Prospects and Potential of the African Lungfish (*Protopterus* spp): An Alternative Source of Fishing and Fish Farming Livelihoods in Uganda and Kenya

Indigenous Species Development/Study/09IND07AU

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ABSTRACT

Culture of species resilient to drought and stressed water quality conditions may be a significant part of the future of African aquaculture. Air breathing fishes potentially have a role in low-management culture systems for small farms because dissolved oxygen does not threaten the fish crop. The African lungfish (*Protopterus spp*) is advantageous because it is: an indigenous fish with good quality flesh, an air-breather, and a biocontrol agent against schistosome vector snails. African lungfish wild stocks in Uganda are falling, while no clear, sustainable strategies have been formulated to replenish the diminishing natural populations. Little is known about indigenous practices of culture, harvest, and marketing of *Protopterus spp* from farm ponds and water bodies.

Lungfish is highly valued as a food item in eastern of Uganda, and now is becoming more broadly accepted in the central region. Certain health or nutraceutical benefits are also attributed to the species. Most lungfish is consumed fresh but smoked products are also marketed. The fish is increasingly found alongside tilapia and Nile perch in some rural and urban markets. Nonetheless, there also seems to be some countervailing sociocultural beliefs that continue deter consumers from eating lungfish.
This study assesses the status and potential of lungfish aquaculture in Uganda in seven districts in Kampala, Wakiso, Kumi, Busia, Soroti, Pallisa and Jinja. Semi-structured interviews were conducted with key stakeholders; fish farmers, fisher folk communities, Fisheries officers, scientists, fish traders, and consumers. Socio-economic conditions (prices, demand, and public perceptions) that shape the culture of African Lungfish also were assessed.

INTRODUCTION

Globally, rising food prices have shifted 44 million people into extreme poverty while Uganda has nine million people facing an acute food shortage (World Bank, 2010). Aquaculture provides alternative source to food security and livelihood improvement, in the Sub-Saharan region population (Brummett and Williams, 2000). Lake fisheries continue to decline, and aquaculture production (subsistence and commercial oriented) is less than 1% of total national production (FAO, 2010; Isyagi *et al.*, 2009).
Fish is an important source of protein, contributing 42% of animal protein intake for 2.6 billion people, and, developing countries consider it as a human health asset (Brunner *et al.*, 2009). Increasing human demand for fish as natural wild fish populations are plummeting require urgent solutions (Brunner *et al.*, 2009). High prices of Nile perch and tilapia have reported shifted some consumers toward African lungfish, especially in densely populated areas of Kampala. In rural areas, the capita consumption of fish in general is reported to be as low as 1.9 kg (Nnyepi, 2006). Uganda has the some of the highest

population growth rates in central Africa but continues to have high incidences of chronic childhood malnutrition especially in rural areas (Owor *et al.*, 2000; Nnyepi, 2006; Nalwoga *et al.*, 2010). Aquaculture offers an alternative source to food security and livelihood improvement, in the Sub-Saharan region population (Brummet and Williams, 2000). Aquaculture in Uganda is mainly characterized by culture of Tilapia (*Oreochromis niloticus*), Catfish (*Clarias gariepinus*) and carp (*Cyprinus carpio*) at subsistence and semi –commercial levels; contributing less than 1% of total national production in each country (FAO, 2010; Isyagi *et al.*, 2009). Lungfish farming, therefore, will not only diversify farmed fish products in Uganda but will eventually reduce pressure on the declining stocks from the wild.

Shifting rainfall and temperature regimes are bringing new challenges to the management of water bodies and fish ponds in sub-Saharan Africa. The culture of species resilient to drought and stressed water quality conditions may be a significant part of the future of African aquaculture. Air breathing fishes such as the Marbled African Lungfish (*Protopterus aethiopicus*) are able to obtain and utilize oxygen from air to meet all or part of their metabolic demands. These fish are classified obligate air breathers, as adults of the species asphyxiate when denied access to air. They are carnivorous, eating crustaceans, aquatic insect larvae, and mollusks.

Air breathing fishes potentially have a role in low-management culture systems because dissolved oxygen is not a limiting factor. The African catfish (*Clarias gariepinus*) can tolerate low levels of dissolved oxygen but its flesh is often of less consumer interest. Concurrently, the *Pangasius* catfish's flesh is of high quality but is a species exotic to Uganda. Therefore, the African lungfish (*Protopterus aethiopicus* and *Protopterus amphibious*) is advantageous because it is an indigenous fish with good quality flesh, a biocontrol agent against schistosome vector snails (Daffalla *et al.*, 1985), and has some existing level of indigenous culture (Greenwood, 1966). The food value of the lungfish is enhanced by its high muscle to bone ratio, and its bones and cartilage pose less danger of choking consumers. Statistical estimates of per capita consumption of lungfish grew after 2000, but more recently declined to 6kg/year compared to global level of 12kg and the Sub-Saharan Africa of 7kg (DFR, 2011; FAO, 2011).

The African lungfish is native to the natural waters of Uganda (Birt et al., 2006; Greenwood, 1958, 1986) but rapidly declining, and, therefore endangered mainly due to its overexploitation, environmental degradation and the large-scale conversion of wetlands to agricultural land (Balirwa et al., 2003; Goudswaard et al., 2002). Catch trends of the African lungfish from Uganda waters suggest that quantities caught have stagnated for the past two decades with a peak during 1979 to 1985 period. Generally, there is a decline in the fishery from Uganda waters as quantities dropped from 411,800 metric tonnes in 2005 to 366,600 metric tonnes in 2010 (UB0S, 2010) according to statistics from the Uganda Bureau of Statistics (UBOS). And, yet the country has the highest population growth rates (3.2%) in world (UBOS, 2010; MFPED, 2010), that continues to exert pressure of its natural resources. Furthermore, insurgency in Northern Uganda caused migration to lungfish consuming regions of Uganda. A substantial number of affected people settled around lake regions of Kyoga, Bisina, Opeta and Victoria, most of whom who consume lungfish and regard it as a favorable food item. Thus, the lungfish seems to have broad consumer appeal in Uganda.

Physiology

Lungfish are members of the taxonomy class Sarcopterygii; they are lobe finned fishes (together with coelacanths).[1] The African lungfish is native to East African lakes, swamps, rivers and wetlands (Birt *et al.*, 2006; Greenwood, 1958, 1986). Lungfish are locally important food fishes captured from natural habitats in lakes and reservoirs using a variety of gear including gillnets, long lines, and other methods. It

[1] Order: Ceratodontiformes, Australian, S. American and African species Family: Protopteridae; Genus: Protopterus; there are at least four African lungfish species, Species: *Protopterus aethiopicus* (with three subspecies*), Protopterus amphibious, Protopterus annectens,* and *Protopterus dolloi* (Haeckel 1851).

is an endangered fish in Uganda as its natural stocks are rapidly declining mainly due to overexploitation, environmental degradation and the large-scale conversion of wetlands to agricultural land (Balirwa *et al.*, 2003; Goudswaard *et al.*, 2002). In Kenya's Lake Baringo, however, they dominate catches with annual landings of up to 90 metric tons after being introduced in 1970s and the fishery emerged in 1984 (Mlewa *et al.*, 2005; 2007; Mlewa & Green, 2004; Garner *et al*., 2006).

In nature, aestivating lungfish remain buried in mud cocoons relying solely on air to survive drought periods (lasting several months). Lungfish are periodically exposed to water with low oxygen content or situations into which their aquatic environment dries up. Their adaptation for dealing with these conditions is an out pocketing of the gut, related to the swim bladder of other fishes, which serves as a lung. The African lungfishes are obligate air breathers, with reduced gills in the adults. 2

African lungfish breed at the beginning of the rainy season. They construct nests or burrows in the mud to hold their eggs, which they then guard against predators. When hatched, the young resemble tadpoles, with external gills, and only later develop lungs and begin to breathe air (Goudswaard *et al.*, 2002).

Basic work on pond culture by Mlewa *et al.* (2009) finds indications of early breeding behavior, as the trial lungfish attained sexual maturity slightly earlier than those in wild populations since the lungfish that made burrows and were not accessible for harvest. Culture trial results showed that lungfish realized growth increments of 2.7 and 14.5 cm over time periods ranging from 70 to 238 days. The mean absolute growth rate was 0.049 (±0.008 SE) cm/ day, whereas specific growth rates ranged from 0.048 to 0.140% per day. This study demonstrated that marbled lungfish can be raised in earthen ponds and suggested that further research determine its potential in the aquaculture industry. Furthermore, efforts to develop culture techniques must also address handling and harvesting issues associated with a fish that has a "beak" like a snapping turtle and a tendency to burrow in the soil when a pond is drained (Mlewa *et al.* 2009).

Traditional Practice

Local practice is to excavate lungfish, burrow and all, and store it for later use when they want fresh fish to eat. As use of long lines and gillnets are increasing, Uganda lake and river lungfish populations are decreasing. In Uganda, some women do not eat lungfish under the belief that it is a "sister fish," associated with men and manhood (Bruton, 1998).

Little is known about indigenous practices of culture, harvest, and marketing of *Protopterus spp* from farm ponds and water bodies. Anecdotal evidence suggests farmers gather wild nestlings of lungfish and stock small water bodies but with no documentation of management practices or yields (Mwatete *et al.*, 2005). Preliminary attempts in Kenya to grow wild Marble lungfish (*Protopterus aethiopicus*) 'fry' in earthen pond encountered difficulties because most fish went into burrows and disappeared.

Culture trial results undertaken by Mlewa *et al.* (2009) with African lungfish showed growth increments of 2.7 and 14.5 cm were realized over time periods ranging from 70 to 238 days. The mean absolute growth rate was 0.049 (±0.008 SE) cm/ day, whereas specific growth rates ranged from 0.048 to 0.140% per day (Mlewa *et al.* 2009). This study demonstrated that marbled lungfish can be raised in earthen ponds and suggested that further research determine its potential in the aquaculture industry. Baer *et al.* (1992) succeeded in culturing wild-caught *Protopterus amphibius* juveniles grown in concrete tanks at a

[2] They have two anterior gill arches that retain gills, though they are too small to function as the sole respiratory apparatus. The lungfish heart has adaptations that partially separate the flow of blood into its pulmonary and systemic circuits. The atrium is partially divided, to that the left side receives oxygenated blood and the right side receives deoxygenated blood from the other tissues. These two blood streams remain mostly separate as they flow through the ventricle leading to the gill arches. As a result, oxygenated blood flows mainly to the anterior gill arches and the deoxygenated blood flows to the posterior arches (Goudswaard et al., 2002).

density of two fish per m^2. They obtained good results with fish fed with soft balls containing raw minced beef heart and cooked tilapia.

Efforts to develop culture techniques must also address handling and harvesting procedures associated with a fish that has a "beak" like a snapping turtle and a tendency to burrow in the soil when a pond is drained. Lungfish have sharp plate-like that are not well developed like other types of fish and uses them to feed generally on live fish and mollusks. Its teeth are sharp making dangerous to handle that incidence of some fishermen have lost a finger to lungfish attack. Fishermen use baits (mainly *Clarias* spp) and papyrus made baskets to trap it but use hoes or spears to hit it its head to avoid being hurt or bitten. Baer *et al.* (1992) explains how frequent handling of lungfish stresses the fish leading to aggressive actions, and gentle handling reduced the application tranquilizers. Interestingly, fish farmers have succeeded in seining out lungfish from their ponds but still have to use spears to kill or hoe to kill. Implying that lungfish can be harvested using available gears, nevertheless appropriate technologies will have to be developed to address aquaculture perspectives.

Lungfish ferociously protect their eggs and nestlings which makes it difficult to collect fry or nestling for fish farming. Furthermore, lungfish fingerling rarely swims in schools as observed by many fishermen. Fingerlings are normally seen swimming under mats of water hyacinth (*Eichhornia crassipes*) and around papyrus vegetation which makes it difficult to collect large numbers, for example in thousands. However, Mlewa *et al.* (2009) revealed indications of early breeding behavior, as the trial lungfish attained sexual maturity slightly earlier than those in wild populations since the lungfish that made burrows and were not accessible for harvest. Therefore, it may be possible to develop breeding techniques for lungfish in captivity.

Surveys undertaken by the National Fisheries Resources Research Institute (NaFIRRI) indicate the majority of caught using gill nets and hooks are in stage IV-V which is a mature fish (NaFIRRI, 2005, 2006, 2007) which may indicate a fishery under pressure as the recruitment process is interfered with. The sharp decline is attributed to the increase in population and number of fishing boats. Immature fish is also caught and sold in the markets regardless of stringent regulatory policy in place. Interestingly, the existence of 'immature' females from the wild that have mature eggs is a major challenge to current fisheries regulations to protect immature lungfish.

The literature on African lungfish mainly examines lungfish ecology, fishery, biology, and physiology, but few studies treat its use as a food fish in aquaculture (Baer et al., 1992). Therefore, this study applies what is known about lungfish to explore its aquaculture potentials in improving food security and livelihoods in sub-Saharan Africa. The study assesses indigenous practice and understandings about production parameters and approaches. The field work assesses potential paths for producer adoption and training to use lungfish as a culture species and a managed water body resource.

METHODS AND MATERIALS

The first part of this study involved collecting and collating existing information from government fisheries departments; the Department of Fisheries Resources under Ministry of Agriculture, Animal Industry and Fisheries, District Fisheries headquarters and the National Fisheries Resources Research Institute (Jinja and Kajjansi). Discussions were held with government officials on policy towards lungfish in the wild and in aquaculture, as well as market trends. This information was further supplemented with publications or reports from government agencies.

Field Visits

The second part involved gathering primary information obtained through conversations with fishers, marketers, and consumers about the potential for lungfish culture in Uganda. Informal discussions were

held in eight districts (Kampala, Wakiso, Mukono, Kumi, Busia, Soroti, Pallisa and Jinja). These were districts known to have some level of indigenous practice with lungfish. Local field extension workers provided translation where local languages were spoken (Figure 1). We spent more time with those capturing and marketing lungfish and less time with consumers. We met people at fish farms (34), fish landing sites (10), fish markets (10), restaurants (17) and visited government fisheries offices (11) (Table 1).

Fish farmers, residents of fisher communities, district extension officers, fish traders and scientists were contacted to assess indigenous knowledge and practices associated with the culture and use of lungfish on farms in ponds, in natural water bodies and reservoirs. Guiding questions for the discussions centered on reasons for involvement with lungfish, harvest and handling practices, and fish farming and when it started, problems encountered, and overall views on lungfish.

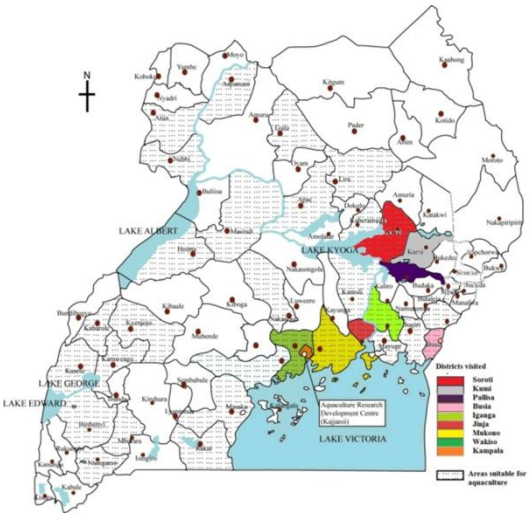


Figure 1. Map of Uganda showing study locales.

We attended fish markets to assess lungfish prices, demand, and public perceptions. We visited fish markets reputed to trade in African lungfish, located within city areas or in proximity to fish landing sites. Lungfish growers, fishers, restaurant owners, consumers, fish traders, wholesalers and retailers were key informants. We asked questions about types of fish supplied or sold, quantity, prices, seasonal variations, and gender participation.

Study districts

Eight districts were purposively selected for field work. We relied on information provided by fisheries officers and administrative records to select study areas. Each is located in areas or zones suitable for aquaculture production and each had reported markets for lungfish.

Table 1. Number of contacts by type and district, Uganda lungfish study, 2011

District	Fish Farmers	Landing sites	Fish Traders	Consumers	Restaurants	Government Institutes*
Soroti	5	1	7	16	2	1
Kumi	6	2	10	11	1	1
Pallisa	2	1	2	5	0	1
Busia	5	1	5	9	1	1
Iganga	0	0	2	0	1	0
Jinja	5	2	6	16	3	2
Mukono	2	0	1	2	2	0
Wakiso	8	2	9	11	3	3
Kampala	1	1	23	24	4	2
Total (n)	**34**	**10**	**65**	**94**	**17**	**11**

*Institutes include District Fisheries Office, National Fisheries Resources Research Institute and Department of Fisheries Resources Headquarters

RESULTS

Lungfish in East Africa

Most lungfish is captured in Uganda's natural waters; contributing over 90% of lungfish caught in the three Lake Victoria countries (Kenya, Uganda and Tanzania). In the period 1975 to 2009, a total of 404,008 tons of lungfish have been caught of which 371,811 tones were caught in Uganda and 32,197 tones captured in Kenya (Figure 2). No records show lungfish caught in Tanzania.
Uganda recorded the highest quantity caught (15,000-22,000 tons) during 1976 to 1985, then decreased during 1985 to 1989, with steady production thereafter. The amount of Lungfish caught in Kenya has stagnated around 1000-3000 tons in the four decades. However, from 2005 onwards statistics generally show a decline in catches.

Figure 2. Lungfish in the market.

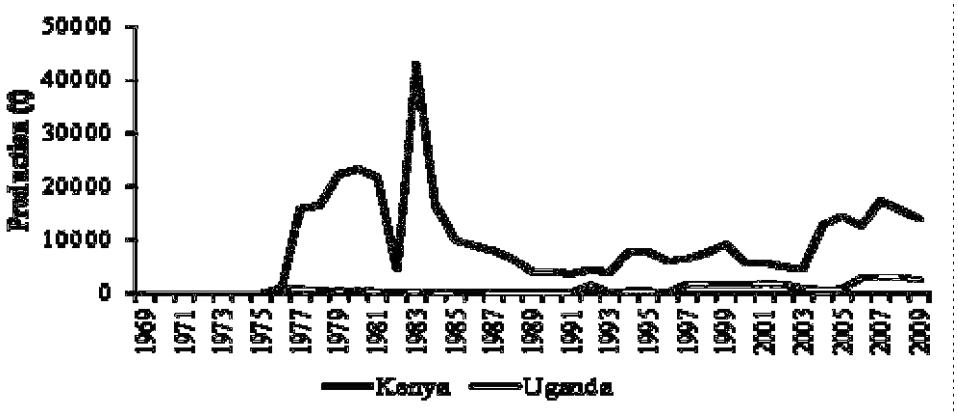


Figure 3. Capture trends of Lungfish caught in Kenyanya, Tanzania and Uganda. Sourced from FAO.

Fisheries of Uganda

Overall, lungfish contributes about 4% of the total fish caught from natural water bodies in Uganda. Tilapia (37%) and Nile perch (42%) are the largest quantity harvested (Figure 3). Lungfish are mainly caught using gill nets, hooks, basket traps, or long-lines.

Nile perch and tilapia catches steadily increased in the period 1969 to 2006, but started declining afterwards. Peak catches of lungfish were seen in the period 1977 to 1983. Thereafter, lungfish catches declined for about six years until 1989 when the quantity stagnated or leveled in thousand tones.

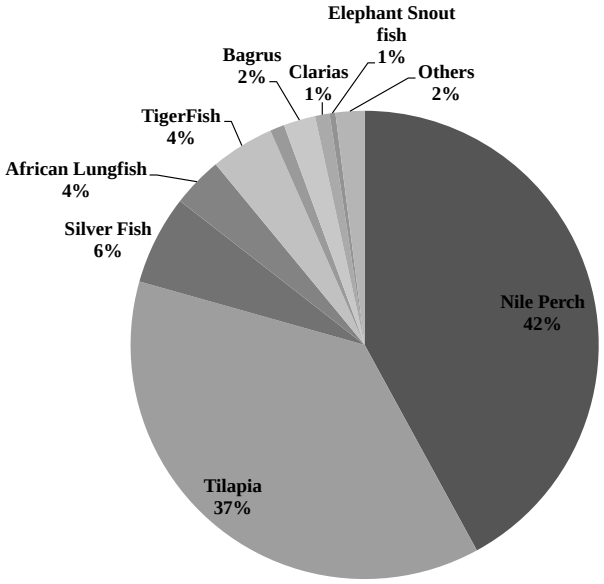


Figure 4. Main fish species caught in Uganda waters (1999).

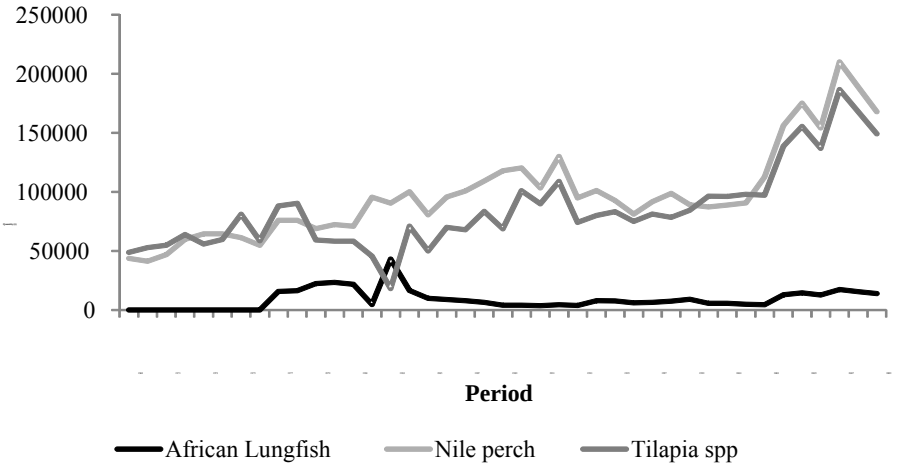


Figure 5. Trends of Fish (Nile perch, Tilapia and African Lungfish) caught in Ugandan Lakes. FAO.

Market Sources

African lungfish is constantly being hunted even during the dry season when it is aestivating. Most lungfish is caught from the wild environments (lakes, swamps or seasonal rivers) and either sold in local markets or consumed directly at home. Breeding sites for African lungfish are disappearing as wetlands are converted to farm land to produce food. Variations in catches occur across districts visited as Kumi and Soroti have the largest quantity caught from Lakes Opeta, Bisina, Nyaguo and Kyoga. Other districts obtain lungfish from Lake Victoria.

Figure 6. A) Fishers at Akidel landing site in Kumi district; B) Size variation of lungfish caught from Lake Opeta.

Over 50% of lungfish (locally known as *Ebileng*) in Kumi district is mainly from Lakes Opeta and Bisina at Ometanga and Akidea landing sites, respectively. Records from Lakes Opeta, Bisina and Nyaguo, taken since 2005, show that lungfish contributes 59% of the total fish harvest, while tilapia (18%), *Clarias spp* (18%), and other types of fish (5%) are also caught (figure 4). High catches of lungfish occur during low tides and the onset of rainy seasons. Nonetheless, most fish are 'immature' or small sized.

Fishermen report that some young female lungfish of sixe 300 grams taken from the wild have mature eggs. Also, according to district officials and residents of fisher communities, the size and numbers of lungfish caught is falling. In the early 1990s, catches were over 3,000 tons per year but recent government records show an annual total of 154 tons. Additionally, over 400 fishing boats are used on the lakes and utilized in turns (day and night), to increase fishing efforts.

Two forms of lungfish are harvested, *eigolo*, the giant lungfish and *ebilongotuba*, a tailless form that is harvested while aestivating in the dry season. Records at landing sites in Busia, Jinja, Wakiso and Kampala districts show that lungfish landings are third after Nile perch and tilapia

There are no clear guidelines to restrain the taking of small lungfish. Most captured lungfish reportedly weight less than a kilogram. In Soroti, lungfish is sourced from Lakes Kyoga and Opeta. However, the average size of lungfish harvested from Lake Kyoga is larger than those caught from Opeta and other small lakes in eastern Uganda.

Evaluating lungfish as a culture species

A total of 34 fish farmers were contacted in eight districts; Soroti, Kumi, Pallisa, Busia, Jinja, Mukono, Wakiso and Kampala. All culture systems visited were earthen ponds averaging 300 m^2. Main fish

stocked include Nile tilapia (Oreochromis niloticus) and the African catfish (*Clarias gariepinus*), cultured in either polyculture or monoculture systems.

Only one farmer in Nangabo (Wakiso district) had stocked ponds with lungfish since 2003. He stocked 1,000 juveniles (length, 15-20 cm) together with Mirror Carp and tilapia in a 400 m^2 pond. He fed the fish with maize bran mixed with mukene (fish meal), once every day for eight months. No proper records were kept to determine the amount fed daily. Fish were kept in ponds for 1.5 years, but yielded 361 adult lungfish that ranged one to three kilograms. He sold the lungfish in Kampala fish markets for about US $ 2.5 – 4.0 per kg. Unfortunately, he abandoned fish farming in 2006 because he was too old to run the farm.

No other fish farmers stocked African lungfish. However, some reported harvesting lungfish from their ponds in areas that are frequently prone floods, especially in Kumi and Soroti. These fish farmers attribute the loss of stocked fish in their ponds to the predation of lungfish from the wild, and, their burrowing habits that cause leaks. One Soroti district farmer claimed to have lost over 70% of the stocked catfish after discovering adult lungfish in his ponds. Furthermore, some farmers reported the presence of lungfish created turbid waters in their ponds. Nevertheless, lungfish found in fish ponds are either consumed at home or sold in nearby markets.

Overall, about 56% of the fish farmers (N=34) were willing to grow lungfish, while 41% where not willing for various reasons. Three percent said they had abandoned fish farming altogether. Those who were willing; Kumi district (28%) had the highest interest then, Soroti (22%), Busia (22%), Wakiso (17%) and Jinja (11%).

The main reasons farmers gave for engaging in lungfish farming were: the availability of markets and good prices (71%); the fish product quality—it does not smell and has a substantial fillet size (23%); and others mentioned the large size—lungfish may exceed one kilogram (6%). Surprisingly, one farmer in Busia had his ponds ready prepared for stocking lungfish fingerlings that he will was going to obtain from shores of Lake Victoria. He felt he could use his catfish-rearing experience to succeed in growing lungfish.

Fish farmers who were not willing to undertake lungfish farming where mainly from the central districts; Jinja (28%) and Wakiso (27%). Others were from Pallisa (18%), Busia (9%), Soroti (9%) and Kampala (9%). The main reasons given were religious and tribal beliefs (36%), centrally concerning attributions of negative impacts on female consumers. Other reasons for not growing the fish related to predation (22%), lack of technical guidance on how to culture lungfish (14%), concerns about its burrowing habits (14%), doubts about its market value (7%), while others had no knowledge of the fish (7%).

Several previous attempts to culture lungfish were reported. In Kumi, some fishermen living around Lake Bisina and Opeta stocked 15-30cm juveniles in excavated holes (40cm diameter; 1m deep). They fed these small batches daily with fish fry (mainly tilapia and catfish), grasshoppers, snails and food trash. No attempts to feed plant materials were reported. After a year, the lungfish reached about 70 cm in length, they were harvested using hooks. According to these fishermen, some lungfish were lost to cannibalism.

Others escaped harvested because they burrowed into pond soils.
In 2009, a fish trader in Bwaise (Kampala) attempted to raise a juvenile (>20cm) in a concrete tank (1x 1 x 0.5 m^3). He fed it with food trash or leftovers from home, harvesting after seven month when the water turned green and smelly. He was disappointed with the 60 cm. average size of the harvested lungfish.

Feeding African lungfish with fry of tilapia and Clarias spp shows that the fish can be polycultured with prolific Tilapia spp. This may be possible if the lungfish is the targeted as the primary cultured fish

because as a carnivore it decimates most of the tilapia population. Raising it in cylindrical dug-holes and concrete tanks provides us with an insight on which culture systems can be used to raise. Lungfish can burrow through pond dykes leading to leaks, and at times of loss of fish. Some advantage could accrue to raising the species in concrete tanks or ponds. One Bwaise trader reported trying to raise lungfish in a concrete tank, but had water quality problems that apparently stunted the fish. Therefore, in culturing lungfish water quality may need to be studied.

Consumption of fish

Per capita fish consumption in Uganda increased from 2000 to 2007, but gradually declined to 6 kg afterwards (DFR, 2011). Most respondents consider fish to be an expensive protein commodity; as result people tended to reduce the amount regularly consumed. Many attribute high fish prices to scarcity from the wild. Most lungfish is consumed fresh, but cured products (smoked and sun dried) also are available in markets.

Diverse views of lungfish as a food item were obtained across the eight districts visited. Those who regularly consume lungfish came from eastern districts (55%)--Kumi, Soroti and Busia. Among the central districts, Kampala (21%) had the highest numbers of consumers of lungfish, in contrast to Wakiso (12%) and Jinja (12%). The main reasons consumers gave for preferring lungfish were: price was cheaper compared to other fish species (Nile perch and tilapia); the taste and fillet size is good and adequate to feed an average family; and for attributed medicinal (treatment and prevention) properties.

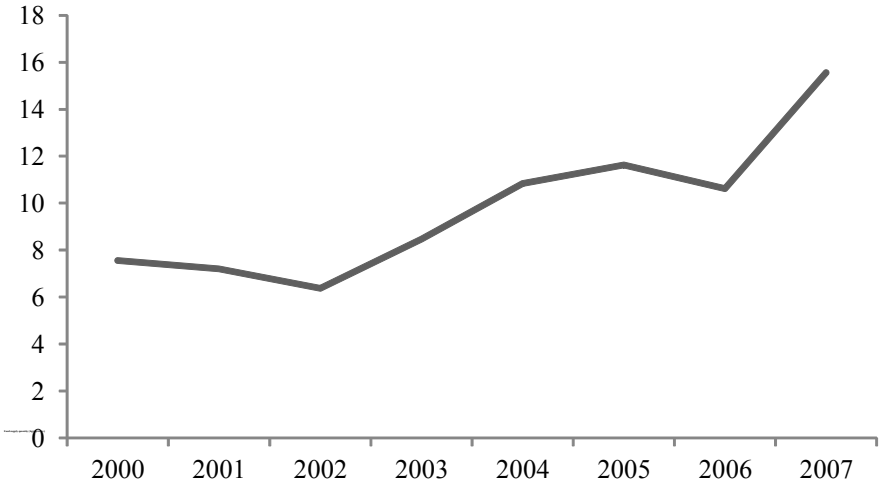


Figure 2. Per capita fish consumption in Uganda from 2000 to 2007. Sourced from FAOSTAT

Lungfish was most highly valued in Kumi and Soroti districts. In the villages, lungfish is often considered a delicacy or special dish that is normally prepared for in-laws. Lungfish seem acceptable to both women and men. Most seem to prefer fresh lungfish, but smoked and salted forms also are found in markets (figure 6). In Busia district, demand for lungfish (locally known as *Emonye*) is high but supply was reported to be low.

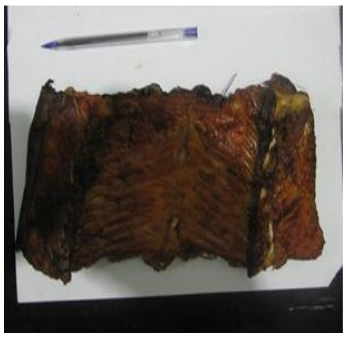
In Pallisa, lungfish is known as *Nakibalo or Mamba* mainly caught from Lake Lamwa. It is not popular amongst the Bagwere communities. It is popular at the landing sites were the Iteso form the majority residents. Central region had the highest number of respondents (82%) who had never eaten lungfish, but far fewer in Wakiso (35%) and Kampala (23%). A few respondents in the eastern region Pallisa (9%) and Busia (9%) had not eaten lungfish; but none in Kumi and Soroti. Main reasons given for not eating

lungfish were: tribal or traditional beliefs that restricts them from eating lungfish (61%); no prior knowledge about the fish (25%); religious beliefs about 'scale-less' fish (11%); and others could not eat it because of its external appearance (3%).

A few respondents came from Mbale district where lungfish is called *Nambere*. In that region lungfish are mainly obtained from Namatala and Mpologoma streams around Lake Nakuwa. In Mbale, lungfish is not popular among the Gisu community to the extent that cooking utensils were separated if used to prepare lungfish.

In this study over 70% of the respondents were female. About 68% report having eaten lungfish. Again, the majority come from the eastern region districts of Kumi and Soroti. One striking difference observed is in Kampala district where over 60% of female respondents eat lungfish. Lungfish also is sought for its ascribed benefits for human health. It is used to treat women's breasts for problems of lactation; the fish's pancreas is reportedly used to treat alcoholism. The tail is used to enhance male's sexual performance. Eating lungfish is believed by some to boost the immune system.

Smoked piece of lungfish



Fresh lungfish gutted

Figure 8 (left). Lungfish products observed in local markets

Figure 9 (right). Lungfish market in Bwaise, Kampala.

Restaurants

Only a limited number of restaurants in the study locales have lungfish on their menu. Only six (35%) restaurants visited prepared lungfish for their customers. Smoked and fried products where the main dish sold in restaurants. However, restaurants in Jinja and Busia reported that lungfish is normally prepared on prior request by customers. Some restaurants or Bars in Kabusu and Owino in Kampala have specialized in selling fried African Lungfish to its customers. Most customers like African lungfish meat because it is not fatty, does not smell like Nile perch and is satisfying.

Lungfish markets

Fish traders play an important role in mediating lungfish fishers, farmers, and consumers. Wholesale prices for fresh lungfish range between US $ 0.9 to 1.80 per kg while retail prices can go beyond US $ 2.5 per kg depending on the location. Price for cured products (smoked) range from US $ 3 – 4 per piece. Prices of lungfish are relatively lower in rural areas than in populated towns or cities. Also, juveniles of about 15cm total length are treated as by-catch and marketed in clusters. Others are prepared and eaten fresh after being gutted.

In some Kampala suburbs, kiosks that used to sell Nile perch products commonly known as “fille” are now substituting it with African lungfish. Low income residents, particularly youth are regular customers. Majority kiosks selling fried lungfish are owned by women who procure the fish from major fish markets in Kawempe-Bwaise (Kampala) and Busega (Wakiso). Some women have taken loans to initiate their lungfish businesses. Fish traders play an important role in mediating lungfish fishers, farmers, and consumers.

Information derived from this study on consumers’ perspective may not be conclusive but we see a change in life style in the consumption towards lungfish. Bruton (1998) reports that some women do not eat the lungfish because they consider it a "sister fish", with some undesirable consequences for the female consumer. In this study we observed not only active participation of women in lungfish trading but also consuming it. Some districts had low rates of lungfish eater among women and men especially in the central region where it is not customary consumed by some clans. Nevertheless, the field observations suggest increasing interest in lungfish consumption, locally and regionally.

Harvesting and handling

Farmers normally harvest the lungfish after completely draining the pond. Others have ever harvested lungfish using pond seine nets. To identify the presence of lungfish in the pond, farmers trace clear waters along the bank and extract it from the holes using hoes and spears. In Soroti and Kumi, farmers detect the presence of lungfish in burrows by tying a tuft of grass around their legs or stick, which the fish seizes with its plate like teeth. As it holds on to bait its extracted from the hole, slowly, hit on the head using a hoe or spear. Other farmers also use baits on hooks usually *Clarias* spp and earthworms caught from the wild. The *Clarias* spp bait is the most effective bait. It is easy and safer to harvest them during the dry season because they are relatively inactive. Lungfish harvested is handled around the neck avoiding the mouth parts.

Figure 10 (left). Lungfish nest with fry along shore of Lake Opeta, Uganda.

Figure 11 (right). Eggs extracted from a female lungfish.

Hooks and basket traps (locally called *Ekolo*) are mainly used to catch the lungfish in seasonal wetlands. In the dry season (December, January and February) lungfish is dig-up from holes using hoes when the local communities cultivate or hunt around the wetlands. Women play a major role in lungfish fisheries; hunting, post harvesting processes and the marketing. In Pallisa, lungfish is locally known as *Nakibalo or Mamba*. The fish is mainly caught from Lake Lamwa using hooks number 5, gill nets of 4 to 4.5 inches and baits used include pieces of meat, rats, and frogs. In Busia lungfish is sourced from the shorelines of Lake Victoria and swampy areas using hooks (number 12), basket traps and spears.

Identifying simple fingerling production techniques

No established procedures have been yet been developed to produce lungfish fingerlings. All fingerlings were acquired from the wild, mainly from mats of water hyacinth (*Eichornia crasipes*) and in the nests. Furthermore, obtaining a substantial number (more than 1000s) may be difficult as many lungfish fingerlings are reported to swim individually rather than in schools. However, fishermen can time breeding seasons of lungfish when the fry or fingerlings are available; during the onset of rains.

It is difficult to distinguish males from males lungfish because they appearance is similar but some speculate orientation of genital opening beneath the pelvic fin may correlate with the sex of the fish. The female genital opens on the right while the male opens to the left. Some fishermen did not agree to this revelation because at times fish that is thought to be a male normally has eggs when gutted.

The female produces very many eggs and lays them in stagnant water in a hole or a nest away from sunlight and guards them. The eggs are deposited on the base of the nest and the male fertilizes them later. It is not known how long it takes for the eggs to hatch in such conditions. It is very difficult to get fertilized eggs or fry from the nest because the lungfish ferociously guards the nest. However, one can extract eggs from a wild caught female.

CONCLUSION

The study assessed indigenous practice and understandings about lungfish as a potential culture species in Uganda and more broadly in Sub-Saharan Africa. Fish farmers already have inadvertently farmed lungfish that entered their ponds during flood periods. An experiment program in needed to establish production parameters as little is known about the growth cycle and nutritional needs of farm-reared lungfish. For example, optimal water temperatures, salinity tolerance, and other basic parameters of the species are not known. It is understood that they survive and grow alongside tilapia, for example, but optimal feed composition and lungfish grow-out strategies remain to be articulated.

At present, growers are reliant on wild-caught lungfish fry for what limited culture is currently taking place. Research must clarify the reproductive cycle of the lungfish to enable farm-based spawning and seedstock production of uniform batches of genetically advantaged fish. A clear foundation for establishing an industry, the biology and manipulation of lungfish reproduction processes is not well-understood.

Farmers have developed indigenous means for handling and managing lungfish in natural water bodies and farms ponds. These are a beginning to be discovered and codified. Promoting wider levels of production of lungfish will require articulation of model production strategies and management systems that account for the burrowing and mobility of lungfish. Clearly, cage culture would overcome some of the known difficulties, but this work has not yet been accomplished.

Lungfish is a delicacy among groups in the Northern, Eastern and some parts of western Uganda. Thus the present and potential consumer demand for the species is fairly well-established. The field work assessed potential paths for producer adoption and training to use lungfish as a culture species and a managed water body resource.

Lungfish may be raised on artificial diets as all fish farms that had the fish in their ponds applied commercial pellets to catfish or tilapia stocked. Efforts to domesticate African lungfish are foundational to the advance of a commercial industry providing a valuable food item to people in need of affordable protein.

This study shows how initiatives to culture the fish build on indigenous knowledge and practice to formulate a broader strategy of widespread production. Future studies will explore the relative advantages of different culture systems (tanks, ponds and cages), while addressing specialized procedures for grow-out and harvest.

The socioeconomic viability of African lungfish as a new culture species is beginning to be established. This report identifies the central issues of reproduction, feeding, and management that must be addressed in order to build an industry with a value chain that delivers quality products to consumers and a sustainable return to small- and medium-scale producers in Uganda and across Sub-Saharan Africa.

ACKNOWLEDGMENTS

This work is being supported AquaCRSP under the USAID. We thank Karen Veverika (Auburn University) who provided technical guidance. Special thanks to government fisheries technocrats and Maureen Kaitesi (Research assistant) for guiding the investigating team.

LITERATURE CITED

Baer, S., Haller R. D., Freyvogel T. A. (1992). Growth of the African lungfish, Protopterus amphibious Peter, in aquaculture. Aquaculture Research 23, 2, 265-267.

Balirwa, J.S, Chapman C. A, Chapman L.J, Cowx I.G, Geheb K, Kaufman L, Lowe-McConnell R. H, Seehausen O, Wanink J.H, and Welocomme R.L and Witte F. (2003). Biodiversity and fishery sustainability in the Lake Victoria Basin: an unexpected marriage? BioScience, 53(8):703-716. 2003.

Birt, T.P, Mlewa. C. M, Green M, Seifert. A. and Friesen V. L. (2006). Genetic variation in the marbled lungfish *Protopterus aethiopicus* in Lake Victoria and introduction to Lake Baringo, Kenya. J of Fish Biology 69, 189-199.

Boyd, C. E., S. Soongsawang, E. W. Shell, and S. Fowler. (2010). Small impoundment complexes as a possible method to increase water supply in Alabama. Proceedings of the 2009 Georgia Water Resources Conference, University of Georgia, Athens, Georgia, USA.

Brummett R.E and Williams M. J, (2000). The evolution of aquaculture in African rural and economic development. Ecological Economics 33 (2) 193-203.

Brunner E. J, Jones P. J.S. Friel. S and Bartley M. (2009). Fish, human health and marine ecosystem health: policies in collision. International Journal of Epidemiology 38 (1):93–100.

Bruton, Michael N. (1998). In Paxton, J.R. & Eschmeyer, W.N.. ed. Encyclopedia of Fishes. San Diego: Academic Press. pp. 70–72. ISBN 0-12-547665-5.

Daffalla, A.A., Elias E.E., Amin M.A. (1985). The lungfish Protopterus annectans (Owen) as a biocontrol agent against schistosome vector snails. J Trop Med Hyg. Apr 88(2):131-4.

Dunbrack, Green & Mlewa. (2006). Lungfish growth - Journal of Fish Biology 68, 443-447.

FAO. (2010). The State of World Fisheries and Aquaculture. 2010. Rome Italy.

Garner, S., T. P. Birt, C. M. Mlewa, J. M. Green, A. Seifert, V. L. Friesen. (2006). Genetic variation in the marbled lungfish Protopterus aethiopicus in Lake Victoria and introduction to Lake Baringo, Kenya. Journal of Fish Biology 69(b), 189-199. Retrieved September 22, 2011 http://onlinelibrary.wiley.com/doi/10.1111/j.1095-8649.2006.01224.x/full

Goudswaard, K.P.C., F. Witte, and L. J. Chapman. (2002). Decline of the African lungfish (*Protopterus aethiopicus*)in Lake Victoria (East Africa). Afr. J. Ecol., 40, 42-52.

Goudswaard, Kees, Frans Witte, Lauren J. Chapman. (2002). Decline of the African lungfish (*Protopterus aethiopicus*) in Lake Victoria (East Africa) East African Wild Life Society, African Journal of Ecology, 40, 42-52.

Greenwood, P. H. (1966). The Fishes of Uganda. The Uganda Society, Kampala.

Greenwood, P.H. (1958). Reproduction in the East African lung-fish *Protopterus aethiopicus* Heckel. Proc. Zool. Soc. London 130, 547-567.

Greenwood, P.H. (1986). The natural history of African lungfishes. J. Morph. Suppl.1,16 3-179. http://www.ubos.org/onlinefiles/uploads/ubos/pdf%20documents/2010StatAbstract.pdf. Retrieved 1st September 2011.

Isyagi N, Atukunda G, Aliguma L, Ssebisubi M, Walakira J, Kubiriza G, Mbulameri E (2009). Assessment of national aquaculture policies and programmes in Uganda. Aquaculture Compendium. 87 pp.

Mlewa and J. Green (2004). Biology of the Kamongo African Journal of Ecology 42, 338-345.

Mlewa, C.M. & J. Green (2006). Introduction and Fishery - African Journal of Aquatic Science 31, 131-136.

Mlewa, C.M. C.M., Green & Dunbrack (2007). Lungfish respiration in the wild. African Zoology 42, 131-134

Mlewa, C.M., Green and Simms (2005). Movement and space Use. Hydrobiologia 537, 229-238.

Mlewa, C.M., J. Green & Dunbrack (in Press) Natural history (Book Chapter: Jorgensen & Joss (Eds).

Mlewa, M. C., Ogola, D. W. and Ngugi, C.C. (2009). Aspects of the biology of marbled lungfish (Protopterus ethiopicus) raised in earthen ponds at the Chepkoilel fish farm, Kenya. Journal of East African Resources Management 16: 231-34.

Moehl, J., M. Halwart, and R. Brummett. (2005). Report of the FAO-World Fish Center Workshop on Small-scale Aquaculture in Sub-Saharan Africa: Revisiting the Aquaculture Target Group Paradigm. Limbé, Cameroon, 23-26 March 2004. CIFA Occasional Paper. No. 25. Rome, FAO. 2005. 54p. Retrieved 14 January, 2009: http://www.fao.org/docrep/008/a0038e/a0038e04.htm#TopOfPage.

Mwatete, M. C., Ogola, D. W., and Ngugi, C.C. (2005). Towards the recruitment of marbled lungfish (Protopterus ethiopicus) in aquaculture in the lake Victoria basin: some preliminary results of culture trials at the Chepkoilel fish farm, Kenya. 2nd National Scientific Conference, Lake Victoria Environmental Management Project. 17th to 19th October 2005. Tom Mboya College, Kisumu, Kenya.

UBOS. (2001). The 2000/01 Ugandan Demographic and Health Survey. Kampala: UBOS

UBOS. (2002). Uganda DHS EDU Data Survey 2001. Kampala: UBOS.

Wikipedia. (2011). Protopterus. Retrieved May 14, 2011, http://en.wikipedia.org/wiki/Protopterus

World Bank. (2010). Global Economic Prospects 2010: Crisis, Finance, and Growth. Washington, DC (www-wds.worldbank.org).