# Prospects and Potential for Aquaculture of African Lungfish in Uganda

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Shifting rainfall and temperature regimes are bringing new challenges to the management of water bodies and fish farms in sub-Saharan Africa (Dixon *et al*. 2003). Culturing species that are resilient to drought and stressful water quality conditions may be a major part of future African aquaculture. Air-breathing fishes, such as the African lungfish *Protopterus aethiopicus*, can use atmospheric oxygen to meet all or part of metabolic demands (Mlewa *et al*. 2007). Air-breathing fish have a role in managed fisheries and low-management culture systems where dissolved oxygen concentration is not a limiting factor. Among air-breathing fishes, the African catfish *Clarias gariepinus* can tolerate low levels of dissolved oxygen but its flesh is held in lower esteem by consumers as compared to lungfish. The quality of *Pangasius* catfish flesh is high but it is not a native species in Africa.

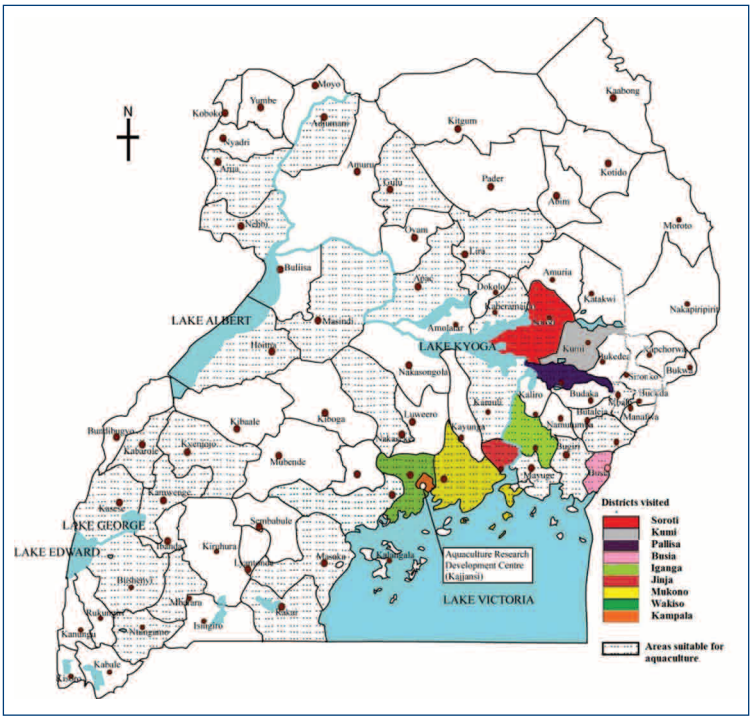


FIGURE 1. *Map of Uganda indicating districts visited for farmer and consumer surveys and districts suitable for pond aquaculture.*

African lungfish is native to the natural waters of Uganda (Greenwood 1958, 1986, Birt *et al*. 2006) but populations are rapidly declining and the species is now endangered, mainly caused by overexploitation, environmental degradation and large-scale conversion of wetlands to agricultural land (Goudswaard *et al*. 2002, Balirwa *et al*. 2003). Therefore, it is essential to develop aquaculture to relieve pressure on natural stocks. This article explores the potential of African lungfish aquaculture to improve food security and livelihoods in Uganda; identifies indigenous production practices and approaches; consumer perspectives and markets; and an outlook for lungfish fisheries and aquaculture in Uganda and sub-Saharan Africa.

## Lungfish Biology and Ecology

African lungfish are members of Class Sarcopterygii[3], lobe-finned fishes, obligate air breathers, with reduced gills in adults[4]. The species is widely distributed in freshwater ecosystems, including swamps, rivers and lakes of sub-Saharan Africa (Greenwood 1958, 1966, 1986). In nature, lungfish are periodically exposed to water with low dissolved oxygen and seasonal drought. In response, lungfish will aestivate for several months in mud cocoons, re-emerging when water levels rise.

Lungfish are carnivorous, feeding on crustaceans, aquatic insect larvae and mollusks. Feeding on snails makes lungfish a suitable biocontrol agent for schistosomiasis (Daffalla *et al*. 1985). The African lungfish has a beak like that of a snapping turtle and dentition in the form of sharp occluding blades that make handling live fish hazardous.

Lungfish reproduce by laying eggs inside a burrow made in shallow water during the rainy season when temperatures reach 24 C (Greenwood 1958, 1986, Mosille and Mainoya 1988, Mlewa and Green 2004). It is very difficult to visually distinguish males from females because genital structures are similar. There is also asymmetry in the position of the cloacal opening in both sexes (Mlewa and Green 2004). Males have broader pectoral fins and snouts than females (Greenwood 1958).

## The Lungfish Fishery

Lungfish are captured using gillnets, hooks on long lines and basket traps. The basket traps (ekolo) are mainly used to catch lungfish in seasonal wetlands. In the dry season, January to March, aestivating lungfish can be dug up easily from holes when residents cultivate or hunt in wetlands because the fish are relatively inactive. Women play a major role in lungfish hunting, post-harvest processing and marketing. In Pallisa and Busia districts, lungfish, nakibalo or mamba (*P. aethiopicus*) were harvested using hooks (no. 5-12), gill nets (10.2 to 11.4 cm mesh), baits (pieces of meat, rats and frogs), basket traps and spears. Most fish caught with gill nets and hooks are mature

fish (NaFIRRI 2005, 2006, 2007), indicating a fishery under pressure because the recruitment process is disrupted.

In the study area (Fig. 1), lungfish ranked third in fisheries catch after tilapia and Nile perch. However, lungfish (ebileng) captured from Lakes Opeta, Bisina and Nyaguwo (Kumi District) represents 59 percent of the catch; other species include tilapia (18 percent), *Clarias* spp (18 percent) and *Mormyrus* spp (5 percent). Two forms were commonly harvested in this region; eigolo, the giant lungfish, and ebilongotuba (*P. aethiopicus*), the tailless form captured while aestivating in the dry season. The average size and numbers of lungfish has fallen markedly in this area during the past decade from increased demand. For example, production from Lake Opeta fell from 3000 t (early 1990s) to 154 t, exacerbated by an increase in fishing vessels (over 400) and consequent overfishing. Also, fishermen acknowledge catching undersized but sexually mature lungfish of less than 300 g (Fig. 2) from Lakes Opeta and Bisina, suggesting a plasticity of response to increased fishing pressure.

FIGURE 2. *Large size variation (100 – 1300 g) of lungfish captured in Lake Opeta, Uganda.*

**AFRICAN LUNGFISH IS NATIVE TO THE NATURAL WATERS OF UGANDA BUT POPULATIONS ARE RAPIDLY DECLINING AND THE SPECIES IS NOW ENDANGERED, MAINLY CAUSED BY OVEREXPLOITATION, ENVIRONMENTAL DEGRADATION AND LARGE-SCALE CONVERSION OF WETLANDS TO AGRICULTURAL LAND.**

Regionally, over 90 percent of African lungfish is caught from Uganda's natural waters, including lakes, rivers and floodplain wetlands that constitute about 20 percent of its surface area (Hecky and Bugenyi 1992). From 1975 to 2009, about 404,000 t of lungfish were harvested; 371,811 and 32,197 t from Uganda and Kenya, respectively and none from other East African countries at the time of this study (Fig. 3). Capture fisheries production of African lungfish in Uganda peaked during 1976 to 1985 but decreased thereafter (Fig. 4). Lungfish contributes only 4 percent to national fish production, as compared to the two major species of Nile perch (42 percent) and tilapia (37 percent).

## Lungfish Fishery Regulation

The lungfish fishery is regulated under the Fish Act (Cap. 197) of 2000, which prohibits capture of immature fish. The law emphasizes tilapia and Nile perch fishing, making enforcement to protect lungfish difficult to implement. The Fish Act does not have a size limit for immature African lungfish. Fish farmers are exempt from marketing undersized fish, allowing these fish to compete favorably with wild fish. The National Environmental Statute of 1995 provides for sustainable use and conservation of the environment and natural resources of Uganda. The Aquaculture Rules of 2003 permits export of live male *P. aethiopicus* from Uganda, which indirectly protects local fish farmers.

## Lungfish Aquaculture

Previous attempts to grow African lungfish in captivity provide insights into its aquaculture potential. Baer et al. (1992) succeeded in growing wild-caught gilled African lungfish *Protopterus amphibious* juveniles in concrete tanks that were fed on soft balls of feed containing raw, minced beef heart and cooked tilapia. In another study, marbled lungfish *Protopterus aethiopicus* fingerlings raised in earthen ponds grew 2.7 to 14.5 cm from 70 to 238 days and at specific growth rates of 0.048 to 0.140 percent per day, with indications of early maturation compared to wild populations (Mlewa et al. 2009). However, all fish could not be harvested because most burrowed into pond soils.

Field interviews were conducted in eight districts: Kampala, Wakiso, Mukono, Kumi, Busia, Soroti, Pallisa and Jinja (Fig. 1). These districts are known to have good potential for aquaculture development and with communities known to consume African lungfish. Fish farmers (n=34) and residents of fishing communities (n=10) were interviewed to assess indigenous knowledge and practices associated with the culture and use of African lungfish.

Most fish farmers in Uganda grow Nile tilapia *Oreochromis niloticus* and African catfish *Clarias gariepinus* in earthen ponds. However, in field interviews with farmers, there were three cases where lungfish were raised in captivity by individuals using indigenous knowledge. Lungfish seed are collected from around lake shores or swampy areas from July to November. It is a challenge to collect a substantial number of seed from the wild, inasmuch as fishermen observe them swimming individually rather than in schools.

One farmer in Nangabo (Wakiso district) polycultured 1,000 lungfish juveniles (15-20 cm) with 400 mirror carp and 800 tilapia fingerlings in a well-constructed, 400-$m^2$ pond. Juveniles were collected from Lake Victoria, beneath nearshore water hyacinth (*Eichornia crassipes*) mats, after contracting fishermen for US$ 0.20-0.50 per fish. Fish were raised for about 1.5 years using mukene (*Rastrineobola argentea*) powder mixed with maize bran, feeding once daily. There were no records to show amount of feed applied but about 400 adult lungfish (1-3 kg) and 381 tilapia (average 250 g) were recovered after completely draining the pond. Live farmed fish in plastic containers (1000-L) were sold in Kampala, where lungfish retailed at US$ 2.50-4.00/kg and tilapia at US$ 1.00-1.50/kg.

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A fish trader in Bwaise attempted to grow seven juveniles (20 cm) in a concrete tank (1 x 1 x 0.5 m) with stagnant water. Fish were fed with an unknown quantity of food waste and harvested after seven months at >500 g (average 80 cm) when water quality deteriorated.

In Kumi, some fishermen excavate holes (40-cm diameter, 1-m deep) adjacent to Lake Opeta and stock 5-10 lungfish juveniles (15-30 cm each). Lungfish are raised on by-catches and fry of tilapia and catfish, grasshoppers, snails and food waste. After one year, lungfish about 70 cm are harvested with hooks. Only a few fish were recovered; the loss was attributed to either cannibalism or its burrowing habits.

In areas prone to floods in Soroti, Pallisa and Kumi districts, farmers accidentally culture lungfish in ponds that are flooded. During the rainy season, mature lungfish make spawning migrations to shallow inshore areas and flooded wetlands (Greenwood 1958, 1986), with some ending up in aquaculture ponds, particularly those where the water supply is not screened properly. Most fish farmers blame the loss of stocked fish to predation and leakages caused by lungfish that enter ponds. Other farmers relate the turbidity of pond water to the presence of lungfish. Thus, lungfish are seen as a pest. Nevertheless, wild lungfish can be easily seined out when ponds are harvested and either consumed at home or sold in local markets.

Farmers routinely harvest lungfish after completely draining their ponds while others successfully seine them out. Lungfish that burrow into pond bottoms can be extracted using hoes and spears. Where available, baits—preferably *Clarias* spp. and earthworms—are used to harvest lungfish from ponds. In Soroti and Kumi, some farmers use dangerous approaches to harvest lungfish, tying a tuft of grass around the leg or a wooden pole to detect the presence of lungfish inside the pond dyke. The sharp blade-like teeth and aggression make African lungfish dangerous to handle. Fish should be handled around the neck or pectoral region.

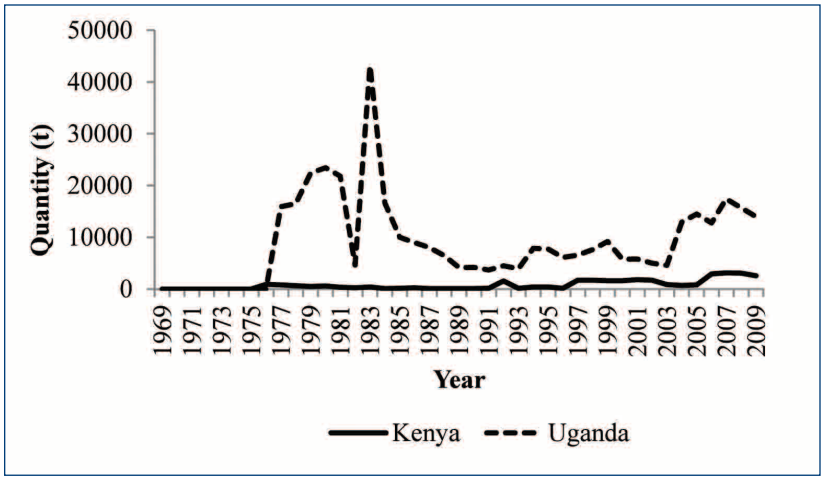


FIGURE 3. *Capture fisheries production of African lungfish in Kenya and Uganda (FAO 2010).*

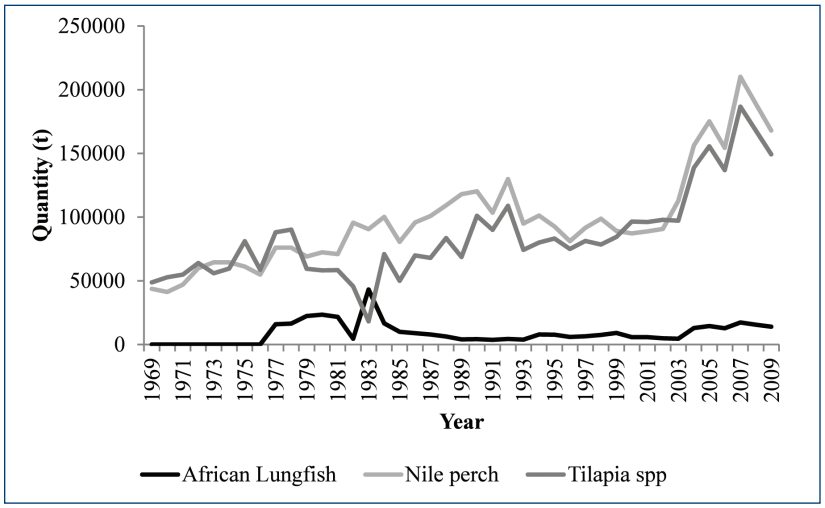


FIGURE 4. *Trends of fisheries production of main species in Uganda (FAO 2010).*

Overall, 56 percent of the fish farmers in the survey were willing to invest in lungfish culture, if production technologies were available. They recognized the availability of lungfish markets, locally and regionally, that presented potential to increase their household income.

## Lungfish Marketing

Per capita fish consumption in Uganda was 12 kg in the late 1990s but has gradually declined to 5.7 kg (UBOS 2001, 2002, 2011, DFR-MAAIF 2011). High prices of tilapia and Nile perch have forced many people to reduce fish consumption.

Lungfish from the fishery are sold locally or exported regionally to western Kenya, Democratic Republic of Congo or South Sudan. Lungfish is a delicacy among groups in northern, eastern and some parts of central and western Uganda (Kayiso 2009). Lungfish is most popular in eastern Uganda, especially among the Teso community. Lungfish is usually purchased fresh, but smoked or cured lungfish is also available in markets.

Wholesale prices for fresh lungfish range between US$ 0.90 to 1.80/ kg while retail prices can exceed US$ 2.50 / kg depending on location. Price for cured products (smoked) ranged from US$ 3.00-4.00 /piece. By-catch of lungfish juveniles (< 15 cm) are marketed in clusters of 3-5 pieces for about US$ 1.00. Prices are lower in rural areas than populated town centers or cities.

In this study, 55 percent of respondents regularly consume lungfish at home with a majority from Kumi, Soroti, Busia and Kampala districts. Women, constituting more than 70 percent of consumer respondents, eat lungfish with their families. Cultural influences that formerly deterred women from consuming lungfish (Bruton 1998) may have changed. As the demand for fish increases, people find alternatives to access fish; likewise changes in social norms occur (Ajzen and Fishbein 1980).

Affordable price, substantial fillet size for an average family, good taste and medicinal uses are the main reasons cited for consuming lungfish. Folk-medicinal purposes mentioned in interviews include treatment for problems with lactation; using lungfish pancreas to treat alcoholism; lungfish tail is said to enhance males' sexual performance; and a daily meal is claimed to boost the immune system against HIV-AIDS infections. Other attributed benefits to humans include treatment of kwashiorkor, gonorrhea, breast cancer, backaches and general revitalization of the body (Kayiso 2009).

FIGURE 4. *Women selling lungfish at the Bwaise market in Kampala.*

Popular kiosks that sell Nile perch by-products ('fille') are now featuring lungfish products. Low-income residents, particularly youth, support this business and some derive a livelihood from it. In Kampala suburbs and rural town centers, women own the majority of these kiosks, selling fried lungfish chunks and boiled lungfish soup during the evening. Furthermore, women actively engaged in the lungfish trade also access financial credit to expand their businesses, as evidenced in fish markets located in Kampala and Wakiso districts (Fig. 5).

Six restaurants in the survey area have lungfish on their menu, preparing fresh, smoked and fried fish meals. Some restaurants in Kabusu and Owino centers (Kampala district) specialize in selling fried lungfish pieces.

## Outlook and Research Needs

We now have a preliminary understanding of the indigenous practices and potential for lungfish aquaculture in Uganda and perhaps more broadly in sub-Saharan Africa. Fish farmers have inadvertently cultured lungfish that enter ponds during seasonal floods. They have developed local knowledge about handling and managing lungfish in natural water bodies and culture systems. Initiatives to culture a new species such as lungfish builds on this knowledge. Integrating indigenous and scientific knowledge can improve subsistence aquaculture production (Madamba 1979, Breidlid 1998) when a lungfish aquaculture production program is developed.

Promoting wider levels of lungfish production requires articulation of model production strategies and best management practices that account for the burrowing and mobility behaviors of lungfish. Lungfish farming, therefore, may be better suited to production systems such as cages or tanks.

Inadequate information is available on the growth potential and nutritional needs of farm-reared lungfish. Lungfish survive and grow with tilapia, for example, but optimal feed composition is not yet established. Lungfish can be raised on artificial diets, inasmuch as fish farms apply commercial pellets to feed catfish or tilapia.

At present, growers rely on wild-caught lungfish fingerlings or juveniles to support the limited culture that is currently taking place. Research is needed to clarify the reproductive cycle of lungfish in captivity to enable spawning in a hatchery setting and seed-stock production of uniform batches of genetically selected fish. Greater understanding of lungfish biology, especially reproduction and spawning, is needed to establish a foundation for commercial aquaculture. Efforts to domesticate African lungfish are foundational to the advance of a commercial sector.

The socioeconomic viability of African lungfish as a new culture species is just beginning. Despite the absence of appropriate culture technologies, African lungfish conforms to criteria suggested by Webber and Riordan (1975) to select suitable candidate species for aquaculture. The central issues of reproduction, feeding and management must be addressed to support development of the production part of a value chain for cultured lungfish. The value chain should deliver quality products to consumers and provide a sustainable return to small- and medium-scale producers in Uganda and elsewhere in sub-Saharan Africa.

## Notes

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[3] 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).

[4] Lungfish have two anterior gill arches that retain gills, though they are too small to function as the sole respiratory apparatus. The lungfish heart has features 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).

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