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Economic profitability of Nile tilapia (*Oreochromis niloticus L.*) production in Kenya

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Abstract

Economic profitability of Nile tilapia production in Kenya was analysed using a model that simulated individual fish growth and took fish population dynamics in the pond into account. The results suggest that the currently practiced mixed-sex tilapia culture is economically unsustainable. It is suggested that research and extension efforts be geared towards developing monosex Nile tilapia production systems. Nile tilapia culture with African catfish predation should be viewed as an intermediate step towards all-male Nile tilapia culture. This will allow accumulation of both physical and human capital to support all-male tilapia culture. Under all-male culture, economic returns are high enough to justify investment in Nile tilapia culture using borrowed capital. However, the success of monosex culture will depend on the availability and affordability of quality fingerlings and low-cost fish feeds. The results have a wide application in Sub-Saharan Africa where mixed-sex Nile tilapia culture is common.

Introduction

The government of Kenya development policy has always focused on alleviating poverty through increased food production and minimization of environment degradation. Consequently, a major priority development need of the government has been low-cost aquaculture, which will increase available protein to local communities. One such initiative is to increase protein production from the aquaculture and fisheries sectors (Ngugi & Manyala 2004). However, aquaculture continues to contribute <1% of the total national production of protein. Despite political support, lack of knowledge concerning returns from aquaculture investment has contributed significantly to slow growth of the aquaculture sector in Kenya. Because of limited knowledge, fish farming is seen as a marginal and risky investment.

Historically, fish farming in Kenya evolved from the introduction of sport fishing in the 1890s and static water pond culture of tilapia species, carp and catfish in the early 1920s to stocking of reservoirs with fish to control aquatic weeds, bilharzia snails, leeches and mosquitoes and to small-scale aquaculture in the 1940s. Since then, commercial fish farming has had some degree of success, such as operation of trout hatcheries for restocking inland water for angling and to supply fingerlings to fish farmers. For aquaculture and small-scale fish operations, water availability does not appear to be a major constraint. Small-scale fish farms are often integrated with other farming activities. Initial stocking of ponds has been based on supplies from farmer to farmer and from government fish farms and demonstration ponds, supplemented by fingerlings caught in lakes and reservoirs. Mixed-sex Nile tilapia culture represents over 75% of fish produced through aquaculture. Polyculture of Nile tilapia and catfish contributes to about 15% of the national aquaculture production (Ngugi & Manyala 2004).

The Kenyan Department of Fisheries, together with other development agents, are currently involved in promoting commercial hatcheries for fingerlings production, ensuring the transfer of small-scale and commercial aquaculture technology and training fish farmers and fisheries extension officers. Research and extension linkage mechanisms are established through training of extension personnel at research institutes and interaction between senior officials of the Fisheries Departments and University researchers. Still, there is lack of information on the economic performance of different fish culture scenarios in Kenya.

We use a dynamic model to estimate the economic profitability of small-scale production of Nile tilapia in Kenya. The main objective was to estimate the costs of producing Nile tilapia fish under different culture systems in terms of required initial investment and operational costs for mixed sex with and without predation and all-male tilapia cultures. The intention was to generate economic information for entrepreneurs and existing aquaculture farms to develop enterprise budgets and business plans. These economic tools are essential for determining credit worthiness and for successful implementation of farm enterprises (Barry, Ellinger, Hopkin & Baker 1995).

In order to accomplish the objectives, small-scale aquaculture farms based on 200 and 634 m^2 pond sizes were utilized in estimating production cost in a dynamic framework. The model of de Graaf, Dekker, Huisman and Verreth (2005) that simulates the production of Nile tilapia in a mixed-sex or mono-sex cultures and with or without African catfish (*Clarias gariepinus*) predation was used. This model is based on population dynamics by following each individual fish in the pond throughout the rearing period. The basic assumption is that the water temperature rarely goes below 23°C and the growth of economically sizable fish depends on proper pond fertilization and supplementary feeding. The model allows simulating the production potential of the selected pond size. The required input data include: type of Tilapia culture, stocking densities, type of feed used, number of days taken to grow the fish and economic information on price of fish, operation costs and investment. The model results give an indication of the required initial investment, labor costs, feed and other input costs, expected price for different categories of fish at harvest and economic profitability of different management options. The results are rich enough to develop farm enterprise budgets, a prerequisite for developing business plans.

Materials and methods

Model structure

According to de Graaf *et al.* (2005), there are two kinds of simulation models for fish reared in ponds: descriptive-empirical models and explanatory-theoretical models. Empirical models describe data without explaining the mechanism leading to relationship among data. There is no relationship between predator density and efficiency to control juvenile fish recruitment in ponds (Hopkins & Cruz 1982). Theoretical models are based on knowledge of biological process and flow underlying the production system. While theoretical models balance the flow of energy, mass, nitrogen and respiration (Ross & MacKinney 1989), population dynamic models balance the numbers of fish or biomass in the production system (Fischer & Grant 1994).

de Graaf *et al.* (2005) presents the economic simulation model based on population dynamics as implemented through Tilapia Farming Support Tool (TFST) software (Nefisco 2003). The main advantages of the population dynamic models include allowing incorporation of prey—predator, and modelling is based on individual fish growth in the pond (Sparre & Venema 1992). In addition, dynamic models are useful for assessing the economic tradeoff associated with different management choices. The de Graaf *et al.* (2005) model consists of two modules. The first module simulates the growth of tilapia males, female and recruits. The second module simulates stocked predators. Each module is based on the principle of length-based fish stock assessment, whereby growth is simulated according to the von Bertalanffy growth function (Somers 1988). The evolution of the number of fish is simulated with an exponential decay function as discussed in Sparre and Venema (1992).

Calibration and validation of the model was carried out by adjusting the value of key parameters on mortality and growth reduction because of increasing fingerlings biomass. The simulation was conducted until the best agreement between observed and simulated data was reached. The agreement between simulated and observed values was quantified through linear equations. Pearson's correlation coefficient was used to examine the significance of the relationship between observed and simulated data. Sensitivity analysis was conducted to investigate the impact of four model input parameters (i.e., growth parameter, stocking length of Nile tilapia fingerlings, length at first maturity of Nile tilapia and fingerling recruitment) on variability of model outputs. Calibration and validation of the model (hence the software) is based on different datasets and can be used to analyse the economics of small-scale Nile tilapia farms in some other parts of Sub-Saharan Africa where mixed Nile tilapia culture is widely practiced. Details of the model structure are presented in de Graaf *et al.* (2005) and the TFST software can be downloaded from the Nefisco Foundation. Kaliba, Osewe, Senkondo, Mnembuka and Quagrainie (2006) present a summary of the model parameters.

Data inputs

The data inputs for this study were obtained from a survey conducted in January–April 2005. This was a survey conducted under the USAID Aquaculture/Collaborative Research Support Program and targeted all farms located in Central, Eastern, Rift and Western Kenya, which are major aquaculture-producing regions. A structured questionnaire was used to collect information on management practices and input–output data from 138 farms. Input–output data were used during model simulation to determine the profitability of mixed-sex tilapia culture with or without catfish predation and hand-sexed all-male tilapia culture for 200 and 634 m^2 ponds. Owing to limited physical and human capital, sex reversal is currently considered to be a high-tech practice and unsustainable in the current aquaculture production system. From the survey data, whereas the pond sizes varied from 40 to 7 200 m^2, 65% of 138 sample households had 200 m^2 ponds and the average pond size was 634 m^2.

Table 1 shows the pond management and economic variables that were used to stimulate the model. Weight and length at stocking are based on research-extension recommendations. The value of land is based on the opportunity cost of not producing maize on the plot allocated to fish farming. Maize is an important crop in areas that have potential for aquaculture operation. The Food and Agricultural Organization of the United Nations (FAO) crop production database shows that in 2004, maize yield in Kenya was about 1.5 MT ha^{-1} and producer price was 10 340 Kenyan Shillings (KES)/MT (FAO 2007). The KES traded at 73.4 per US dollar in June 2006 (Central Bank of Kenya 2007). The opportunity cost of land is the lost revenue (i.e., 15 510 KES ha^{-1} or 1.55 KES m^{-2}) from maize production. Okechi (2004) indicates that the cost of constructing a 0.08 ha pond in 2004 was 36 000 KES. Including an inflation of 6.6% (World Bank 2006), this is equivalent to 47.97 KES m^{-2}. Maintenance and depreciation cost item is based on 10% of the pond construction cost and equipment cost. The equipment cost includes the value of fishing gear, feeding and maintenance equipment specifically for pond operation. On average, the value of owned equipment was about 3% of the pond construction cost.

Table 1. Data input on pond management and economic variables for base case

Variable	Unit	Value
Pond characteristics		
Area of ponds	m^2	200, 634
Weight at stocking		
Tilapia	g	20
Catfish	g	30
Density stocked		
Tilapia	# m^{-2}	2
Catfish	# m^{-2}	0.2
Economic variables*		
Fixed costs		
Land†	KES m^{-2}	1.55
Pond construction	KES m^{-2}	47.97
Equipments	KES ha^{-1}	1.44
Maintenance and depreciation	10%	4.94
Interest on capital	8%	3.95

* The exchange rate on 30 May 2005 was US $ 1=76.85 Kenyan Shillings (KES).

† The calculation is based on the opportunity cost of producing maize instead of fish. Based on the FAO database, maize yield in Kenya is averaged at 1.5126 tonne ha^{-1} in 2004 and the producer price was 10 340 KES $tonne^{-1}$.

‡ It is estimated that one unskilled individual will spend 5% of the available time to manage the pond, which includes feed preparation/collection, feeding, harvesting and marketing. The cost is based on the minimum wage of 4 279 KES $month^{-1}$.

FAO, Food and Agricultural Organization of the United Nations.

During the survey, the respondents indicated that in each household, there was one person responsible for managing the fishponds. Management included maintaining the pond, feeding, harvesting and marketing the fish. Based on hours spent on these activities, it was estimated that the pond manager spent about 5% of the yearly full-time equivalent of about 20:80 hours to manage a 200 m^2 fishpond. Cost per day is calculated from the minimum wage set by the government at 4279 KES $month^{-1}$. Apart from supplementing natural food in ponds, Liti, Cherop, Munguti and Chhorn (2005) showed that high-protein feed supplementation was important for fish weighing more than 140 g. The farmers in the survey used maize bran and manure to feed the fish and fertilize the ponds at an average rate of 9 tonne ha^{-1}. Farmers also used kitchen leftovers and leaves that were assumed to have a marginal cost of zero. The crude protein content of maize and rice bran was set at 12.5% (Muir & Massaete 1996). The nitrogen content of cow manure is about 2.5% (Hotland 1993). During the survey period, a 50 kg bag of ammonium nitrate with 50% nitrogen cost 1846 KES or 74 KES per 1% of nitrogen. In Table 1, the prices of maize bran and fish were estimated from survey data. During the analysis, the modes were preferred to the means as they included costs/prices that were incurred/received by the majority of respondents.

Results

The three Nile tilapia culture systems were simulated based on combinations of model parameters (de Graaf *et al.* 2005) and economic variables presented in Table 1. This enabled generation of results presented in Tables 2 and 3. The results in Tables 2 and 3 were used to generate the enterprise budgets of the three cultures presented in Appendix A. In Table 2 and for a 200 m^2 pond, ownership and operating costs generated a total annual cost of 3144 KES for a mixed-sex tilapia culture without catfish predation. The analogous amounts for mixed-sex tilapia culture with catfish predation and hand-sexed all-male tilapia culture were, respectively, 4606 and 4274 KES. There was no significant dramatic increase in cost on switching from one tilapia production system to another.

Table 2. Economic variables generated by the model for a 200 m^2 pond

Variable/culture*	Quantity (kg)	Amount (KES)
Mixed tilapia without predation		
Costs		
Feed		233
Fish		2520
Operational		391
Total variable cost		3144

Variable/culture	Quantity (kg)	Amount (KES)
Revenue		
Large tilapia	2	277
Medium tilapia	8	818
Small tilapia	52	4750
Total	62	5845
Gross profit		2701
Unit variable cost per kg of fish		51

* With a maximum of 300 rearing days.

† A 5% marginal of error is allowed.

KES, Kenyan Shillings.

Table 3. Economic variables generated by the model a 634 m^2 pond

Variable/culture*	Quantity (kg)	Amount (KES)
Mixed tilapia without predation		
Costs		
Feed		721
Fish		11 158
Operational		1238
Total		13 117
Revenue		
Large tilapia	5	663
Medium tilapia	28	284
Small tilapia	160	15 262
Total	193	16 209
Gross revenue		3092
Unit variable cost per kg of fish		68
Mixed tilapia with catfish predation		
Costs		

* With a maximum of 300 rearing days.

† A 5% marginal of error is allowed.

KES, Kenyan Shillings.

The total annual cost per pound of fish harvested was 51 KES for mixed-sex tilapia culture without catfish predation, 58 KES for mixed-sex tilapia culture with catfish predation, and 46 KES for hand-sexed all-male tilapia culture. The results show an increase in unit cost from mixed-sex cultures to mixed tilapia culture with predation and a decrease in unit production cost from polyculture to monoculture. The feed cost was between 6% and 18% of the total production cost. The cost of fingerlings accounted for more than 80% of the total cost. Operational expenses accounted for <12% of the total cost. Management technique to reduce fingerling costs may have the highest impact on cost reduction in Kenyan Nile tilapia culture.

Table 2 also shows expected revenue from a 200 m^2 pond. Owing to difference in fish growth, which is associated with competition and predation in pond, different sizes of fish are harvested (i.e., large, medium and small fish). The annual sale was 5845 KES for the mixed-sex tilapia culture without predation, 8018 KES for mixed-sex tilapia culture with catfish predation and 10 919 KES for hand-sexed all-male tilapia culture. Revenue was mainly from small-sized fish for mixed-sex tilapia culture without predation (81%), and likewise for the mixed-sex tilapia culture with catfish predation (58%). Catfish contributed about 28% of the total revenue in the second culture. For the hand-sexed all-male tilapia culture, 88% of the revenue came from larger tilapia fish and the small fish contributed only 2%. The medium tilapia fish contributed about 10% of the total revenue. The estimated total revenue and cost generated about 2701 KES in annual gross profit for mixed-sex tilapia culture. Annual gross profits for the mixed-sex tilapia and hand-sexed all-male tilapia cultures were 3412 and 6645 KES respectively. The results indicate higher returns for each KES invested in the all-male tilapia culture.

Economic analysis results for a 634 m^2 pond are as shown in Table 3. The annual costs were 13 117 KES (mixed-sex tilapia without predation), 14 573 KES (mixed-sex tilapia with catfish predation) and 15 652 KES (hand-sexed all-male tilapia). Feed contributed between 5% and 8% of the annual total cost. Unit cost per kg of fish produced was 68 KES for mixed-sex tilapia without catfish predation, 60 KES for mixed-sex tilapia culture with catfish predation and 50 KES for hand-sexed all-male tilapia culture. The results indicate a decrease in unit cost from mixed-sex to all-male Nile tilapia culture.

Annual sales for each culture were 16 209 KES for the mixed-sex tilapia culture without predation, 25 092 KES for mixed tilapia culture with catfish predation and 30 645 for all-male tilapia. Again, revenue was mainly from small-sized fish for mixed-sex tilapia culture without predation (94%), and likewise for the mixed-sex tilapia culture with catfish predation (60%). Catfish contributed about 26% of the total revenue in the second culture. For all-male tilapia culture, 51% of the revenue came from larger tilapia fish and the small fish contributed only 26%. The medium tilapia fish contributed about 23% of the total revenue. The estimated total revenue and cost generated about 3092 KES in annual profit for mixed-sex tilapia culture without predation. Annual profits for the mixed-sex tilapia and hand-sexed all-male tilapia cultures were 24 392 and 30 645 KES respectively. While the costs were relatively similar for mixed tilapia culture and all-male tilapia culture, the revenue was significantly higher (about twofold) for all-male tilapia culture.

Discussion

The results in Tables 2 and 3 indicate that hand-sexed all-male tilapia culture was superior to mixed-sex culture with and without predation. Mixed-sex tilapia culture with catfish predation was superior to mixed-sex tilapia culture without predation. The realized gross profit margins (profit/revenue) of more than 45% for a 200 m^2 pond and more than 19% for a 634 m^2 pond justify investment in Nile tilapia culture through borrowed capital. With the exception of mixed tilapia without predation in the 634 m^2 pond, the realized gross profit margins were more than 40%. Introduction of catfish predation into the pond decreased the profit margin from 46% to 43% for a 200 m^2 pond but increased the profit margin from 19% to 42% for a 634 m^2 pond. Rearing all-male tilapia increased the gross profit margin to 46% and 56% for the 200 and 634 m^2 pond respectively. Because there is no significant increase in cost after introducing catfish predation into mixed-sex culture and due to accompanied high returns, mixed-sex culture with catfish predation may be the best alternative tilapia culture while the technique of separating males and females at the fingerling stage is used by farmers.

In all scenarios, moving from a 200 m^2 pond to a 634 m^2 pond was accompanied by about a three-fold increase in both revenue and production costs. The pattern is similar regarding the results on the quantities of fish produced. This is an indication of constant returns to scale. The most adopted pond size of 200 m^2 may be too small to be economically efficient. The optimal pond size may be around the mean (634 m^2). Moreover, as shown in Tables 2 and 3, feed and operation expenses are not very high. An aquaculture production system that is based on the production of Nile tilapia should be more concerned with the availability of quality fingerlings at an affordable price. In terms of culture, research and extension efforts should be focused on moving from mixed-sex culture to all-male tilapia culture. Meanwhile, as the technique used to separate the sexes at the fingerling stage evolves among fish farmers, mixed-sex tilapia culture with catfish predation should be viewed as a transitional stage towards developing an economically sustainable Nile tilapia production system in Kenya. With targeted capacity building, the technique of hand-sex tilapia fingerling is simple and economically sustainable within rural communities of Kenya. However, the observed pond management practices in Kenya are almost similar to the management practices observed in Tanzania (Kaliba *et al.* 2006), Rwanda (Engle, Brewster & Hitayezu 1993; Molnar, Rubagumya & Adjavon 1991), Zambia (MacPherson 1990) and several other countries in Sub-Saharan Africa (Wijkstrom & MacPherson 1990; FAO 2004; Moehl, Halwart & Brummett 2004). The general results from this study may apply to other countries in Sub-Saharan Africa with similar pond management practices.

Summary and conclusion

Aquaculture development among rural households with limited resources remains a challenge. The rural poor face many constraints to entry into aquaculture and subsequent adoption of improved technologies and management practices. Among others, the availability of startup capital, operational resources and reasonable prices are important in order to adopt, operate and sustain improved fish-farming practices and produce quality fish. Most developing projects are more concerned with increased production of fish. Producing more fish does not necessarily imply profitability of the fish-farming business. Economic analysis is an important management tool necessary for business planning, seeking financial assistance from formal institutions and identifying economically sustainable enterprises.

The results from this analysis indicate that despite being economically feasible and profitable, mixed-sex culture was inferior to the other two culture systems. Switching from no predation to predation culture does not add a significant amount of operational cost. Mixed-sex culture with catfish predation should be a middle stage for developing an all-male Nile tilapia production system in Kenya. This will give time for capacity building in terms of physical and human capacity development on separating the sexes at the fingerling stage.

The success of developing an economically sustainable Nile tilapia production system in Kenya also depends on developing and supplying affordable and quality fingerlings. Quality fingerlings will ensure production of larger and quality fish that attract a reasonable price at the farm level. Economies of scale are common in aquaculture and analyses of the optimal scale of production will provide critical guidance to smallholder farmers interested in fish culture. Therefore, pond dynamic studies are needed to determine optimal pond sizes for the best tilapia culture. Improvement in economic profitability by changing the existing farming system is more likely to attract formal financial institutions into Nile tilapia financing in Kenya. Because management practices under small-scale tilapia culture tend to be similar, the results apply to many countries in Sub-Saharan Africa.

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Appendix

Appendix A

Table A1. Enterprise Budgets for Nile tilapia production in Kenya

Item	Descriptions	Units	Price/ cost	Total		
				Mixed tilapia	Mixed with predation	All-male tilapia
200 m^2 pond						
Revenue	Large tilapia	KES kg^{-1}	121	277	385	9615
	Medium tilapia	KES kg^{-1}	101	818	776	1140
	Small tilapia	KES kg^{-1}	81	4750	4630	164
	Catfish	KES kg^{-1}	125	0	2227	0
	Total receipts			5845	8018	10 919

Item	Descriptions	Units	Price/ cost	Total		
				Mixed tilapia	Mixed with	All-male

Operational cost: includes cost on labour and interest on operating expenses.

Gross profit: sales minus costs directly related to the production level.

Gross profit margins: what remains from sales after paying out the cost of goods produced. It is calculated by dividing gross profit by sales/revenue and is expressed as a percentage.

Direct expenses: those costs that can be easily traced or associated with the level of production.

Fixed expenses: cost items that do not vary by production or sales levels.

KES, Kenyan Shillings.

References

Barry P.J., Ellinger P.N., Baker C.B. & Hopkins J.A. (1995) *Financial management in agriculture*. Interstate Publisher, Darville, IL, USA.

Google Scholar

Central Bank of Kenya. (2007) *2005/06 annual report*. Central Bank of Kenya, Nairobi, Kenya (available at http://www.centralbank.go.ke).

Google Scholar

De Graaf G.J., Dekker P.J., Huisman B. & Verreth J.A.J. (2005) Simulation of Nile tilapia culture in ponds, through individual-based modeling, using a population dynamic approach. *Aquaculture Research* **36**, 355–471.

Web of Science® Google Scholar

Engle C.R., Brewster M. & Hitayezu F. (1993) An economic analysis of fish production in a subsistence agricultural economy: the case of Rwanda. *Journal of Aquaculture in the Tropics* **8**, 151–165.

Google Scholar

Fischer G.W. & Grant W.E. (1994) Use of native predator to control overcrowding in warm-water polyculture ponds: simulation of a tucunare (*Cichla monoculus*)-tilapia (*Oreochromis niloticus*) system. *Ecological Modeling* **72**, 205–227.

Web of Science® Google Scholar

Food and Agriculture Organization of the United Nations (FAO) (2004) *Aquaculture Extension in Sub-Saharan Africa. FAO Fisheries Circular No. 1002*. Fisheries Department, Rome, Italy.

Google Scholar

Food and Agriculture Organization of the United Nations (FAO) (2007) *FAO Statistical Year Book 2004: Web Edition*. FAO Statistical Division, Rome, Italy.

Google Scholar

Hopkins D.K. & Cruz E.M. (1982) *The ICLARM–CSLU integrated animal-fish farming project: final report*. ICLARM contribution no. 86, Hamburg, Germany.

Google Scholar

Hotland G. (1993) *Ecological sustainability and economic viability of smallholder zero-grazing system in destocked areas of semi-arid Central Kenya*. Livestock based systems in semi-arid area workshop, Arusha, Kenya.

Google Scholar

Kaliba A.R., Osewe K.O., Senkondo E.M., Mnembuka B.V. & Quagrainie K.K. (2006) Economic analysis of Nile tilapia in Tanzania. *Journal of the World Aquaculture Society* **37**, 464–473.

Web of Science® Google Scholar

Liti D., Cherop L., Munguti J. & Chhorn L. (2005) Growth and economic performance of Nile tilapia fed on two formulated diets and two locally available feeds in fertilized ponds. *Aquaculture Research* **38**, 746–752.

Web of Science® Google Scholar

MacPherson N.J. (1990) *Integration of fish-farming with small-scale farming system in Zambia*. Project report, Food and Agricultural Organization of the United Nations, Washington, DC, USA.

Google Scholar

Moehl J. Halwart M. & Brummett R. (2004) Report of the FAO-Worldfish Center Workshop on small-scale aquaculture in Sub-Saharan Africa. Revisiting the aquaculture target group paradigm. CIFA Occasional Paper No. 25, FAO, Rome, Italy.

Google Scholar

Molnar J.J., Rubagumya A. & Adjavon V. (1991) Sustainability of aquaculture as a farm enterprise in Rwanda. *Journal of Applied Aquaculture* **1**, 37–62.

Google Scholar

Muir J.P. & Massaete E. (1996) Seasonal growth in rabbits fed wheat and maize bran with tropical forages. *Livestock Research for Rural Development* **8**, 1–8.

Google Scholar

Nefisco. (2003) *Tilapia Farming Support Tool: TFST 1.0 Manual*. Nefisco Foundation, Amsterdam, the Netherlands.

Google Scholar

Ngugi C.C. & Manyala J.O. (2004) Aquaculture extension services in Kenya. In: *Aquaculture Extension Services in Sub-Saharan Africa. Fisheries Department Circular – C1002*. (ed. by FAO), pp. 35–42. FAO Fisheries Department, Rome, Italy.

Google Scholar

Okechi J.K. (2004) *Profitability assessment: a case study of African catfish* (*Clarias gariepinus*) *farming in the Lake Victoria basin Kenya*. Final report, United Nation University, Skulagata/Reykjavik, Iceland.

Google Scholar

Ross L. & MacKinney R. (1989) *Production modeling*. Aquaculture News, January 1989.

Google Scholar

Somers I.F. (1988) On a seasonal oscillating growth function. *ICLARM Fishbyte* **6**, 8–11.

Google Scholar

Sparre P. & Venema S.C. (1992) *Introduction to tropical fish stock assessment*. FAO Fisheries Technical Paper 306-1. FAO, Rome, Italy.

Google Scholar

Wijkstrom U.N. & MacPherson N.J. (1990) *A cost benefit analysis of culture based fisheries development in small dams and dugouts*. Field Work Paper 1: The Economics of Culture Based Fisheries, Field Doc, F1:TCP/GHA0051, FAO, Rome, Italy, p. 7.

Google Scholar

World Bank. (2006) *Kenya inflation data*. 2006 Development Report, Washington DC, USA.

Google Scholar

Citing Literature