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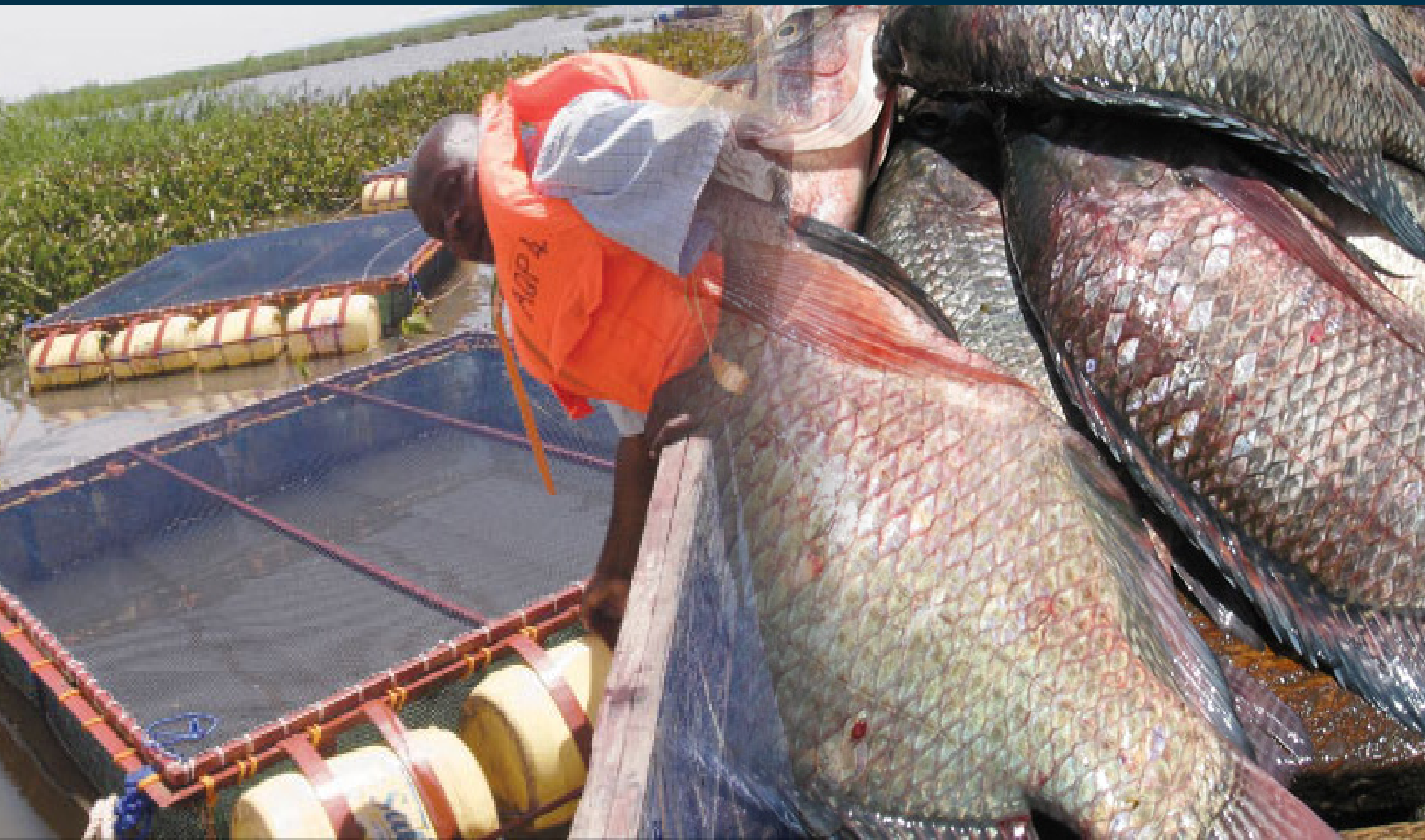
HARNESSING FLOATING CAGE TECHNOLOGY TO INCREASE FISH PRODUCTION IN UGANDA



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July 2017

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JULY 2017

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ABSTRACT

The fishery sub-sector is the second largest foreign exchange earner in Uganda's economy (estimated at US$ 135 million) after coffee. However, declining trends in annual fish production are a real threat in terms of the loss of potential foreign exchange earnings, household income and food security. This study demonstrates that favourable international fish prices have supported steady foreign exchange earnings in Uganda amidst declining fish volumes. To enable Uganda to take advantage of this opportunity, innovations capable of overcoming supply-side constraints will play a critical role. We find that aquaculture has tremendous potential to stir growth of the fishery industry as well as generate employment. The results demonstrate that innovative technology such as floating cage culture is a more productive system in comparison to capture fishery - a farmer using floating cage technology produces 12 times more tonnage per annum than his or her counterparts practising capture fishery. Therefore, to increase fish production, adoption of cage farming technology must be expanded. We identified policy gaps that delimit the development of aquaculture in Uganda, which must be remedied. Policy lessons are drawn from China and Egypt – with the most successful stories in aquaculture technology and support services, which enormously increased fish farming productivity and exports.

1. INTRODUCTION

Fishery development is one of the key global development goals embodied in agenda 2030 under the fourteenth Sustainable Development Goal (SDG), in which countries seek to support the restoration of fish stocks to improve safe and diversified healthy diets. In Uganda, fish is one of the strategic enterprises identified at the policy level in terms of its contribution to export earnings as well as high investment returns (Ministry of Agriculture, Animal Industry and Fisheries [MAAIF] 2010, 2015). Over the last 10 years, the fisheries sub-sector has taken a strong position in the country's economy as the second largest foreign income earner after coffee. In 2014, Uganda earned approximately USD 135 million from fish exports (MoFPED 2015), translating into 8 percent of non-traditional export revenue (approximately 0.6 percent of gross domestic product). Conversely, the contribution to total employment at the household level remained less than one percent (167,157 jobs in 2.1 percent of households) in 2012/13. During the same period, nearly two-fifth of households reported having consumed fish in the last seven days[1]. Uganda's main international market is the European Union. In addition, there has been a dramatic increase in regional export markets to neighbouring countries such as Sudan, Democratic Republic of Congo, Kenya, and Rwanda.

Despite these potential benefits from the fish sub-sector, there are several binding constraints that must be addressed if Uganda is to fully realize these benefits. Some binding constraints are related to supply, including the low usage of productivity-enhancing technologies, which has partly resulted in overfishing and the declining fish stock (Department of Fisheries Resources, 2011). Consequently, Uganda's fish exports have suffered negative consequences, even in the era of high global fish prices. To illustrate this point, exports declined from a peak of approximately 39,000 metric tonnes in 2005 to 17,600 tonnes in 2014, whereas the per unit value of fish increased from 3,200 to 7,700 US dollars, respectively. The dwindling trends in annual fish production presents a threat to Uganda's export sector - e.g., closure of 9 out of 21 fish export processing factories in 2015 - as well as Uganda's achievement of Sustainable Development Goal # 14. The decline in fish catches has been accompanied by a decrease in fish size and quality, suggesting that fisheries are under serious pressure and have already exceeded optimum production in relation to the available resources and technological capabilities. In other words, actions must be taken now rather than later if Uganda is to salvage the sub-sector.

Notwithstanding, there have been both national and regional efforts to address the declining fish stocks through innovative technologies. The major water bodies providing higher opportunities for fish production in Uganda are trans-boundary in nature. Because of the transboundary nature of fishing in East African countries, especially Uganda, Kenya, and Tanzania, there is a joint agreement in principle regarding the idea of furthering the use of fish cage farming (Nambogga, 2014). Regional open access to such natural water bodies may require a wider understanding of the outcomes (the positive as well as the negative) of embracing caging across countries that share the water body.

At the national level, fish cage culture and aquaculture parks have been identified as strategic cutting-edge technologies with the potential to increase fish production (Rutaisire *et. al*., 2009; MAAIF 2012; Mugamire *et al*., 2013). Such innovations are viewed by the National Fisheries Resources Research Institute (NaFIRRI) as critical in closing the gap of declining fish catches. However, a decline in fish volumes continue to persist, despite years of efforts by the government and donors to promote aquaculture (Food and Agriculture Organization, 2010). Embracing innovative technologies to combat declining fish stocks, as well as allowing communities the right to exploit the freshwater bodies

1 Author's computations based on the Uganda National Household Survey of 2012/13.

for their livelihood, would necessitate updating and developing policies, legal and institutional frameworks, strategies and action plans related to the fishery sub-sector (MAAIF, 2012). A lack of empirical evidence to guide the design of policies and implementation strategies is cited as one weakness (MAAIF, 2013), as well as a low appreciation of the economic potential presented by cage culture and aquaculture parks by the private sector. For instance, information is needed to establish productivity and production differences if the government opts to focus on switching technologies from wild fishing to organized floating cage fish farming in designated aquaculture parks around freshwater bodies.

It is against this background that this paper sought to provide insights into the likely outcomes of adopting fish cage farming and aquaculture parks as innovative avenues (pathways) for future commercial exploitation of fishery resources in Uganda, and the East African Community (EAC) region in general. Specifically, this paper synthesises existing information on enhancing capabilities and potential within communities for commercial exploitation of fisheries resources and opening up avenues for gainful employment in the sub-sector. The paper makes a case for how fish cage farming and aquaculture park technologies can be harnessed into creating commercial fish producing hubs to build and/or complement the requisite fish stocks as a means to turn around (resuscitate) the struggling fish processing industry in Uganda. Success stories elsewhere in the world are discussed, and lessons for Uganda are articulated. Finally, the paper critically reviews the current policy and regulatory frameworks by identifying gaps, missing policies and required institutional changes to promote and accelerate the uptake of NaFIRRI technological innovations as a way to increase fish production for higher economic or financial gains.

The paper is organized as follow: The next section is the study approach and data sources. Section three discusses fundamentals in the fishery sub-sector including fish export fortunes. Section 4 explains decline in fish production and alternatives for Uganda. Section 5 discusses the potential of aquaculture (including cage culture) to stir growth of the fishery sub-sector. Section 6 presents economic prospects, employment outturn, productivity from aquaculture (including cage culture), and a summary of binding constraints facing aquaculture. The last section is the conclusion and policy recommendation.

2. STUDY APPROACH AND SOURCES OF DATA

The study employed a multi-pronged analytical approach, involving, first, a quantitative analysis of secondary data from the FAO fishery database and administrative data from DFR and NaFIRRI. Second, extensive desk reviews of documents and/or literature were used to build a basis to understand reasons for un-sustainable fishing efforts that have led to the decline in capture fish quantities. The literature also provided background information to pinpoint floating fish cage farming as a suitable aquaculture production system, and an alternative or complement to declining fish stocks in the country. The main government policy documents reviewed included the following: fishery policy document(s) – e.g., National Investment Policy for Aquaculture Parks (NIPAPs), Sector Strategic and Investment Plan, Fishery Annual Performance Reports, annual sector performance reports, agricultural statistical abstracts, and fishery survey reports and data by NaFiRRI and DFR.

The other component of the qualitative analysis involved Key Informant Interviews (KIIs) conducted with technical and policy level officials from MAAIF – Directorate of Fisheries Resources (DFR). The KIIs were prominently used to solicit information on the key challenges facing aquaculture in the country, including cage culture and aquaculture park development.

Third, a case-study component was included (using the Chinese and Egyptian success stories) as a research exemplar for understanding how floating fish cage farming (and aquaculture in general) is a viable solution or complement for solving the declining productivity dilemma in Uganda's fishery industry. The two case studies strengthened the argument that floating fish cage farming and aquaculture in general is a viable pathway for stirring growth in the fisheries sub-sector in Uganda.

The fourth analytical approach followed was a direct proportional analysis to accentuate the likely employment opportunities generated along the fishery supply chain with increases in fish production. The direct proportional analysis was premised on fishery employment statistics established by NaFIRRI and DFR. The paper makes a very restrictive assumption that each metric ton of fish produced creates employment by a factor of approximately 0.288 under capture fishery[2], implying that every 1000 metric tons of fish produced creates almost 290 jobs. Here, we assume that employment conditions in the fishery sector prevail such that when fish are produced, similar jobs that are created at each stage of the fish value chain under capture fishery are also created through the aquaculture production system.

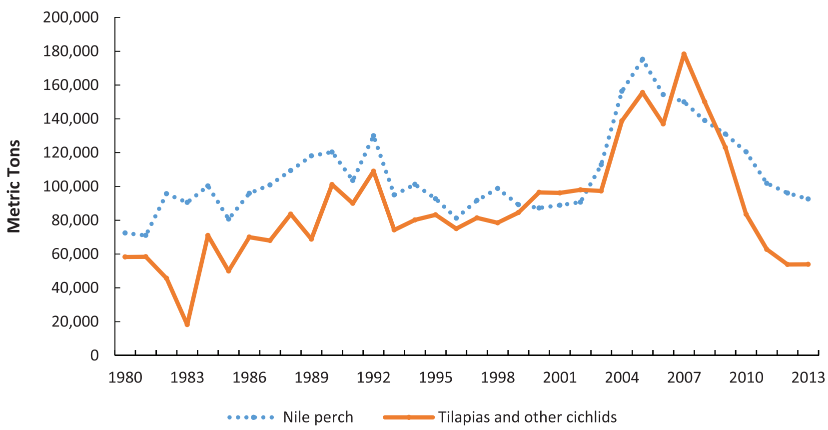
3. FUNDAMENTALS IN THE FISHERY SUB-SECTOR

3.1 Declining Trends in Capture Fish

Fishery resources are among the most significant natural endowments of Uganda. With approximately 20 percent of its surface area covered by water, Uganda has enormous fishery resources potential for both capture fisheries and aquaculture production (DFR, 2011). Nile Perch, Nile Tilapia and silver fish (Mukene) form the bulk of the fishery catches.[3] Evidently, Uganda's fish subsector performance has suffered a significant decline since 2007 and is yet to recover, as illustrated in Figure 1. These trends are greatly explained by the weak regulatory framework that has not supported control of overfishing in the freshwater bodies. This phenomenon is exacerbated by illegality in fish trade, which is known to represent 14 percent of all informally traded goods in Uganda (MAAIF, 2015).

The contribution of the fish sub-sector to overall agricultural GDP is depicted in Figure 2. For example, in financial year 2007/08, there was a 12.6 percentage decline in growth in the sub-sector. The subsequent recovery over the period from 2009 to 2012 was interrupted by another cycle of negative growth (of 4.5 percent) in 2013/14.

Figure 1: Trends in fish catches by major species, metric tons

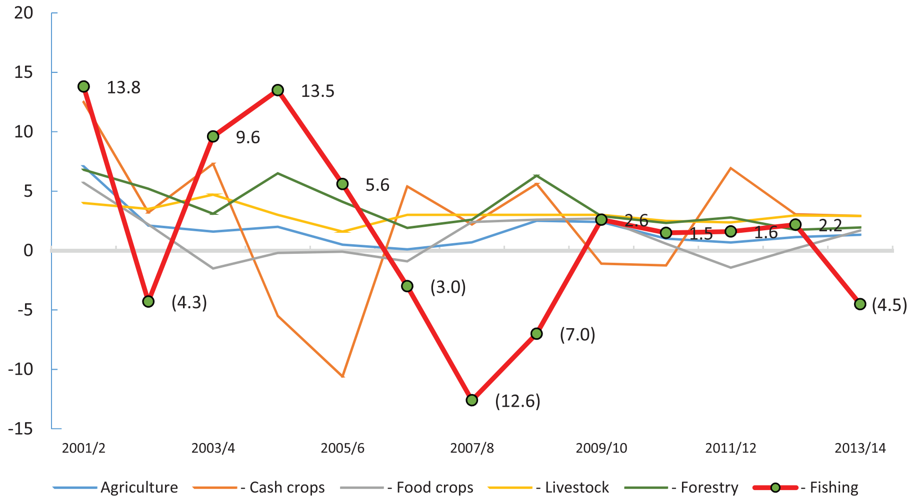


Author's computation based on FAO fishery statistics (2015)

2 Each MT of fish produced generates employment by a factor of 0.28803169 (statistic computed based on fish production and employment data from NaFIRRI and DFR.

3 Fish production is mainly from the existing five major lakes and 160 minor water bodies (Figure A1 & Table A1, Annex). Lake Victoria (the world's second largest fresh-water lake) is the main source of capture fish (Figure 1A).

Figure 2: Comparison of GDP growth rates between fisheries and other sectors, %



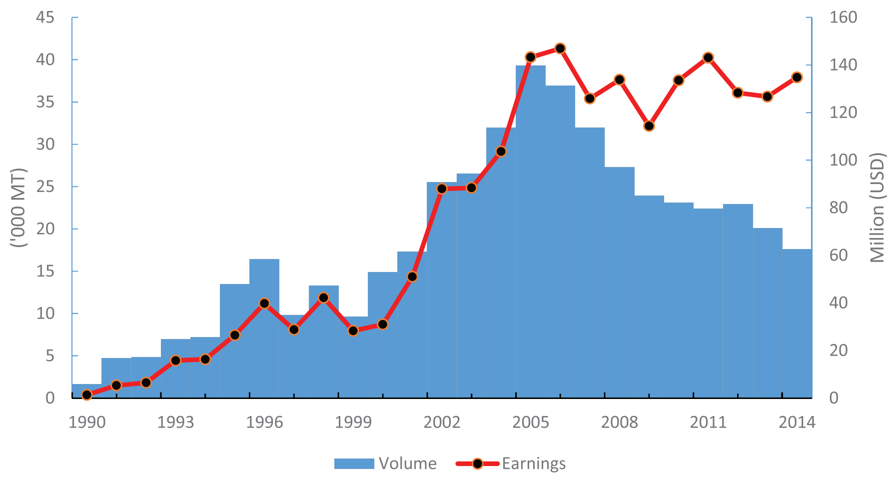
Source: MoFPED, Background to the Budget reports (several issues)

The poor performance of Uganda's second foreign exchange earner sub-sector must be reversed using appropriate and/or complementary interventions. Aquaculture is one possible option. Aquaculture in the country is growing at approximately 2 percent per year, mainly from African Cat Fish (Clarias) and Tilapia. Intensive investments in cage culture have also taken place, with over 2,000 cages on L. Victoria alone, with an estimated production of 1.74 metric tons of Tilapia fish (MAAIF 2015; NaFIRRI 2015). However, many changes are needed to fully realize these seemingly promising innovations.

3.2 Fishery Export Earning Fortunes

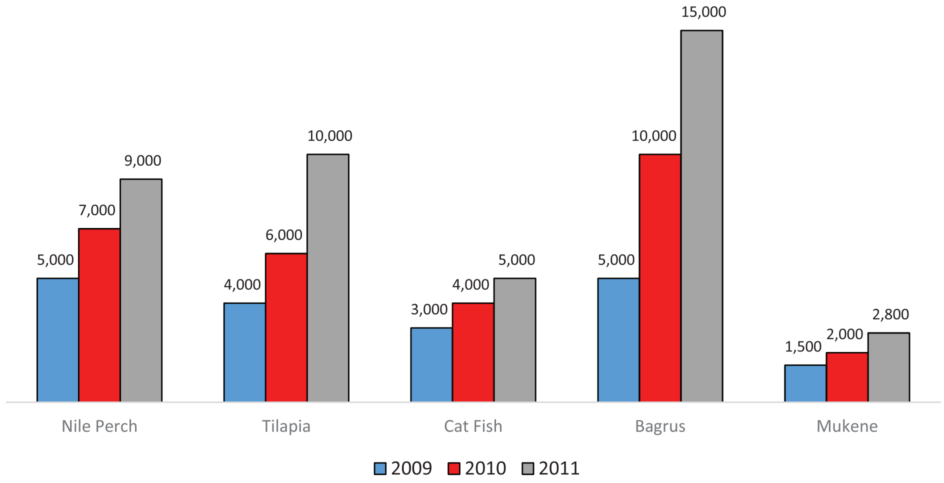
The international market for Ugandan fish is favourable, but it remains underexploited from the Ugandan perspective as illustrated in Figure 3. Since 2005, supply-side constraints have had a limited capacity to export enough fish. Fishery export volumes peaked to over 39,000 metric tons in 2005, but later plummeted to approximately 17,600 tons in 2014 (Figure 3), whereas the international fish value per metric tonne increased from USD 3,200 to 7,700 during the same period. This implies first, that limitations in fish production (i.e., supply side challenges) contribute to failures in taking advantage of a growing lucrative international fish market. Second, such different trajectory growth patterns in volume exported vis-a-vis revenue earning points towards an export sector that is riding on the fortunes of favourable international fish prices.

Figure 3: Trends in volume ('000 metric tons) and export earnings (USD, million), 1990-2014



Source: Computed using FAO Stat Fisheries database (2011-2011) & MoFPED (Background to the Budget (2015/16)

Figure 4: Estimated average retail price value of fish (UGX/kg), in nominal terms



Source: DFR Field reports 2012.

At the production level, negative changes in the availability of fish (natural capital) are reported to affect total revenues and harvesting costs (net revenues), resulting in greater costs in managing and accessing natural capital (Marie-Caroline Badject *et al*., 2010). In Uganda, reductions in the net revenue arising from declines in fish stock and subsequent catches are commonly cited as a consequence of overfishing and poor management practices of natural fisheries bodies (Kaelin and Cowx, 2002; Katurole and Wadanya, 2000). As a result, most Ugandans cannot afford to buy fish due to the increasing retail price per kilogram (Figure 4), which in turn impacts protein intake.

4. CAUSE OF THE DECLINE IN CAPTURE FISH AND ALTERNATIVES FOR UGANDA

4.1 Unsustainable Fishing Efforts

The high level of pressure on the capture fishery in Uganda has climaxed into the need to accelerate the development of strong complementary technologies - aquaculture production systems such as cage culture farming and aquaculture parks. These are new or innovative fish production avenues that have been adopted internationally. An extensive body of literature cites the existence of high pressure on capture fisheries in Uganda's natural water bodies, requiring the development of aquaculture as an alternative or supplement.

Ogutu-Ohwayo (1990) has provided a review of how fish catches have inhibited fishery industry development since 1929 with any intervention working for a short duration before the catches plunge to low levels. Subsequent studies (such as LVFO, 2013) revealed that fishing efforts are expanding at an alarming rate, especially in Lake Victoria. Indicators for increasing fishing efforts are known to include overwhelming increase in the following: *(i) capacities to capture more fish even in restricted areas such as fish breeding zones; (ii) the number of landing sites and fishing crafts and their mode of propulsion; (iii) the number of fishers and fish mongers; (iv) fishing gear and their size; (v) fishing infrastructure at landing sites; and (vi) service providers including Beach Management Units (BMUs).* This alarming expansion in fishing efforts signals high pressures on the natural water bodies for fish catches in Uganda. In a Catch Assessment Survey (CAS)[4] report, NaFIRRI (2011) showed decreasing fish stocks in Lake Victoria for all fish species. Likewise, a hydro-acoustic survey conducted for the same lake showed a decline in

4 Catch Assessment Survey CAS reports provide estimates of the quantities of fish landed in the beaches, monetary value of fish catches, the contribution of different fish species to the catches and trends in fish catch rates.

biomass of commercial fish (Taabu et al., 2010). The highest decline of fish stock was reported among the haplochromines, while both Nile Perch and Dagaa populations were relatively stable. The environment for fish has been deteriorating, consequently reducing suitable available habitats.

In a study detailing the impact of fishing pressure on Nile perch fishery on Lake Victoria, Katurole and Wadanya (2000) noted that Uganda's fishery management constraints on Lake Victoria include – insufficient budgetary allocation for the fishery sub-sector and ineffective fishery monitoring and regulatory mechanisms. These constraints have led to high fishing pressure and a reduction in fisheries. This study revealed that approximately 62.7 percent of fishing canoes targeting Nile Perch use methods and fishing gears that catch immature Nile perch in high proportions. Immature and illegal Nile perch were caught by approximately 7.1 percent of the canoes. The Nile perch smaller than the size at first maturity made up approximately 43.4 percent and 99.7 percent of males and females, respectively. Summarily, the study makes a strong case with evidence for high fishing pressure on the lake, and recommends the need for improved fishery management.

High pressure on catch fisheries has partly led to the closure of fish processing plants in Uganda, although data are limited to support this claim. According to DFR, frequent closures of fish processing factories have been reported with no specific cause, despite fish decline being cited in every incidence (MAAIF 2012, 2015). In particular, USAID (2009) associated complete closure of three out of 21 fish processing plants and operation at 30 percent of the installed fish processing capacity to a decline in fish stocks and firm financial constraints.

Nyombi and Bolwig (2004) associated excessive fishing efforts and the use of unsustainable fishing methods to overexploitation above the maximum sustainable yield (MSY), due in part to ineffective national and regional regulation. The authors highlight that the impact of overexploitation has led to a tremendous reduction of fishermen's income and of fish availability in the market, loss of business and employment by local processors/traders, and processing plants operating below the installed capacity.

Bagumire (2009) associated the closure of fish factories to a global financial crisis that resulted to high operational costs for exporters and less access to bank loans. The development of a reliable aquaculture system will facilitate enhancement of a sustainable and competitive fish industry in Uganda (MAAIF, 2010). An over-reliance on catch fishing has detrimental effects on fishery sub-sector development. The pressure on lakes (or catch fisheries), which has been vastly cited, can be eased by interventions capable of providing alternative methods of fish production, such as aquaculture - cage culture and aquaculture parks. It is pertinent to examine how cage culture fish farming and the use of aquaculture parks can be exploited as alternative tactics or supplements to improve overall fish production and productivity in Uganda.

4.2 Identification of Aquaculture Production Systems as an Alternative

World-wide, many techniques are used for aquaculture production across continents, broadly under freshwater- and ocean-based systems. This study adopts the Rothuis et al. (2013) broad categorization of the aquaculture production systems into four groups as discussed below and summarized in Figure 5.

<u>Semi-intensive pond culture:</u> Examples of where such a system is important is in Egypt – where it has been successful for developing the fisheries sub-sector based on concerted efforts in fish farming. Semi-intensive pond culture systems comprise approximately 85 percent of the total production using earthen ponds. The size of the fish ponds varies from 0.5 to 13.0 ha and from 50 to 150 centimetres in depth. The main culture species grown in these ponds are Nile Tilapia and Mullets. The typical farming cycle

under semi-intensive aquaculture begins in January when fry and fingerlings are produced in tanks with simple greenhouse structures. Between March and April, the grow-out ponds are stocked, and harvest occurs between September and November. In terms of volume, approximately 5 to 10 tonnes are produced per ha over the seven to twelve-month production cycle.

Intensive production in ponds and tanks (intensive pond culture): The intensive pond culture system uses smaller and deeper earthen ponds (lined with polyethylene sheets in some cases), and the main species grown is Nile tilapia (majorly mono-sex). Tanks are also used under intensive fish production, and when using freshwater from underground reservoirs, Nile tilapia and African catfish are the major species cultured under the system.

Cage farming[5] (intensive production in cages): Cage culture is fish farming carried out in caged enclosures. It involves raising fish in containers enclosed on all sides and on the bottom with mesh material that secures the fish inside while allowing relatively free water exchange with the surrounding environment (Schmittou et al. 1998)[6].

In Uganda, the practice of fish cage culture farming commenced in early 2006 in natural water bodies of Lakes Victoria and Kyoga (Blow & Leonard 2007). The actors that support the Ugandan cage culture value chain include the following: national government, local government, development partners such as the Belgian Technical Corporation (BTC), Non-governmental Organisations (NGOs), individual farmers, and youth groups (Kifuko, 2015). Recently, the European Union (EU) has also supported cage culture development.

Cage culture farming is a relatively new fishery intervention in Uganda and is still in its infancy. According to Blow & Leonard (2007), with support from the USAID aquaculture development programme, in 2007 Uganda had only three fish pilot-scale cage culture sites on Lake Victoria, in the areas of Entebbe and Jinja.

The predominant fish species grown using cage culture is Nile Tilapia (*Oreochromis niloticus*) (Blow and Leonard, 2007). Uganda had approximately 15 cages by 2007, and based on pilot technology, all cage sites in Uganda are inshore and have intensively stocked cages of, at most, 5 cubic metres each. In terms of stocking density, the trial cages used 200 fish per cubic metre, and it is expected that the harvest stocking density will be 100 kilograms per cubic metre (ibid). Cage sites are in shallow areas with depths of less than 5 metres. Cage frames are produced in the country and are made of polystyrene floats and wooden walkways. The cages use production nets that are made from nylon in the country. In terms of seed production and supply, a government hatchery (based at Kajjansi) is intended to produce Tilapia fry, while Son Fish Farm Ltd. (located in Jinja) is also expected to produce fish seed. Regarding employment creation, cage culture was employing less than 20 people by 2007, but the major lakes (Victoria, Albert, Kyoga) and the Nile river provide immense opportunities for cage culture development (including job creation) due to the good and favourable water quality and temperature, respectively (Blow and Leonard 2007).

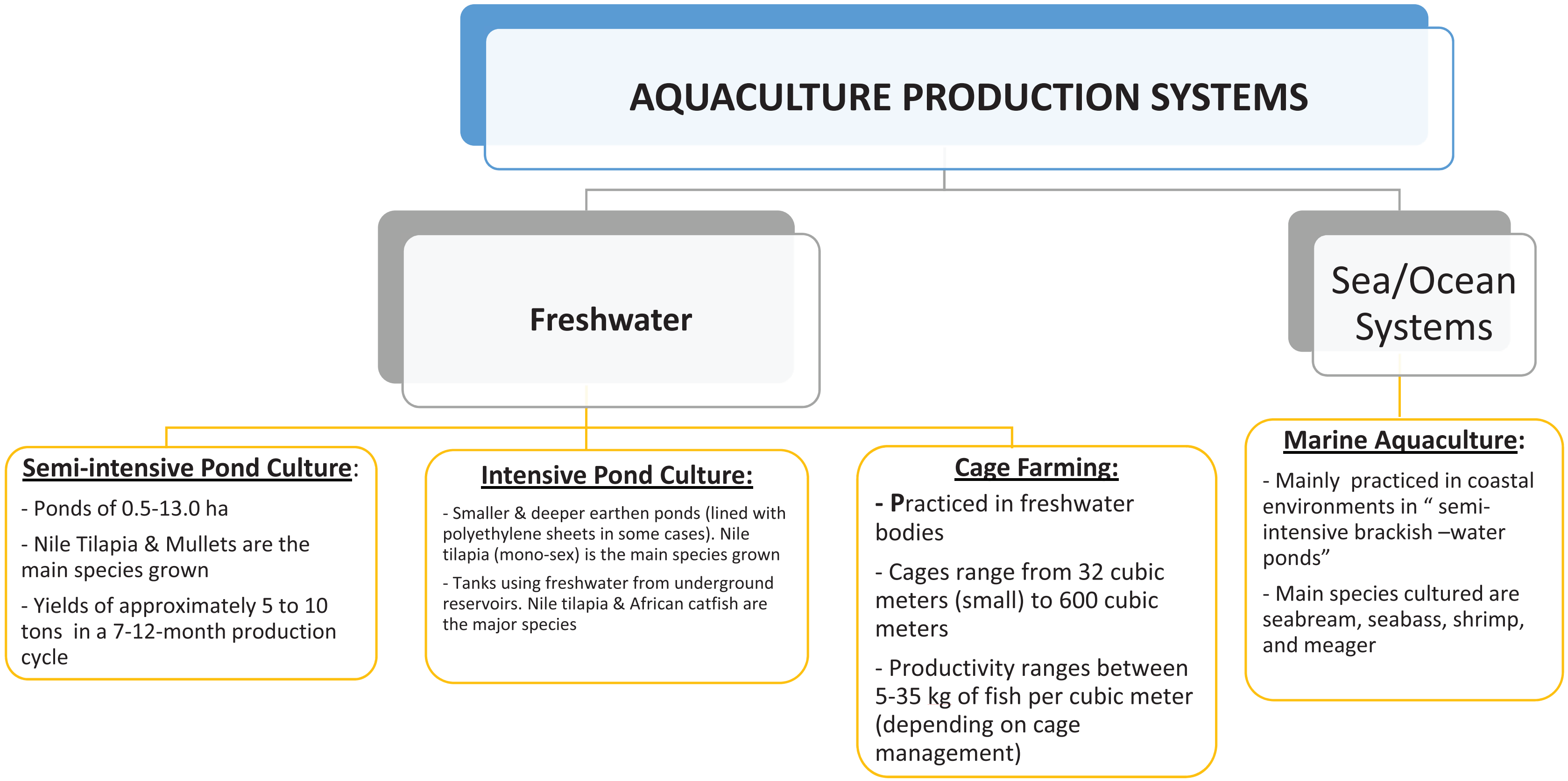
Small cages are approximately 32 cubic metres in size, while larger cages are approximately 600 cubic metres. Cage culture productivity is mainly dependent on cage management, and it ranges between 5 to 35 kilograms of fish for every cubic metre. Yields are higher in open pond cultures (in terms of pounds per acre), and it can be practised in standing water bodies such as ponds, rivers and streams. According to Rothuis *et al.* (2013), government policy to restrict and re-allow cages to operate is a major factor influencing the number of cages in operation.

5 Swann et al. (1994) define cage culture as an intensive fish production method whereby the fish farmers use farm ponds and pits; and fish is enclosed in pens or cages.

6 Cage culture technology in sub-Saharan Africa is predominantly comprised of tilapia farms. Working examples can be drawn from Ghana, Kenya, Zambia, Malawi, Zimbabwe, and Uganda (Blow & Leonard 2007).

Other aquaculture production systems: Marine aquaculture and traditional extensive systems. We do not discuss these systems in detail because they are not relevant for Uganda.

Figure 5: Aquaculture Production Systems



Source: Adopted from Rothuis et al. (2013).

Box 1: Summary of information from the available literature on the fish cage culture system

Authors/country	Pros/Benefits	Challenges	Recommendations
Swann et al (1994). United States of America	Less costly for the development of fish husbandry skills; easier to monitor fish health and growth; simple to carry out harvesting; when existing ponds are used, the cost of constructing ponds is not incurred.	Water quality may be reduced due to high stocking density; easy or more rapid spread of fish diseases; easier to poach fish; Production rates are less than those in production ponds.	Species for successful cage culture should be as follows: - fast rate of growth given environmental conditions, ability to tolerate crowded conditions, and of good market value. The most vital fish management practice on a daily basis is feeding, with careful selection of quality feeds.
Rutaisire (2011). East Africa	Cage culture technology satisfies the universal goals of producing high quality fish; it is relatively inexpensive and simple, and therefore easily adaptable by smallholder farmers with limited resources; it is applicable in most existing water environments and does not require conversion of land into new bodies of water.		
USAID (2009). Uganda	_Pros_: Cage culture shows similarity to ponds on returns above variable costs but lower capital investment in cages.	The risk of losing crop is higher in cages than in ponds. There are major concerns regarding high production costs, quality feed, seed and market availability, potentially negatively impacting cage culture.	
Blow & Leonard (2007) – Sub-Saharan Africa; Chen et al (2007) - China; Grottum & Hjelt; 2006) - Norway	No case of diseases reported for cage culture in Africa.		Lessons from other regions where the technology has been practised for a long time resulting in the incidence of diseases may need to be considered for any investment.
Jansson and Vennerstrom (2014) Hambrey (2006b). Asia,		There are diseases associated with cage culture - seven viral diseases with high mortality rates are cited. Other diseases include eight that are caused by bacteria, parasites and nematodes.	Information on fish diseases highlights the need to consider all factors that may have an economic bearing on cage culture and implementing sufficient safe-guards, i.e., comprehensive redress of constraints of seeds, feed, finances, skills/information and marketing. *Additionally, African (or locational)-based cage culture system development due to diversity in the operating environment is recommended. The challenge for governments and other development agencies involved in the promotion of cage culture is to identify bottlenecks to development and implement short and effective interventions. Policy and regulatory framework that address issues of resource allocation, cumulative environmental impact and input as well as product quality are needed for the success of cage culture.*

Phillips & DeSelva, 2006. Asia	Expansion of cage culture is feasible due to the advantage of the existence of water bodies; cage culture allows the landless to engage in fish production.	Cage farming has been observed to be vulnerable to environmental pollution, fish diseases and sustainability challenges.	Well-articulated interventions are required for success in cage culture farming, such as the Asian cage culture farming success story. The interventions should be associated with evolution from traditional to modern cage farming involving specially constructed cages, better designs and synthetic materials, use of hatchery-reared fry and fingerlings, high-quality feeds, better organized management practices, and adoption of various fish species and environments.
Hambrey (2006a): A review of small-scale cage culture in Asia and its potential	The strength of small-scale cage culture in reservoirs include a high return per unit investment; no land requirements, seasonality of labour use; no flooding risks, exploitation of family labour, high price for fish, reliable supply, little disease threat, ability to use an established distribution and marketing network developed for capture fish; and a high upstream multiplier effect among the poor engaged in feed and seed collection.	Lack of economies of scale in the use of labour, cage cost and marketing; high loss to poor management and water quality; vandalism and theft; high management skills and knowledge requirements; production costs higher than in ponds, increasing incidences of disease outbreaks; expensive for the poor; and access to private or public water bodies not readily available or secure.	
Chen et al (2007). China	Cage culture allows direct and efficient utilization of natural water resources; saving of national land resources because there is no need to dig ponds; opportunity for energy savings, as there is no need for facilities for irrigation or aeration; high-yielding intensive culture methods; employment opportunities for rural labourers; contribution to poverty alleviation; and conservation of natural fish resources and enhancement of the total fishery output of a given lake area.	Using examples of the Chinese cage reveal constraint issues in addressing environmental problems and profitability challenges due to excessive investment and shortages of operational techniques for offshore cages and associated facilities.	
Grottum & Hjelt (2006) Cardia (2006). Norway and Italy	Adopt a highly regulated system of cage farming development accompanied by research – such as the Norwegian case. In Norway, research led to increased knowledge regarding site selection, better adaptable technology and feeds, increased knowledge about management, development of vaccines and development of markets. Other facets of the Norwegian cage culture system that may provide lessons for cage culture development are adherence to strict laws that require quality assurance, maintenance of the environment and disease control before license issuance or renewal.	Cage culture is regulated through fragmented laws; for instance, in Italy - mostly provincial, national or European Union (EU) aquaculture regulations.	Use of capital intensive cage culture with automatic plant systems that are able to monitor the physical, chemical and biological status of the cage and with an integrated feeding system, among other attributes. The need for lighter requirements for operating the cage culture with fewer bureaucratic procedures.

In this paper, we focus on fish cage farming - justified by observation that approximately 20 percent of Uganda's surface area is covered by water, providing potential for both capture fisheries and aquaculture production. However, it is becoming apparent that high levels of fishing efforts exert pressure on capture fisheries in Uganda. A potential option to leverage the water resources with limited pressure on land would be cage culture farming, which has not yet been fully exploited in the country. Box 1 presents a summary of a wealth of information in the literature on the pros and cons of cage farming. This strategy is performed with the objective of informing policy on available avenues for reducing levels of fish efforts on freshwater bodies in Uganda. For example, the existing literature highlights the strength of small-scale cage culture in reservoirs to include the following: a high return per unit investment; no land requirement, seasonality of labour use; no flooding risks, exploiting family labour, high price for fish, reliable supply, and little disease threat.

4.4 Barriers to cage culture and aquaculture park technology development

Nyombi and Bolwig (2004) recommend the strategy of the introduction and promotion of cage or pond aquaculture to revitalize the fisheries sub-sector in Uganda. This strategy will boost the fish supply in local and regional markets, the incomes of fish farmers or fishermen, and improve nutrition, among others. Notwithstanding these benefits, the authors argue that challenges remain. These challenges include - low extension efforts; inadequate fry (seed) and feed production; and environmental threats due to pollution. In 2004, FAO organized a conference of experts to identify key issues requiring priority action for sustainable cage culture in Africa and elaborated a framework of good managerial practices based on practical cage growing experience globally. Among others, the constraints to cage culture development observed were poor seed and feed quality (also see Blow and Leonard, 2007), risks associated with environmental pollution and fish diseases, trans-boundary water resources, conflict where water bodies have multiple uses, lack of prerequisite legislation and regulation, and inclusiveness in its development. Observed constraints notwithstanding, cage culture represents an important developmental opportunity for many African countries, but it requires an effective policy framework to overcome developmental challenges and to ensure that it is equitable and sustainable.

Blow and Leonard (2007) reviewed cage culture operations in Uganda, Ghana, Malawi, Zambia, Zimbabwe and Kenya in terms of technical, socio-economic, environmental and institutional as well as legal issues. According to their study, constraints to cage culture in these countries include – an uncompetitive nature of growth performance of tilapia on a global level; lack of economies of scale in operations; traditionally low prices and quality of wild-caught fish; and a lack of understanding and commitment by the government to aquaculture development. The major barrier to competitive cage culture development asserted (ibid) the inadequacy or lack of availability of domestically made high-quality extruded fish feeds at competitive prices. Other barriers include a lack of or insufficient processing facilities and difficulties in marketing due to the unavailability of routes or links connected to developed markets, lack of training in cage culture, and lack of potential investors or serious engagement of the private sector to invest in cage culture. There is also a lack of expertise in disease identification and management, especially on the side of fish farmers. The constraints highlighted in the review by Blow and Leonard are mainly broader – general industry level constraints with no major focus at farmer levels. The current study attempts to close this gap in the case of Uganda by documenting cage culture constraints even at the fish farmer level (i.e., cage culture adopters).

Farmers also lack technical knowledge/skills on aquaculture husbandry. In Uganda, the knowledge gap is exacerbated due to the difficulty associated with promulgating new or innovative knowledge and technologies to farmers because aquaculture sites (such as ponds and cages) tend to be scattered and distant from each other (Rutaisire et al., 2009; MAAIF, 2012). Consequently, the unorganized and uncoordinated production system undermines efforts towards aquaculture development in the country. Uganda's proposed concept of Aquaculture Parks (APs) is meant to mobilize farmers and bring them together in a coordinated manner to address this challenge and ultimately cluster and promote production. However, establishment of the APs has been partly delayed due to the government's slow progress in adopting the potential guiding policy - National Investment Policy for Aquaculture Parks. The policy has remained in draft form, although, as such, this is not peculiar to the fish sub-sector; it remains a major challenge throughout the entire agricultural sector.

Other key constraints faced by fish farmers are scarce and costly fish fry, high investment costs due to a lack of capital including inaccessibility to low-cost credit facilities, and a limited number of fast growing fish species. Furthermore, there are limited production technologies and systems that include choice of culture species. According to non-fish farmers, the barrier that prevents them from venturing into fish farming enterprises are lack of capital and aquaculture skills (Republic of Uganda 2005).

Pertaining to financing barriers, the Fisheries Credit Fund that was provided under the African Development Bank (AfDB)'s Fisheries Development Project was not channelled specifically for aquaculture, and its credit fund component could have just been a drop in the ocean since it covered both capture fisheries and aquaculture. Additionally, the same fund was also used to finance two other components of the project.

5. AQUACULTURE: A PROVEN PATHWAY FOR STIRRING GROWTH IN THE FISHERY SUB-SECTOR

5.1 Lessons from China and Egypt

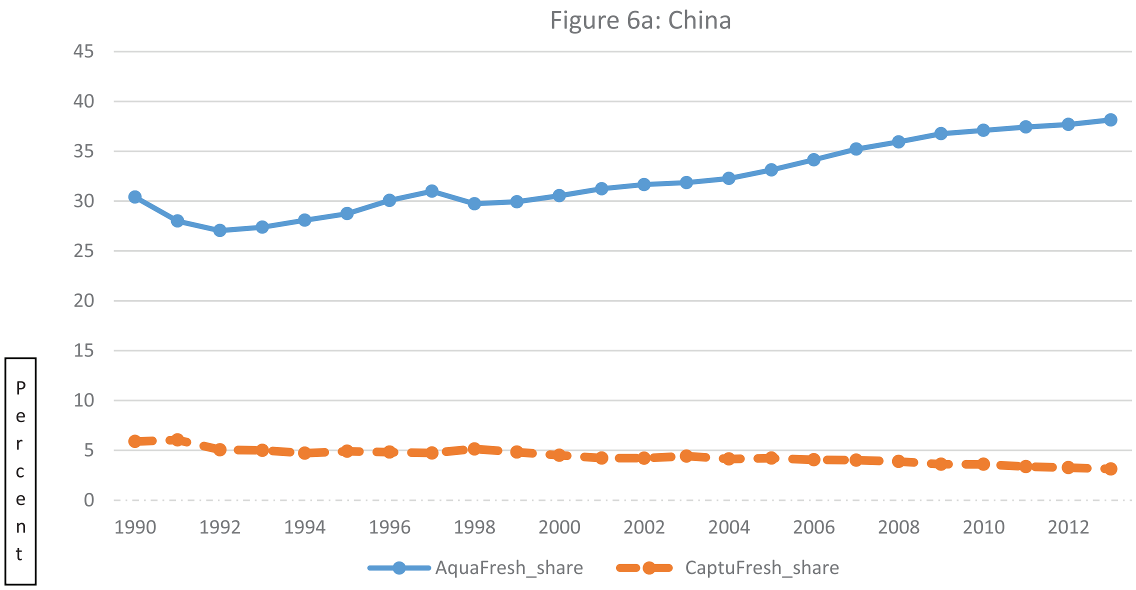
The study uses China and Egypt as examples to demonstrate that countries that have managed to develop and expand the fishery sub-sector have done so via aquaculture rather than capture fishery (Figure 6). The analogy is derived from FAO fisheries time-series data and illustrate the extent to which aquaculture has accelerated growth of the fishery sub-sector in the two countries. For example, in China since 1990, the steady positive growth in the fishery sub-sector was driven by growth in aquaculture (Figure 6a). Egypt's increase from approximately 280 thousand metric tons in 2005 to over 550 thousand tons in 2013 in fresh fish production is also directly linked to growth in aquaculture (Figure 6b).

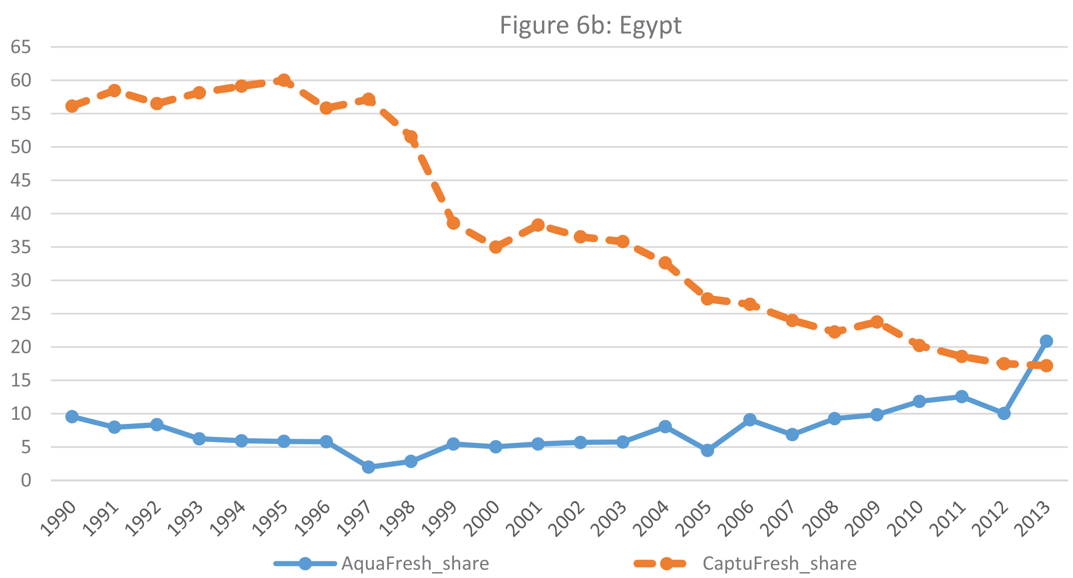
5.1.1 China

From around the mid-1990s, structural changes occurred in the Chinese fishery sub-sector towards an aquaculture-led fresh fish production system (Figure A2 - Appendix). Considering freshwater fish only, aquaculture has been predominant in China over the years, with some elements of slow uptake in the early and mid-1990s (Figure 6a). The slowdown in expansion of freshwater fish species in the 1990's was largely due to fish seed demand that outstripped the supply from wild-capture fish. In response to this challenge, the Chinese government took active and stimulating roles in the development of aquaculture (NBSO, 2010). The government of China instituted and implemented a strategy for aquaculture development in its five-year development plans. The development plan accords high priority to the provision of a good infrastructure for aquaculture development, scientific Research & Development (R&D), and training. The government developed Technology Extension Centres

(TEC) that provide assistance to companies and local farmers in terms of implementation of new technologies and knowledge or skills generated through R&D. Indeed, in the recent past, the Chinese government has placed more emphasis on aquaculture to mitigate natural fisheries resource depletion through extension of the fish culture area *(ibid)*.[7]

Figure 6: Shares of freshwater aquaculture & capture fish in total production across major countries





Author's computation based on FAO Stat Fisheries database (1990-2013)

7 AquacFesh is freshwater aquaculture and CaptuFresh is freshwater capture fishery.

Indeed, the focus of the Chinese government is on new technology and the development of a healthy culture; and China's key milestone in that regard includes accelerating the transfer of scientific and technological achievements into commercial production; the development of strain seed and breeding technologies; disease prevention for cultured species (through fish vaccines) and food safety control systems; and enhancing processing of aquatic products, among others. Regarding the added value and exports of aquatic products, most of these products are exported in processed form.

China's trend on fish cage culture therefore points to successful development of the technology (Chen *et al*., 2007). In addition to the aquaculture development strategies discussed above, the following also contributed to the success of Chinese cage aquaculture: an increase in the number of fish species cultured, a willingness to adopt cage culture by farmers (including those with little capital), and production efficiency and excellent market competitiveness. Other facilitative policy interventions that resulted in Chinese cage culture development include, among others, waiving of rents for the use of open waters, providing interest-free or low-interest loans, and dispatching experts to disseminate aquaculture techniques and experimental demonstrations to farmers.

5.1.2 Egypt

In Egypt, capture fish has been prominent for decades, but the turn-around and sizeable gains in fish production occurred in the early 2010s when aquaculture gained momentum. Currently, Egypt depends more on aquaculture for fish production than on capture fishery (Figure 6b).

Egypt's success has been driven, by and large, by its long-term aquaculture policy intervention. The Egyptian government designed the national aquaculture 2030 strategy, which focuses on the further development of freshwater aquaculture that also encompasses cage farming and desert aquaculture for improving fish quality and production. This strategy was implemented in response to the fish supply shortage in the country, with the aim of significantly reducing fish imports *(*Rothuis et al*.,* 2013*).* The great strides in Egyptian aquaculture thus resulted from implementation of a wide range of policy interventions. Some of the key interventions are described below.

Efficient use of freshwater: There has been a focus for fish production systems to use freshwater more efficiently through the Recirculation Aquaculture System (RAS) and integrated cultures. The system comprises land-based fish farms that allow year-round controlled fish production. In a RAS, fish are reared in indoor tanks in a controlled environment, rather than using open ponds. The recirculating system filters and cleans water for recycling through fish culture tanks. RAS facilities can use freshwater, as well as marine or brackish water. The system ensures high quality fish production, in a stable manner (throughout the year). In RAS, the risk of diseases is reduced, resulting in low mortality rates. The system is also advantageous due to its low water requirements and use of relatively small space (area) to produce high output levels.

Financial resources for aquaculture: The Egyptian government has made great strides in financing aquaculture, but key challenges remain (Rothuis et al., 2013). These challenges include the following, among others. First, similar to in Uganda, financial institutions (banks) are hesitant to finance aquaculture projects due to lack of knowledge about the sector and not being in a position to conduct a thorough risk assessment in the sector. Second, most small and medium scale aquaculture enterprises fail to access loans because they are unable to provide guarantees such as land (because they do not own the land that they use), fixed assets such as housing, and other assets such as agricultural machineries and equipment. Therefore, only large aquaculture enterprises have been able to access credit from formal financial institutions since most of them are in possession of such guarantees or assets. Consequently, small and medium aquaculture enterprises have primarily been relying on informal credits, which are, in most cases, not consistent, with conditions that may not be favourable.

Considering the above challenges, the Egyptian government has initiated innovative mechanisms aimed at overcoming limitations in aquaculture financing. The Multi Sector Support Programme and the Agricultural Research and Development Fund have been instituted to provide soft loans for the aquaculture sector. The sector has, however, not obtained significant loan amounts from such soft loans due to implementation challenges. Another financing mechanism that was established is the Social Fund for Development, but the challenge with this fund in regard to aquaculture is that the credit that is channelled for aquaculture is very small. Other forms of financial support provided to aquaculture farmers represent more informal arrangements such as the purchase of inputs on credit. Suppliers provide inputs such as feeds and seeds on credit to farmers, and interest is not charged on the deferred payment of inputs; however, the farmers are required to pay for the inputs at the time of harvest. The challenge with the provision of inputs on credit is that farmers are forced to harvest and sell fish at harvest time, without paying attention to whether it is the best time to market fish, hence selling fish at a time even when prices are at the lowest level. Another arrangement consists of traders providing farmers with credit opportunities for purchasing inputs, whereby farmers sell fish to them at harvest time at an agreed price, but unfortunately, in most cases, the price is below market price.

Land access: Egyptian farmers usually obtain land through rent from a government agency – General Authority for Fish Resources Development (GAFRD). This process has eased land access for aquaculture production given that the rents for land are set at low levels to allow affordability by farmers. However, the challenge is that lease periods are short (between 3 to 5 years). The government's plan is to extend the five-year lease period to a maximum of 25 years. Other than leasing land, there are private farmers who purchase land on their own with the intention of investing in the costly fixed infrastructure for intensive aquaculture farming.

Fish feeds and fingerling production: Feed mills have been established to produce fish feeds. There are registered feed mills that produce extruded fish feeds, and small-scale pelletizing units. Pelletizing units are used to pelletize farmer's feed ingredients and utilize simple technologies without air driers. For fingerling production, private hatcheries are licensed by the Egyptian GAFRD, but there are also unlicensed private hatcheries in operation.

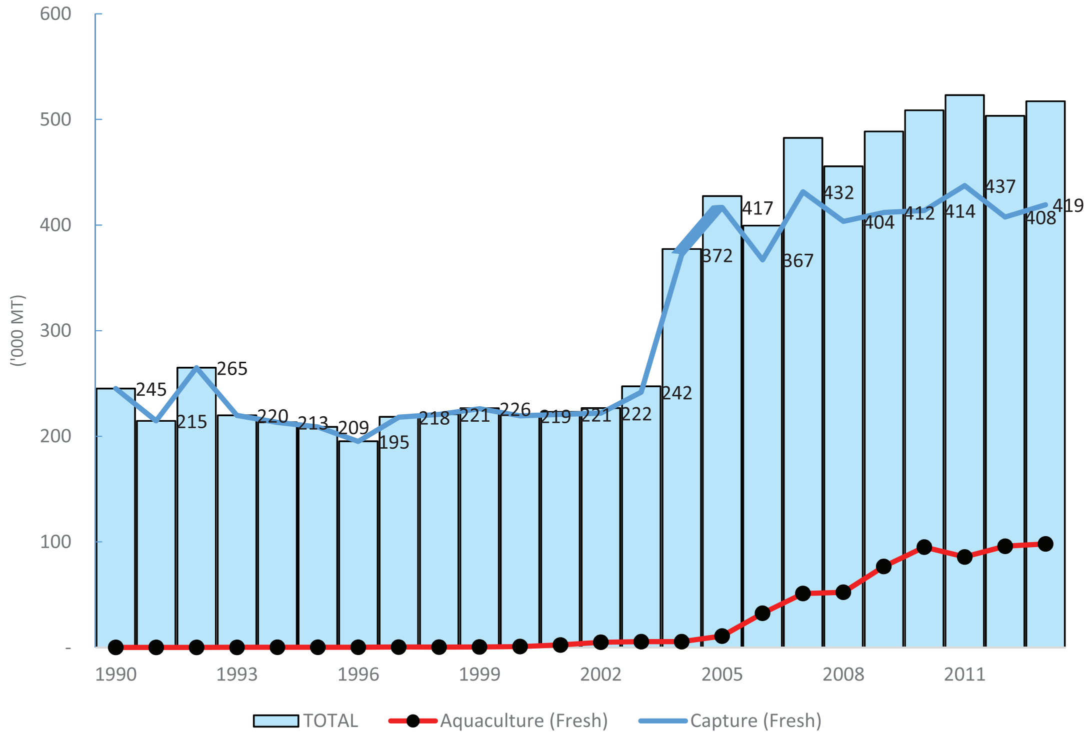
Value chain organization: The Egyptian value chain for farmed fish is "short and efficient". The efficiency in the domestic distribution system is due to the following: a short time period from fish harvest to fish final consumption (approximately 1-2 days), and low losses during the post-harvest period (Rothuis *et al*., 2013). The actors along the fish value chain (ibid) are as follows: fish producer, trader/wholesaler, retail/ food service, and final consumer.

6. ECONOMIC PROSPECTS AND OUTTURNS FROM AQUACULTURE IN UGANDA

6.1 Production Capabilities and Trends in Capture and Aquaculture Fisheries

Figure 7 shows the trends in fish production; specifically, it reveals Uganda's greater dependence on capture fisheries. That said, there are promising signs of gains in fish production both from capture and aquaculture production systems. Aquaculture fish production increased from approximately 10 thousand MT per annum in 2005 to approximately 100 thousand MT per annum in 2013 - accounting for approximately 20 percent of the total national fish production in the country.

Figure 7: Trends in Capture Fish and Freshwater Aquaculture Production (Tons) in Uganda (1990-2014)



Author's computation from FAO Stat Fisheries database (1990-2014)

6.2 Efforts towards aquaculture development in Uganda

The study analysed some of the responses to the heightened and emerging challenges resulting from the decline in capture fish in Uganda's freshwater bodies. The problem of declining fish stocks has invigorated the need to rethink future alternative pathways for developing the fisheries sub-sector. In this regard, government policy efforts have been directed towards establishing Aquaculture Parks (Aps). The concept of APs was proposed by government in 2012 as a pathway to mobilize and bring together fish farmers in a coordinated manner to accelerate growth in the aquaculture-based fish production system in Uganda. Fish cage farming is one of the options among the aquaculture production systems (see Figure 5) that could be integrated into the aquaculture park framework. The study therefore laboured to generate more information on the likely benefits of cage farming and aquaculture in general to complement the already stressed capture fish production system in the country.

There is compelling evidence from the literature reviewed in this paper that cage fish farming could be used to leverage Uganda's underutilized abundant water resources to support the fisheries industry. The subsequent sections provide insights into the current state of APs and cage culture and how these revered forestalled cutting age technologies could drive the future development of an aquaculture driven fisheries industry in Uganda.

6.2.1 Aquaculture Parks - An intervention in waiting?

Historically, aquaculture was introduced in Uganda around the 1950s. In the late 1960s, fish farming was at its peak, covering an area of approximately 410 ha, with approximately 11,000 ponds and producing approximately 800 to 900 MTs of fish annually (Republic of Uganda 2005; Ssebisubi 2011). However, aquaculture production declined significantly around the 1980s to approximately 30 to 40 MTs per annum. The decline was associated with factors such as civil unrest, lengthy economic turmoil, and a collapse in infrastructure and public service delivery, among others. Production started accelerating again in the late 1990s at 50 metric tonnes and was 98,063 metric tonnes in 2013.

To revive and leverage the achieved gains, government intervened in 2012 by proposing the National Investment Policy for Aquaculture Parks (NIPAPs)[8]. The main objective of this policy was to create a framework for a conducive investment environment for increased fish production through APs. Under this arrangement, government aimed at boosting aquaculture production by increasing it from the 2013 level to an ambitious target of 300,000 tonnes by 2016.

The 2012 NIPAPs outlines four strategic objectives for developing aquaculture in Uganda within a timeframe from 2012 to 2016. These are *(i) identification and demarcation of areas suitable for AP establishment; (ii) mobilization of aquaculture producers to access and utilize APs; (iii) provision of support extension services to the APs together with marketing and market linkages; and (iv) institutional support and coordination, among others* (Republic of Uganda 2012).

As part of the strategy, government established some conditions that must be met for a site to be considered appropriate for the establishment of APs. The NIPAP details and articulates guidelines for establishing the planned aquaculture parks. Important for this study is the emphasis that (i) a given site must have an appropriate size to handle production or a mixture of production systems, and when fully operational, it should be capable of producing more than 5,000 tonnes of fish per annum; (ii) government establishes the availability (full supply) of water sources as a priority for APs; (iii) AP sites must be located where farmers reside; (iv) sites must have easy access to infrastructure (e.g., communication, power, potable water, among others); and (v) in the case of commercial or industrial producers, the APs must have an adequate area for the expansion and development of support services systems.

Despite the desirable intention and effort by government to create a policy framework to guide the development of a conducive investment environment for increased fish production through APs, Uganda's progress towards the establishment of APs is very slow, and no APs have been established to date. The implementation of the NIPAPs are traceable only to the first objective pillar - where only two viable areas have thus far been identified for AP establishment, namely, the River Mpologoma in Buyende district and Mwena in the Kalangala Islands[9]. Therefore, the other three strategic objectives of the draft policy as mentioned above are yet to be implemented[10], underscoring the need to review the proposed policy or fast-track it including its implementation to establish APs to boost fish production.

6.2.2 The Level of Cage culture technology in Uganda

There are 28 registered cage culture farmers in Uganda, with a total of 2,135 cages around Lake Victoria (see Table 1). The limited numbers of registered fish farmers using caging technology is because this farming technique is a relatively new fishery intervention in Uganda and has not moved far beyond its infancy stage.

8 NaFIRRI, defines Aquaculture Parks (APs) as zones identified by the government to attract investors and to promote out-grower organization into feasible market segments. The parks are meant to be concentrated aquaculture production areas.

9 According to the information given to the research team by the directorate of fisheries resources at MAAIF in 2015.

10 Since the proposed policy covers the period from 2012 to 2016, government is now left with at utmost one year for the policy to be fully adopted and implemented by policymakers. The period left is seriously limited and thus not adequate for adoption and full implementation to attain the set targets, objectives and goal.

Table 1: Fish Cage Culture in Uganda

Region/district	Numbers		Fish production (Mt/cage)		Productivity MT/annum	
	Cages	Fish Farmers	6-8-month production cycle	Per Annum	Cage	Each Farmer
Eastern						
Jinja	704	6	144.6	216.9	0.31	36.15
Central						
Mukono	420	1	4.5	6.75	0.02	6.75
Buikwe	779	6	733.4	1,100.10	1.41	183.35
Wakiso	150	10	16.1	24.15	0.16	2.42
Rakai	7	1	0.72	1.08	0.15	1.08
Kalangala	75	4	-			
Total	*2,135*	*28*	*899.32*	*1,349.00*		
Median					*0.16*	*6.75*
Average					*0.41*	*45.95*

Notes: Cages captured are those mainly on the major lake of Victoria.

Source: NaFIRRI 2015.

Table 1 further shows that total fish production from cages is approximately 899 tonnes for every 6- to 8-month production cycle. However, it is apparent that the cages in Lake Victoria are mostly concentrated in the central region (districts of Mukono, Buikwe, Wakiso and Rakai). A relatively large number (704) of cages are owned by only six registered farmers located in Jinja district. It is worthwhile to note the disparities in production capacity within the fish cage farmer community (districts). For example, cages operated by the six (6) fish farmers in Buikwe district are more productive, producing approximately 1.41 metric tons per cage annually – and each farmer produces more than 180 metric tons of fish per annum compared with an annual productivity of approximately 20 kg per cage recorded in Mukono district. Having some high and low-end performers within the fish caging production system illustrates some capacity gaps within the fish cage farming community, which implies that more work must be done in terms of fish cage farmer capacity strengthening for Uganda to benefit from this cutting edge innovative technology in the fisheries sub-sector.

6.3 Employment and Economic potential of Fish Cage Culture Technology

This section provides insights into the job creation potential of cage culture and aquaculture park technologies, as well as the productivity of fishermen. Direct and indirect forms of employment generated through the establishment of technologies capable of boosting aquaculture production - aquaculture parks and cage culture- are considered where the available data permit.

6.3.1 Productivity and Employment (Capture Fisheries vis-à-vis Cage Farming)

Table 2 shows that from over 400,000 metric tons of fish produced from the capture fishery production system, the employment of approximately 120,757[11] people is created. Of these, 116,225 (nearly 96 percent) are fishers. Other employment consists of 1,685 traders, 1,380 processors, 15 exporters, 995 transporters, and 457 boat builders and gear repairers. An extended productivity analysis of the capture fishery production[12] system has shown that each fisherman captures approximately 4 metric tons of fish per annum. The 1,349 metric tons produced through cage culture technology by the 28 farmers yield 48 metric tons of fish per fish farmer annually (Table 2), implying that cage culture technology is the most productive system.

11 This figure is based on the most recent available data obtained from NaFIRRI / various sources

12 This involves fish production from natural water bodies (i.e., sum of catches from boats by all fishermen) in a year.

Table 2: Current employment outturns and productivity

Type of fishery activity/technology	Current production (tonnes)	No. of fishers employed	Other employment[13]	Total employment created	Productivity
Capture fishery	419,249	116,225	4,532	120,757[14]	4
Cage culture technology	1,349	28[15]	-	28[16]	48
Aquaculture parks	-	-	-	-	-
Aquaculture - All	98,063	-	-	53,000[17]	-
Fishery – All (capture & aquaculture)	517,312	116,253	4,532	173,785	5

Source: FAO statistics (2013), FAO (2014), NaFIRRI & DFR (various years). Author's own computation of productivity figures (last column).

Therefore, beyond the provision of jobs, cage culture offers a superior alternative for fish production with reduced fishing efforts (in terms of the number of fishermen) to produce more fish. This finding also implies that cage culture can go a long way to save natural resources under capture fishery from depletion since fewer resources and/or fishing efforts are required to produce greater fish volumes.

Conversely, AP initiative has not yet been implemented in the country, and hence no production or jobs have yet been registered under this arrangement. Overall aquaculture production is maintained at 98,063[18], providing an estimated 53,000 jobs. Therefore, the fishery sub-sector as a whole provides more than 173,000 jobs in the country.

6.3.2 Employment projection scenarios

At status quo, this paper makes two basic assumptions, namely (i) NIPAP is adopted or implemented, and (2) the 2,135 cages continue to be functional (refer to Table 1). If the above conditions hold, then a boost in aquaculture is expected and production is projected to grow by more than three-fold from approximately 90,000 to 300,000 metric tons by the end of 2016 - as per the target of NIPAPs. This will boost Ugandan fishery sub-sector to an overall fish production of approximately 718,000 metric tons or more (contributed from both capture and aquaculture technologies) annually, boosting Uganda to the level of Egypt, a leading fish producer in Africa, and hence generating more jobs in the fishery sub-sector.]

Scenario 1: Establishment of aquaculture parks and cage culture (Projections based on NIPAPs)

Based on the medium-term planning framework as in the draft NIPAPs, this paper estimates total job creation assuming the NIPAPs target of 300,000 tonnes by 2016. The underlying assumption is that current employment conditions in the fishery sub-sector will prevail and the direct proportionality relationship will hold. If aquaculture park and cage culture technologies are embraced by policy makers and APs established as planned, nearly 86,410 jobs will be created through aquaculture by the end of 2016 (Table 3), which would translate into a rise in job creation by approximately 19 percent from the current 173,785 to approximately 206,814 jobs by the end of 2016.

13 Trade, processing, exports, transporters, boat builders, and gear repairers
14 This figure does not include other indirect employment such as fish net making and other fishing equipment, among others, due to insufficient data
15 At the time of analysis, data from NaFIRRI showed 28 cage culture farmers. The data were not disaggregated into individual farmers or companies/firms.
16 This only includes cage culture farmers – comprehensive employment data on cage culture were not available
17 FAO - 2014
18 FAO statistics - 2013

Table 3: Employment projection under Scenario 1

Type of fishery activity/ technology	Current production (tonnes)	Estimated total production by 2016 (tonnes)	Total employment created by 2016
Cage culture technology	899	-	-
Aquaculture parks	-	-	-
Aquaculture - All	98,063	300,000[19]	86,410
Capture fishery	419,249	418,021[20]	120,404
Grand total	517,312	71,8021	206,814

Notes: Projections are based on the assumption that capture fish production will stagnate or decline, as it has been the case over the past approximately 5 to 10 years (see Figures 1 and 6) – implying almost no change in capture fish production and employment or a slight reduction by the year 2016.

Source: Authors' computation based on FAO fishery statistics, NaFIRRI & DFR data (various years).

Scenario 2: Assumes NaFIRRI's proposed aqua park establishment

According to a proposal by NaFIRRI in collaboration with DFR in 2013, 45 lake-based aqua parks and 5 land- and river-based aqua parks were recommended to be established to boost fish (aquaculture) production (Table 4). From these parks, the expected (targeted) production levels were 11,250,000 and 25,000 tonnes from the lake-based and land/river systems, respectively, yielding a total production of 11,275,000 tonnes. Assuming a direct proportional relationship between the jobs created and the level of fish production whereby each MT of fish produced creates jobs by a factor of 0.288, the proposed aqua parks is capable of generating over 3.2 million new jobs in the fishery sub-sector (Table 4). It is therefore imperative that the proposed aqua park establishment is considered and fast-tracked by the government to boost both fish production and employment in the country.

Table 4: Proposed aqua parks and expected fish production

Establishment area	No. of Aqua parks	Expected fish production (tonnes)
Panel A: Lake based aqua parks		
Lake Victoria – Eastern region	1	250,000
Lake Victoria – Central region	2	500,000
Lake Victoria – Northern region	1	250,000
Lake Victoria – Western region	1	250,000
Lake Albert	10	2,500,000
Lake Bunyonyi	5	1,250,000
Lake Edward	5	1,250,000
Western region – Crater Lakes	20	5,000,000
Sub-Total	45	11,250,000
Expected new jobs (numbers) (a)		*3,240,357*
Panel B: Land and river based systems		
River Nile and Sezibwa systems	2	10,000
Masindi Port – Panyimur, Adjumani-Yumbe	1	5,000
Mpologoma system – Eastern region	1	5,000
Western Uganda	1	5,000
Sub-Total	5	25,000
Expected new jobs (numbers) (b)		*7,201*
Grand Total	50	11,275,000
Total expected jobs (a+b)		**3,247,558**

Source: NaFIRRI 2015.

19 Based on the production target of the National Investment Policy for Aquaculture Parks

20 Capture fish production is expected to stagnate or even decline. This figure is from the average of the capture fish production over the last five years (2009 – 2013) based on FAO fishery statistics

6.3.2 Economic viability of cage culture technology and capture fisheries

Using information on the economics of the capture fishery system based on 2014 statistics from NaFIRRI, this paper further informs and strengthens the case for floating cage fish farming. Comprehensive financial indicators are provided, including costs, revenues, gross profits, breakeven points and payback associated with the different fish species (i.e., *Nile perch; Tilapia; Mukene; B. Nurse/N. bredoi; and Hydrocynus*), as reported by fishermen. For details, see the NaFIRRI technical report in Odongkara *et al.* (2014).

Summary results (Table 5) show that for Nile Perch, the average annual gross profit (before taxation) under capture fishery, is approximately Shs. 38.4 million and the break-even point and payback period are 4.6 tonnes and 1.3 months, respectively. To achieve all these, the average fish catch per day must be 24.7 kilograms (in a low catch season) and 89.2 kilograms (in a high catch season)[21]. In the case of Tilapia, the average annual gross profit is approximately Shs. 11.3 million, with a break-even point of 4.6 tons and a payback period of 7 months, requiring an average fish catch of 16.7 and 55.8 kilograms per day in low and high catch seasons, respectively[22]. It is worth noting that Nile Perch has a higher annual gross profit than Tilapia.

These profitability measures generally show that both Nile Perch and Tilapia (major fish species) are economically viable through capture fisheries when more than 4.6 metric tons of fish are captured. However, with declining fish stocks, the average productivity per annum is 4 metric tons (refer to Table 2), implying that capture fish fraternity is reaching sub-optimal levels. With limited financial information on floating fish cage farming units, it was difficult to undertake a detailed comparison of the viability of capture fisheries versus aquaculture (through cage culture). However, a cohort analysis, as shown in Table 2, demonstrates that caging is 12 times more productive than capture fishing, costs notwithstanding.

6.4 Current challenges facing aquaculture (including cage culture)

6.4.1 Inadequate aquaculture policy framework

There is currently a lack of a policy to comprehensively address issues that are specific to aquaculture. Since the NIPAPs has not been approved/implemented, there is no policy framework that guides investment in the aquaculture sub-sector. In addition, revision of the phased-out national aquaculture policy is a protracted process.

Table 5: Economic viability (profitability) for capture fishery by major fish species[23]

Economic viability indices	Fish species				
	Nile Perch	Tilapia	Mukene	B. Nurse/N. Bredoi	Hydrocynus
Average Annual Total Cost per boat (Shs.)	25,016,983[24]	18,665,587[25]	21,129,148	14,854,780	10,725,377
Annual Revenue per boat – Average (Shs.)	63,451,614	29,993,427	57,975,840	92,342,467	72,063,160
Gross Profit – Annual (Shs.)	38,434,631	11,327,840	36,846,693	77,487,687	61,337,783
Break Even Point (tons/basins @ year)	4.6 (tons)	4.6 (tons)	1,091 (basins)	1,427 (basins)	-
Payback Period (months)	1.3	7.0	0.8	0.2	-

Source: National Fisheries Resources Research Institute (NaFIRRI) – 2014.

21 National Fisheries Resources Research Institute (NaFIRRI) – Odongkara et al (2014).
22 National Fisheries Resources Research Institute (NaFIRRI) – Odongkara et al (2014).
23 Profitability is based on three lakes - Albert, Kyoga, and Victoria
24 Average annual total cost per boat (non-motorized)
25 Average annual total cost per boat

6.4.2 Fishery extension is missing

The current extension support system in Uganda does not sufficiently support fish farming. Indeed, fishery-specific extension support is lacking, affecting the transfer of new fishery technologies and fish farming knowledge or skills to farmers. The problem related to extension is worsened to the extent that there are cases of individual farmers with an interest in fish farming who prepare fish ponds to perform fish farming but experience a collapse of their initiatives within a short time due to lack of knowledge resulting from an absence of aquaculture-specific extension support to guide them.

6.4.3 Limited functionality of fry centres

The government through MAAIF established fry centres intended for fish seed (fingerling) production at the regional level in Gulu, Mbale, Bushenyi, and Kajjansi. However, due to poor maintenance, the facilities in the fry centres have collapsed, and currently all the centres are non-operational, thus jeopardizing access to quality fingerlings for fish farmers.

6.4.4 Inadequate quality fish feeds

Based on information generated through key informant interviews at MAAIF, quality fish feed production level in the country is inadequate to meet the fish feed demand. Fish feed production is purely private sector-driven, and the private feed producers are insufficient to manufacture sufficient feed. Feed producers are unevenly distributed across regions, with the major actors located in the Central region (mainly Kampala). Limited quality assurance measures in terms of government regulation of fish feed standards remains a challenge, and therefore there is no guarantee for fish farmers regarding the quality of the feed being produced by private sector players. Additionally, there is limited Public Private Partnerships in quality feed production and the entire aquaculture production system.

7. CONCLUSION AND POLICY RECOMMENDATIONS

This study reviews progress on the development of cage culture and aquaculture park technologies in Uganda, examines the potential of fish cage farming and aquaculture park technologies for stirring the growth of the fishery industry, analyses the likely employment outturns accruing from adoption and implementation of cage culture and aquaculture park technologies, undertakes an economic viability analysis of cage culture technology compared to wild fishing practices, and documents the current challenges facing adopters of fish cage culture in Uganda. The study followed a multi-pronged analytical approach that is a detailed qualitative analysis (plus document review) and provides descriptive statistics including the use of direct proportional analyses.

The findings show that the fish export sector enjoys fortunes from favourable international fish market (prices) and thus has a great potential to boast export earnings, but the capacity to export fish is limited by supply-side constraints. We also note that fish represent a growing local market. Uganda's National Investment Policy for Aquaculture Parks has remained without implementation, and there has been slow progress in adopting it. Endeavours towards the establishment of aquaculture park and cage culture technologies are therefore slow.

We also show that aquaculture has a tremendous potential to stir the growth of the fishery industry, hence providing a practical solution or complement to address the fish production gap plagued by supply-side constraints. The evidence demonstrates that it is possible for the fishery sub-sector to predominantly place a reliance on aquaculture (including cage culture) for fish production rather than too much dependence on unpredictable and struggling capture fisheries. Uganda can draw key lessons from successful and leading aquaculture producing countries (like China and Egypt) to bolster its aquaculture sub-sector. The key lessons include, among others, the development and provision of quality fish seed and feed, introduction of new fish species through R&D, TEC including experimental demonstrations for the transfer of techniques or skills for new culture to small rural aquaculture farmers, and the provision of low-cost financial resources for aquaculture.

Pertaining to employment, the results show that if aquaculture park and cage culture technologies are embraced by policy makers and fully established, an additional 86,410 total or more jobs will be created in the fishery sub-sector by the end of 2016, causing the total employment in the industry to rise from the current 173,785 to approximately 206,814 jobs by the end of 2016. Additionally, the targeted production of 11,275,000 tonnes from 50 proposed aqua parks is capable of generating an estimated more than 3.2 million new jobs in the fishery sub-sector. Furthermore, cage culture technology has been shown to be the most productive system, with a productivity level of 48 tonnes per fisherman annually compared to only 4 tonnes per fisherman per annum in capture fishery. Therefore, beyond the provision of jobs, cage culture offers a superior alternative for fish production with fewer fishing efforts. The results also show that the key challenges facing the aquaculture sub-sector (including cage culture) in Uganda are an inadequate policy framework to guide investments in the sub-sector, inadequate fishery (aquaculture)-specific extension support, limited functionality of regional fry centres, insufficient production of fish feeds, and limited Public Private Partnerships.

Interventions aimed at establishing cage culture technologies should be initiated or strengthened, and there is need to review the proposed National Investment Policy for Aquaculture Parks or fast-track it, including its implementation to achieve the establishment of Aquaculture Parks to boost fish production and employment in the country. Drawing lessons from the path taken by China and Egypt can guide the development of a productive and efficient fisheries sub-sector based on aquaculture. Some of the policy lessons include the following: the development of an effective fishery-specific extension system, such as the use of the TEC model, initiatives for quality fingerling and fish feed production, low-cost financing, and effective fish farmer mobilization.

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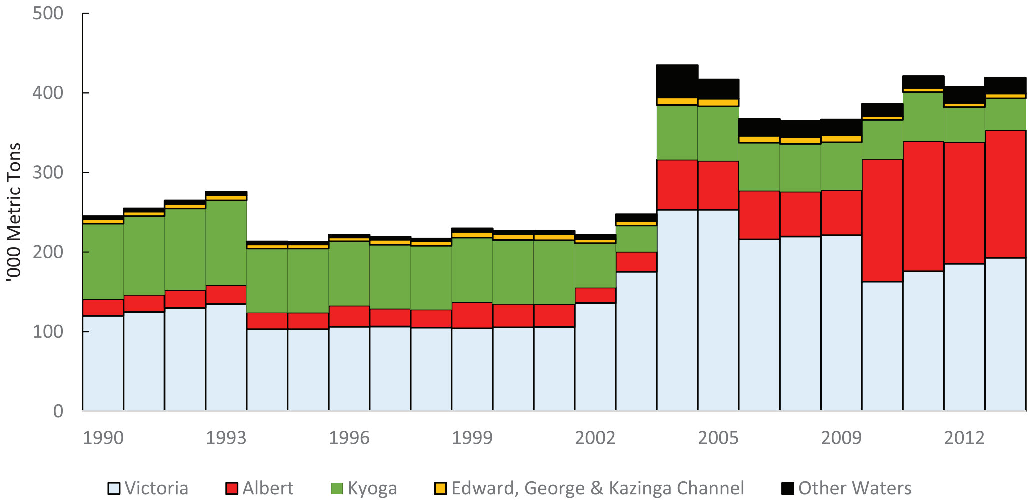
APPENDIX

Figure A 1: Fish Catch by Major Water Bodies



Source: Statistical abstract – UBoS, 2014

Table A 1: Fish Catch by Major Water Bodies ('000 Metric Tons)

	Victoria	Albert	Kyoga	Edward, George & Kazinga Channel	Other Waters	Total
1990	119.9	20.9	94.9	5.5	4.0	245.2
1991	124.7	21.7	98.7	5.7	4.1	254.9
1992	129.7	22.5	102.6	5.9	4.2	264.9
1993	134.9	23.4	106.7	6.4	4.6	276.0
1994	103.0	21.2	80.2	5.2	3.7	213.3
1995	103.0	21.1	80.2	5.2	3.7	213.2
1996	106.4	26.5	80.6	4.8	3.7	222.0
1997	106.6	22.5	80.1	6.4	3.7	219.3
1998	105.2	22.6	80.2	5.6	3.5	217.1
1999	104.2	32.8	81.1	7.4	4.3	229.8
2000	105.4	29.6	80.2	7.2	4.5	226.9
2001	105.8	29.0	80.1	7.4	4.5	226.8
2002	136.1	19.4	55.6	5.2	5.6	221.9
2003	175.3	25.1	32.9	5.9	8.3	247.5
2004	253.3	62.8	68.5	9.6	40.6	434.8
2005	253.3	61.4	68.4	9.6	24.1	416.8
2006	215.9	61.4	60.0	8.8	21.1	367.2
2008	219.5	56.5	60.0	8.8	20.0	364.8
2009	221.3	56.5	60.0	8.8	20.0	366.6
2010	162.9	154.2	49.1	4.5	15.3	385.9
2011	175.8	163.6	61.6	5.3	14.8	421.1
2012	185.5	152.6	44.1	5.2	20.3	407.6
2013	193.0	160.0	40.0	6.3	20.0	419.3

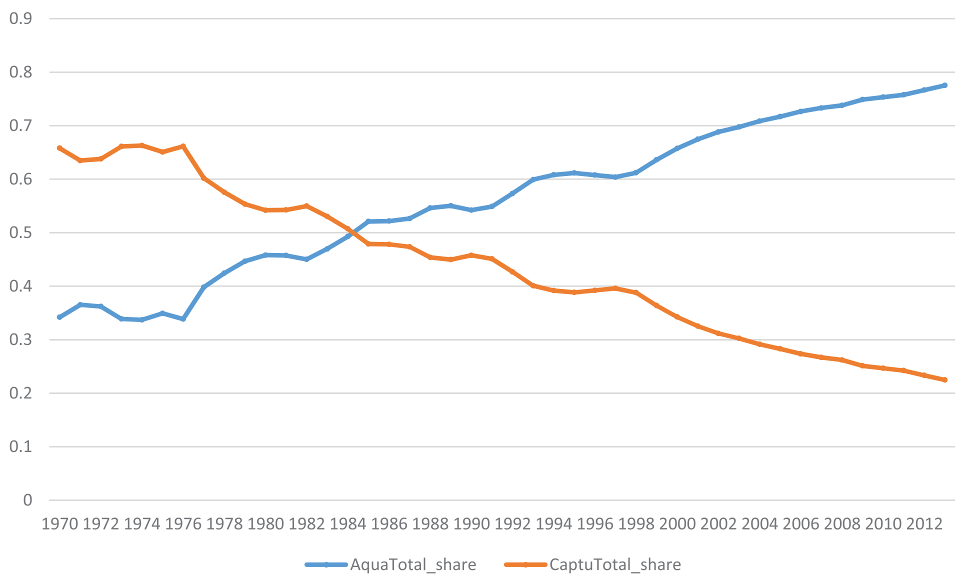
Source: UBoS, Statistical abstract (several issues).

Table A 2: Catches from Small Water Bodies (2010)

Lake/Water Body	Area in Sq Km	Current Production (MT)2010	Total Potential
Buhwenju Lakes	3	64	111
Bunyaruguru Lakes	21	513	889
Kisoro/ Kabale	34	633	1,096
Paliisa/Bugiri Lakes	125	125	217
Nyamusingiri	4	60	104
Kachera	38	1,104	1,912
Kijanebalola	38	849	1,470
TOTAL		**416,757**	**721,823**

Source: DFR Field Reports 2010.

Figure A 2: Overall[26] share of aquaculture and capture fish in total production - China



Source: Computed from FAO – aquaculture and capture production statistics (1970-2013).

Table A 3: Volume and value of Ugandan fish exports, 1991-2010.

	Volume MT ('000)	Value Million ($)	Unit (MT) Value $'000
1991	4.8	5.3	1.1
1992	4.8	6.5	1.3
1993	6.0	8.8	1.5
1994	6.6	14.8	2.3
1995	13.0	25.9	2.0
1996	16.4	39.8	2.4
1997	9.8	28.8	2.9

26 Overall implies total aquaculture and total capture fish production, including both fresh water and marine fish.

1998	13.8	34.9	2.5
1999	13.4	36.6	2.7
2000	15.9	34.4	2.2
2001	28.7	80.4	2.8
2002	25.2	87.6	3.5
2003	25.1	86.3	3.4
2004	30.1	102.9	3.4
2005	36.6	143.6	3.9
2006	32.9	136.9	4.2
2007	28.4	117.4	4.1
2008	23.4	115.3	4.9
2009	17.3	85.4	4.9
2010	24.0	119.6	5.0

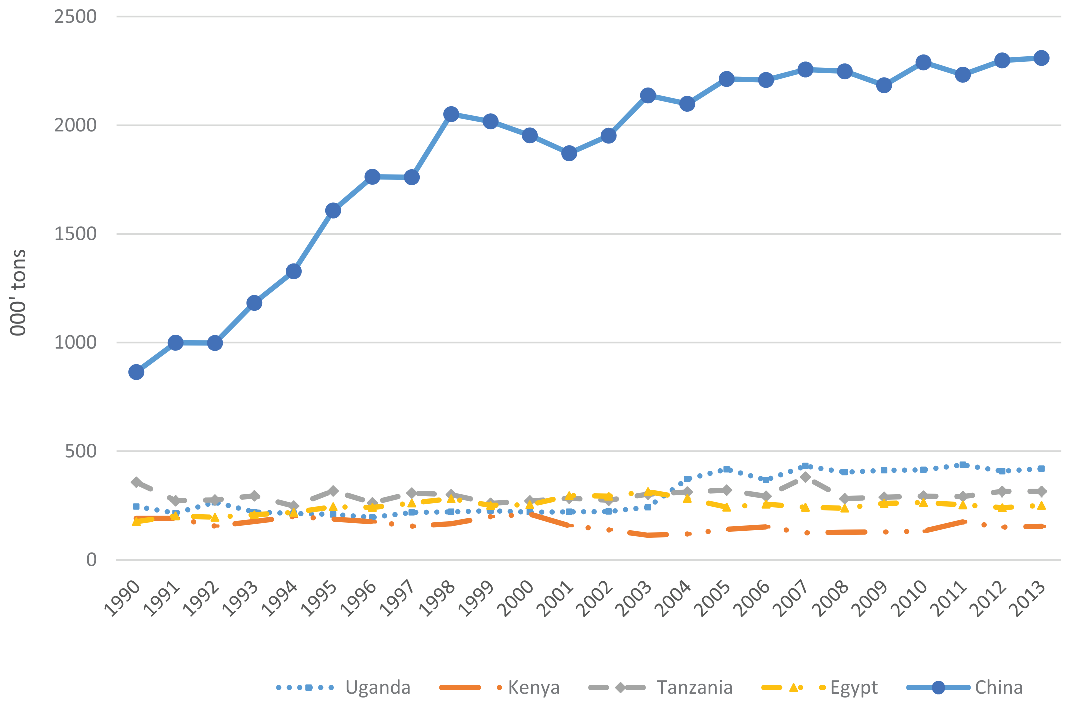
DFR Field reports 2010

Table A 4:Movement in Volume and Value of Uganda's Fish Exports (1990-2011)

	Export Volume		Export Value		Value/MT	
	Volume ('000)MTs	Annual Growth Rate	Million USD	Annual Growth Rate	Unit Value	% Change
1990	1.664		1.4		0.83	
1991	4.687	182	5.3	283	1.13	36
1992	4.851	3	6.5	22	1.34	18
1993	6.943	43	15.8	143	2.27	70
1994	7.216	4	16.3	3	2.26	(1)
1995	13.471	87	26.5	62	1.96	(13)
1996	16.396	22	39.8	50	2.43	24
1997	9.839	(40)	28.8	(28)	2.93	21
1998	13.32	35	42.2	47	3.17	8
1999	9.596	(28)	28.3	(33)	2.95	(7)
2000	14.911	55	31.0	10	2.08	(30)
2001	17.318	16	51.0	65	2.95	42
2002	25.534	47	88.0	72	3.44	17
2003	26.555	4	88.4	0	3.33	(3)
2004	31.958	20	103.7	17	3.24	(3)
2005	39.324	23	143.3	38	3.64	12
2006	36.935	(6)	147.0	3	3.98	9
2007	31.986	(13)	125.9	(14)	3.94	(1)
2008	27.269	(15)	133.8	6	4.91	25
2009	23.931	(12)	114.4	(15)	4.78	(3)
2010	23.073	(4)	133.6	17	5.79	21
2011	22.377	(3)	143.1	7	6.39	10
AVG GROWTH RATE:						
1990-2011		***20***		***36***		***12***
2005-2011		***(4)***		***6***		

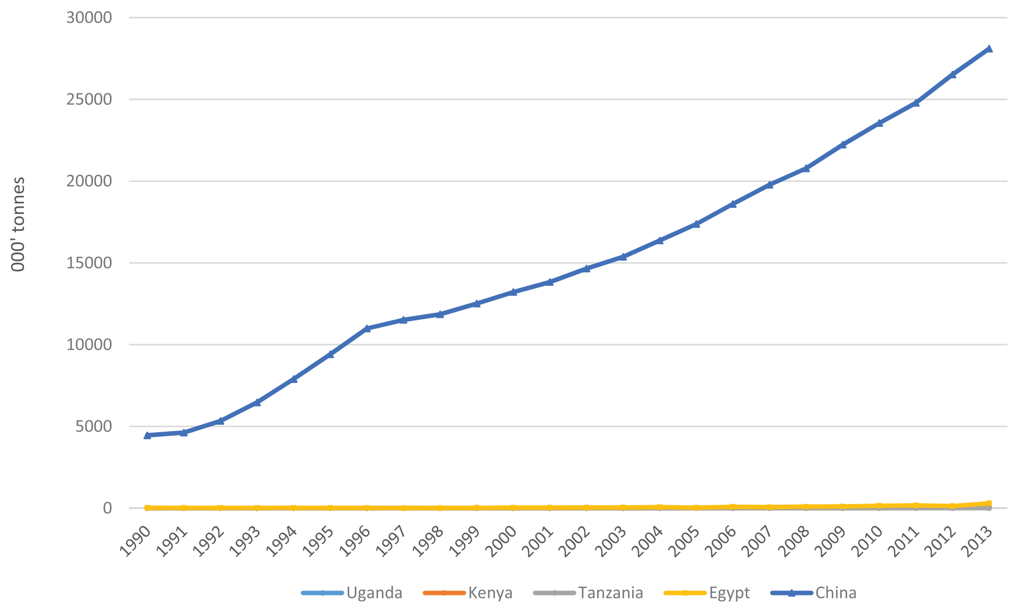
Source: FAO stat (2015).

Figure A 3: Fresh water capture production in East African Countries, Egypt and China ('000tonnes)



Source: Computed from FAO fishery statistics, 2015.

Figure A 4: Fresh water aquaculture production in East African Countries, Egypt and China ('000tonnes)



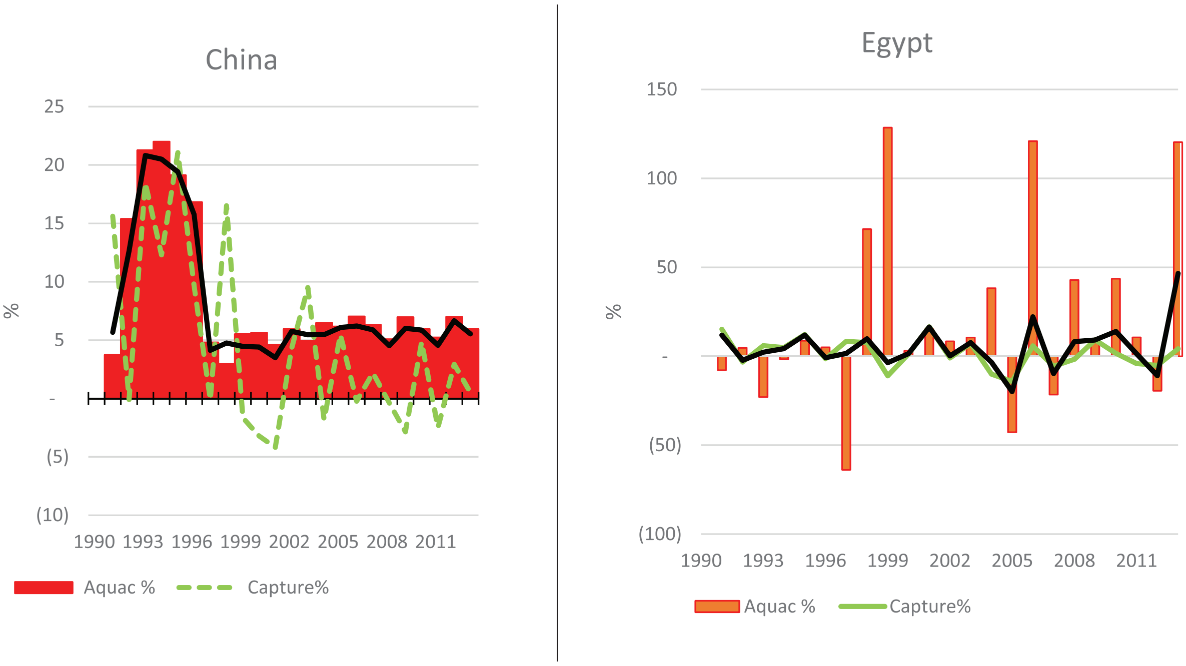
Source: Computed from FAO fishery statistics, 2015.

Table A 5: Fresh Water Aquaculture and Capture Fish Production (Tons) in Egypt and China (1990-2013)

	Egypt (MT)				China (MT)		
	Aquac_Fresh	Capture_Fresh	Total		Aquac_Fresh	Capture_Fresh	Total
1990	29,916	175,669	205,585		4,459,100	864,144	5,323,244
1991	27,577	202,300	229,877		4,625,900	998,961	5,624,861
1992	28,895	195,700	224,595		5,337,900	998,028	6,335,928
1993	22,262	207,473	229,735		6,472,599	1,182,390	7,654,989
1994	21,887	217,700	239,587		7,896,594	1,327,785	9,224,379
1995	23,813	244,300	268,113		9,407,600	1,607,385	11,014,985
1996	24,993	240,900	265,893		10,989,505	1,762,860	12,752,365
1997	9,037	261,167	270,204		11,518,294	1,760,744	13,279,038
1998	15,492	281,141	296,633		11,859,013	2,051,450	13,910,463
1999	35,405	250,318	285,723		12,512,819	2,017,838	14,530,657
2000	36,520	253,470	289,990		13,218,387	1,953,134	15,171,521
2001	42,087	295,450	337,537		13,829,889	1,871,295	15,701,184
2002	45,613	292,662	338,275		14,652,790	1,951,889	16,604,679
2003	50,409	313,742	364,151		15,372,593	2,137,496	17,510,089
2004	69,686	282,099	351,785		16,369,346	2,098,777	18,468,123
2005	39,914	242,100	282,014		17,378,634	2,213,303	19,591,937
2006	88,189	256,288	344,477		18,601,550	2,208,156	20,809,706
2007	69,156	241,743	310,899		19,777,182	2,256,533	22,033,715
2008	98,833	237,572	336,405		20,781,165	2,248,347	23,029,512
2009	107,609	259,577	367,186		22,228,557	2,184,049	24,412,606
2010	154,539	263,847	418,386		23,552,712	2,289,603	25,842,315
2011	170,937	253,051	423,988		24,785,076	2,232,661	27,017,737
2012	137,788	240,039	377,827		26,517,693	2,298,199	28,815,892
2013	303,628	250,196	553,824		28,098,250	2,309,812	30,408,062

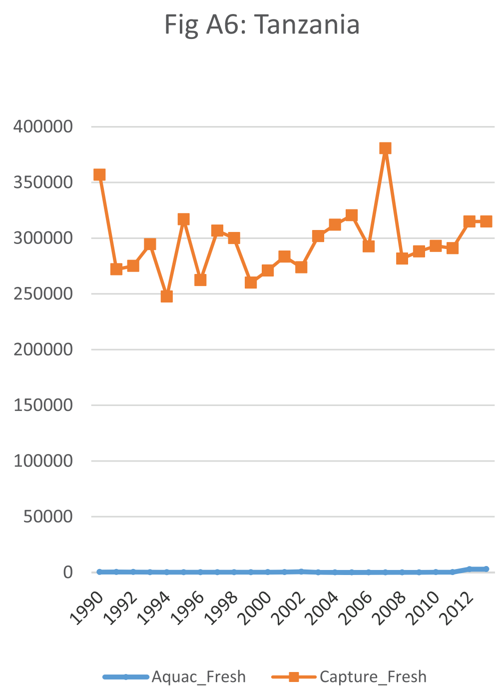
Source: Computed from FAO fishery statistics, 2015.

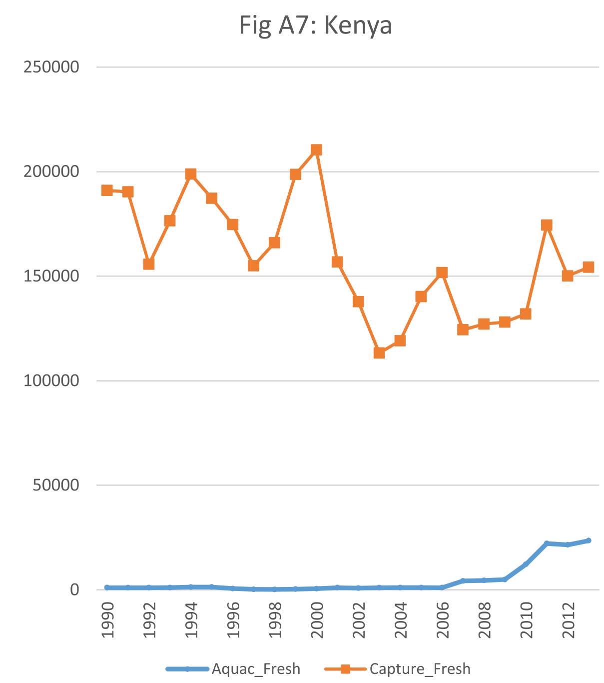
Figure A 5: Production shares in China and Egypt



Source: Computed from FAO fishery statistics, 2015.

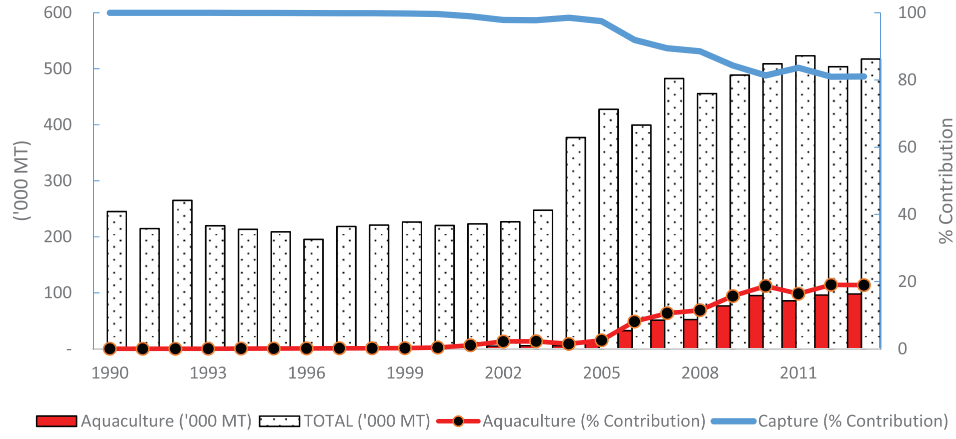
Figures A6-A8: Fresh Water Aquaculture and Capture Fish Production (Tons) Across Major East African Countries





Source: Computed from FAO fishery statistics, 2015

Figure A 8: Trends in Capture and Aquaculture Fisheries Capabilities in Uganda (1990-2013)



Source: Computed from FAO fishery statistics, 2015.

Table A6: Employment by Actors in the Fisheries Value Chain in Uganda

Lake	Fishers	Traders	Processors	Exporters	Transporters	Boat_ Builders	Gear_ Repairers	Total
Victoria	64,617	703	420	14	659	244	136	66,793
Albert	19,925	348	250	1	34	7	1	20,566
Kyoga	28,953	455	456		127	31	22	30,044
Kazinga Chanel	2,730	179	254		175	8	8	3,354
Total	116,225	1,685	1,380	15	995	290	167	120,757

Source: NaFIRRI 2015.

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