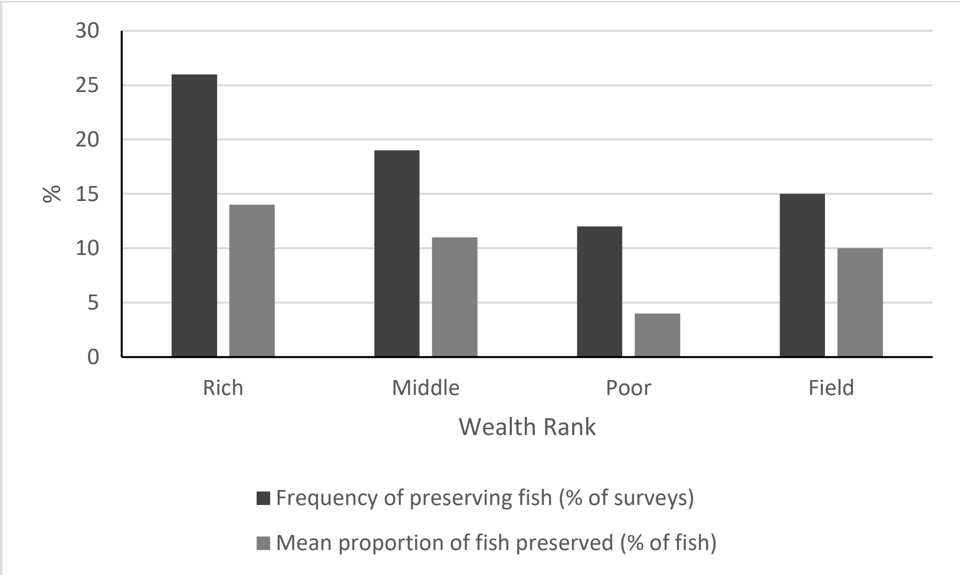


Figure 7.

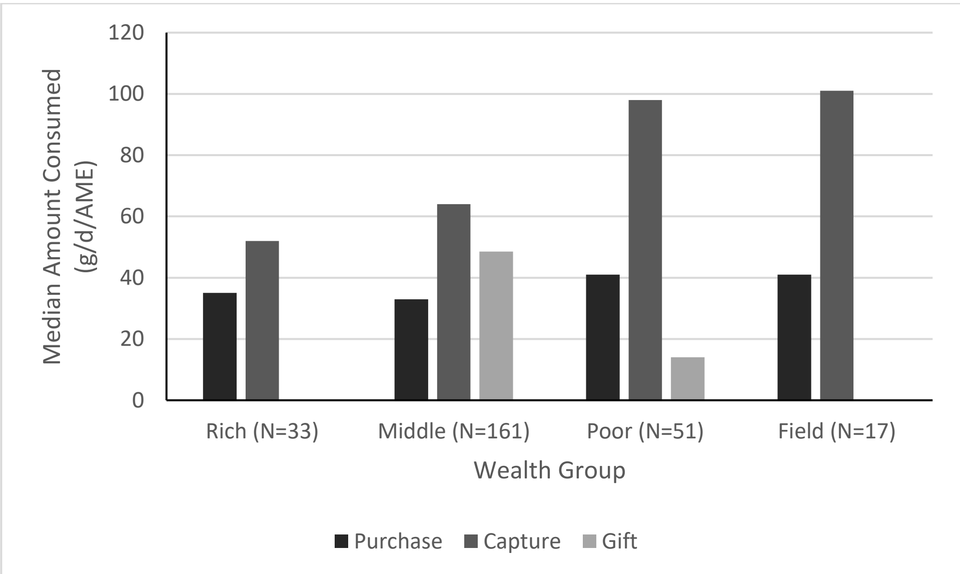


Figure 8.

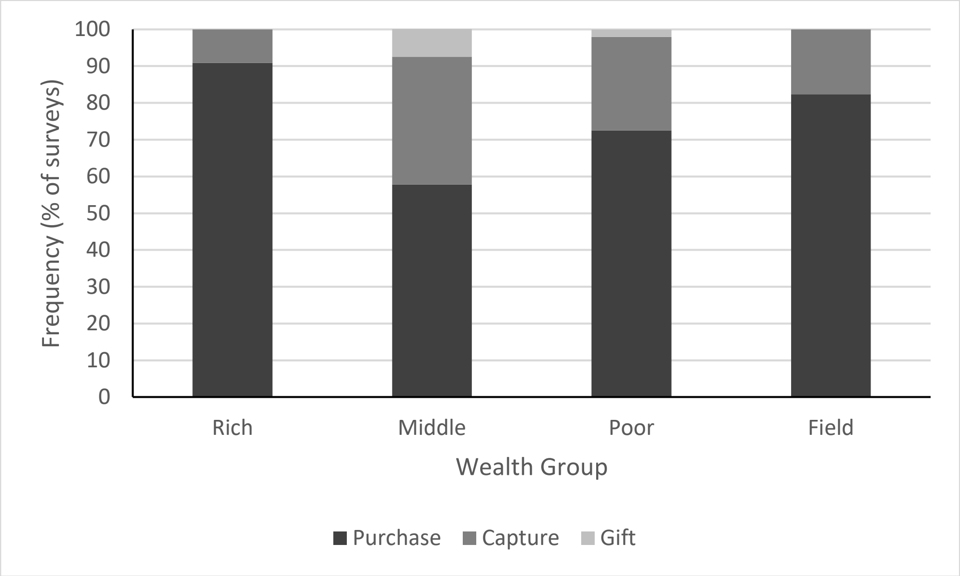


Figure 9.

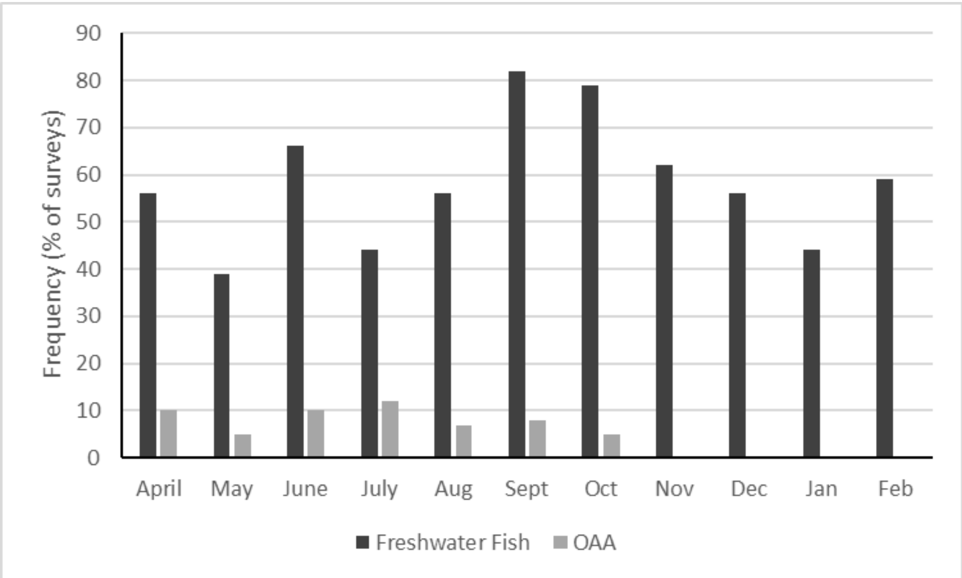


Figure 10.

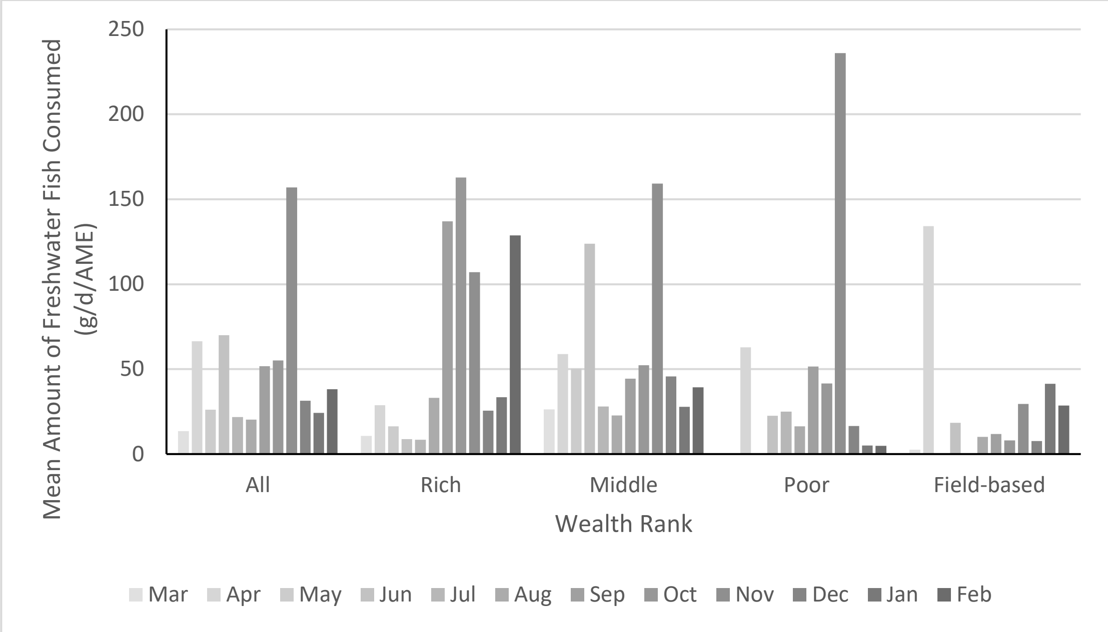

250
200
150
100
50
0
Mean Amount of Freshwater Fish Consumed (g/d/AME)
All
Rich
Middle
Poor
Field-based
Wealth Rank
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb

Figure 11.

Table 1. Frequency of occurrence, number, estimated total weight, proportion purchased (and as fresh, fried or smoked), proportion of sold, and preference score for freshwater fishes reported by households, HARS and group discussions.

Fish Local name	% of freshwater fish records[(1)]	No. of specimens	Est. total weight (kg)	% of records acquired by purchase	Proportion of fish purchased			Of captured fish, proportion sold	Food Preference Score[(2)]
					Fresh (%)	Smoked (%)	Fried (%)		
Kumba	25.4	588	35.5	58.5	92.7	1.8	5.5	25	1
Pele	25.1	3893	183.5[(3)]	74.2	84.1	2.9	13	35	2
Kogo	16.2	831	27	38.3	100			27	1
Ngocho	8.4	169	5.9	77.4	62.5	4.2	33.3	29	3
Kambale	8.1	110	38.7	43.3	69.2	30.8		13	1
Mbufu	3.5	24	17.7	46.2	83.3	16.7		57	2
Tungu	2.7	45	3.9	40	75		25	80	3
Bubu	2.2	21	.1	62.5	60		40	0	3
Kasa	1.9	32	2.9	57.1	25		75	0	1
Beme	.8	170	1.4	33.3			100	50	3
Ndundundundu	.8	?	.3	66.7	100			0	3
Sasile	.8	55	.1	33.3	100			0	-
Zozo	.8	9	.2	-				0	1
Viliampunga	.5	3	.3	-				0	2
Kokoto	.3	5	.01	-				0	3
Mkunga	.3	1	.5	-				0	-
'Mixed'	2.2	162	4.8	62.5	80		20	67	-
Kange*	-	-	-	-	-	-	-	-	2
Mbata*	-	-	-	-	-	-	-	-	2
Mbimbisilo*	-	-	-	-	-	-	-	-	-
TOTAL	100%	6118	323						
N	370								

Notes: Scientific name given in text and Appendix. [(1)]Each mention of a separate aquatic resource on a survey counts as one record. [(2)]Preferred food fishes as ranked by women in our discussion groups, where 1 is most preferred and 3 least. [(3)] Two households landed two large catches, primarily for sale. 'Mixed' were fishes reported as mixed species bunches. *Mentioned in group discussions only.

Table 2. Local aquatic animals (other than fish) named by informants as used for food, medicine and/or other purposes, Ruwe, Tanzania

Local name	*Scientific name* / English name	Food	Medicine/ Witchcraft	Other
Animals				
Boko	*Hippopotamus amphibius*/ Hippopotamus	X		X: cooking oil
Sato	Snake	X		
Ndasi	Turtle	X		
Kamba = Ngamba	Shrimp (*Macrobrachium* sp.?)	X	X	
Mamba	*Crocodylus niloticus /* Crocodile		X	X: sell skin and teeth
Luba	Leeches		X	
Lukorombe / Ukarasa	Clams	X*		X: spoons
Konokono	Snails			X: fish bait
Birds				
Ngolongolupanje	?	X		
Kyobelele	?	X		
Kitipa	?	X		
Bata maji	?	X		

* *Not commonly eaten. Source*: Women's discussion groups, informal interviews.

Table 3. Mean amounts of fish consumed per day as reported in various studies of African populations.

Population	Fish (g/d)	Consumption unit	Source
Lagos State/ Niger State, Nigeria	18/ 31	Per capita	Gomna and Rana 2007
Rural inland community, Gabon (wet/dry season)	39.8/38.3	Per capita	Blaney et al. 2009[1]
Mvae hunter/farmers Cameroon	41	Per capita	Koppert et al. 1993 in Hodgkingson 2009
Farmer/fishermen, Rufiji, Tanzania	**49**	**Per AME**	**This study**
Non-Aka, hunter/farmers, CAR	53.6	Per AME	Hodgkinson 2009
Agricultural community, DRC	60	Per capita	de Merode et al. 2004
Mixed urban, Equatorial Guinea	116.3	Per AME	Albrechtsen et al. 2005
Rural coastal community, Gabon (wet/dry season)	188.2/211.4	Per capita	Blaney et al. 2009
Mixed urban, rural, coastal, forest, Equatorial Guinea	228.6	Per capita	Fa et al. 2009

[1] Includes shellfish

Appendix. Local and scientific names of freshwater fishes reported in study area

Scientific names were assigned by matching local names reported by informants with the taxonomic work carried out by Olivier Hamerlynck and colleagues (pers. comm.). Entries marked with a (*) were reported in group discussions but not recorded on the survey.

Family	Local Name	Scientific Name
ANGUILLIDAE	Mkunga or Mkonga	*Anguilla mossambica, A. bengalensis, A. bicolar*
BAGRIDAE	Mbufu	*Bagrus meridionalis*
CHARACIDAE	Beme or Bembe	*Brycinus* sp. with green fins
CHARACIDAE	Kasa or Ngacha	*Brycinus affinis*
CHARACIDAE	Viliampunga	*Brycinus* sp. with red fins
CHARACIDAE	Kange (*)	*Hydrocynus vittatus*
CICHLIDAE	Kokoto/ Kikokoto	*Astatotilapia bloyeti*
CICHLIDAE	Kumba	*Oreochromis urolepis*
CITHARINIDAE	Pele or Pelege	*Citharinus congicus*
CLARIIDAE	Kambale	*Clarias gariepinus*
CYPRINIDAE	Ngocho or Nguchu	*Labeo congoro*
DISTICHODONTIDAE	Tungu	*Distichodus petersii*
GOBIIDAE	Bubu	*Glossogobius giuris*
MOCHOKIDAE	Kogo	*Synodontis rukwaensis*
MORMYRIDAE	Ndundundundu	*Mormyrus* sp.
MORMYRIDAE	Zozo	*Marcusenius livingstonii*
SCHILBEIDAE	Mbata (*)	*Schilbe moebiusii*
?	Mbimbisilo (*)	*?*
POECILIIDAE	Kisasile/ Sasile	*Pantanodon stuhlmanni*