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Aquaculture Development Potential in and around Lake Naivasha, Kenya







Cyrus Mageria
Roel Bosma
Arjen Roem

August 2006

AQUACULTURE AND FISHERIES GROUP

Sponsored by AwF & Nutreco

Departement Dierwetenschappen
Leerstoelgroep Visteelt en Visserij
Marijkeweg 40, Postbus 338
6700 AH Wageningen
Tel: (+31) 0317-483307
Fax: (+31) 0317-483937
E-mail: office@alg.venv.wag-ur.nl
Internet: http://www.zod.wageningen-ur.nl

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List of Abbreviations

AwF	Aquaculture without Frontier
IUCN	International Union of Conservation of Nature and Natural Resources
KMFRI	Kenya Fisheries and Marine Institute Naivasha
KWSTI	Kenya Wildlife Service Training Institute
LNGG	Lake Naivasha Growers Group
LNRA	Lake Naivasha Riparian Association
NGOs	Non- Governmental Organizations
Nutreco	An International Animal Nutrition and Fish Feed Company –The Netherlands

Executive Summary

Lake Naivasha in Kenya is shallow and its fishery landings are affected adversely by water level fluctuations and human activities around and in the Lake. The observed fluctuation in the Lake's fish catches could be attributed to excess fishing pressure, to changing anthropogenic activities and to changes in water levels, due both to nature and human. The primary objective of the current study was to assess the possibilities and to appraise the capacities and outlook of the local community for aquaculture development. A review of existing literature and other relevant information was carried out to improve our insight in opportunities and constraints on the current situation in Lake Naivasha. This was supplemented with information collected during a six week fieldsurvey that ran from 1st may to 15th June 2006. The feasibility study was sponsored by Aquaculture without Frontiers (AwF) and NUTRECO, while Wageningen (Aquaculture and Fisheries Group) University offered the technical support and supervision.

The lake ecosystem faces an array of serious threats to its ecological stability and functioning. These threats revolve around unsustainable resource exploitation both within the lake and its catchments. These include pollution from agricultural activities, sewage waste, siltation, water level & abstraction, habitat degradation and illegal fishing. These threats have transformed the lake's ecological processes causing far reaching socio-economic consequences, affecting biodiversity, water quality and lake's fishery. The sustainable restoration of Lake Naivasha's natural potential requires a participatory management plan together with law enforcement.

While the yields from capture fishing are declining, the consumption and demand for fish within Naivasha basin and the surrounding areas is increasing. The opportunity, therefore, exists for Lake Naivasha and its catchments area to develop aquaculture to supply the ever increasing demand for fish. Lake Naivasha's surroundings and catchments areas are scattered with small communal water bodies and multifunctional private ponds. Aquaculture development in the region is constrained by lack of aquaculture tradition, of practical experience and training, of finances & credit for starting-up aquaculture and by limited or no access to water and suitable land.

A SWOT analysis demonstrates that Lake Naivasha region present some strengths and opportunities for aquaculture development and its' promotion could improve the fishery status of the lake and provide means of livelihood. To achieve this positive contribution of aquaculture, two main actions reducing weaknesses have to be undertaken: (1) provision of the seed of the desired species at the appropriate time, and (2) access to credit facilities and information. The two opportunities to establish a small hatchery for the provision of fingerlings are either to rehabilitate the KWSTI-annex or to identify a suitable partner within the lake vicinity and construct one. The rehabilitation of the non-functional KWSTI-annex demands very high investments. We advise to identify a private partner ready to invest land, time and money. NUTRECO Holding NV could assist in the identification of complementary funding in a bilateral public private partnership. Staff can be trained at low cost in Uganda. The hatchery should have an extension assignment. The Kenyan government could support the initiative, also by investing in extension and training for aquaculture.

Based on our preliminary assessment and results from the fieldwork, on capabilities, potential and opportunities of developing aquaculture in and around Lake Naivasha, we recommend:

- To start a private hatchery with capacity to producing annually 100,000 fingerlings. The estimated cost of a state-of-the-art hatchery, including capacity to provide extension services, are € 50,000 (≈ Ksh 5 million). However, various options exist to start on a smaller scale in the vicinity of existing private infrastructures
- To identify partners that make micro-credit available and accessible for small farmers interested to stock their pond, for landless to start a finger-pond, for communities to restock small water bodies or for groups to manage and stock net-enclosed parts of the Lake and it's surrounding wetlands.
- To make available riparian land for ecological sound aquaculture;
- To put in place a participatory management plan together with law enforcement for the sustainable exploitation of Lake Naivasha's resources.

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Introduction

Lake Naivasha, located in Kenya is one of the Rift Valley lakes in East Afrcia. People have lived round the lake since long. The Maasai migrated from the north during the 16th and 17th century increasing connections with the Lake surroundings. Changes in land use pattern have occurred due to the arrival of sedentary farming and ranching, giving room to intensive irrigation, land subdivisions, intensive use of agrochemicals and deforestation. The lake support a rich ecosystem coupled with quite a number of human activities, and its' capture fishery makes a vital contribution to the livelihood of fishermen and to the food security of the local communities and the surrounding urban population. In addition, fish has become a leading trade commodity to the local fish traders. Yet these benefits are at risk as the exploitation of natural fish stocks is reaching limits and the catches have been on a downward trend in the last couple of years. This leaves a great deficit in the fish supply that is not able to meet the consumption demand. The fish community in the lake is under pressure from excessive fishing, decreasing water levels, changes in aquatic macrophyte densities, pollution from municipal and agricultural activities and inadequate species diversity (Hickley *et al* 2002; Hickley & Harper 2002).

The projected increase in demand for fish and fishery products will continue to further burden the lakes fishery resource. Aquaculture could have the potential of meeting this increased demand and hence sustaining the livelihood, food security and alleviation of poverty among the rural poor in the region. The aquaculture sector is currently the fastest growing segment of food production in the world and could be an alternative around Lake Naivasha. A preliminary evaluation on literature and expert opinion shows that the improvement of both land-based and water-based aquaculture may be feasible options in and around Lake Naivasha. It seems imperative to establish a fish hatchery that can cater for the demand for fingerlings requirements. The overall goal of this feasibility study was to assess aquaculture potential around Lake Naivasha and to assess possibilities of starting up a fish hatchery that will supply quality fingerlings both for aquaculture and for restocking the Lake.

The following research questions guided the fieldsurvey and subsequent analysis:

1. Is our preliminary assessment on Lake Naivasha's situation correct?
2. Is it feasible to develop land-based aquaculture?
    a) What are the capacities and outlooks of local people (farmers, fishermen, flower growers) to develop aquaculture?
    b) What is the availability of land/soil quality/easiness of digging ponds?
    c) What is the availability of markets and threshold for market prices?
3. What is the potential to establish a fish hatchery?

This feasibility report starts by outlining the methodology used to gather information, views and opinions of stakeholders and interested parties concerning aquaculture development and restocking the Lake. It goes ahead giving background information of Lake Naivasha, it surrounding catchments areas, status of the fishery and economic activities, and our analysis of the prospects for aquaculture and restocking the Lake. We discuss the research questions that guided the field work and the analysis before presenting our conclusions concerning the feasibility, the potential and the practicability for having aquaculture development in the region.

Methodology

The assessment was based on (i) a literature survey, (ii) interviews with experts having studied the fishery of Lake Naivasha, and (iii) a questionnaire with a set of closed-ended questions (iv) in-depth interviews with from individuals from Government departments, private enterprises and NGOs, and (v) focusgroup with a broad range of stakeholders. We used a desk study SWOT to analyse the potentiality of developing aquaculture in the region using the results obtained from the methods mentioned above. The study was carried out at Wageningen University, Netherlands and over a six weeks field research in Kenya.

The literature provided information on the socio-economic context and the ecology of the lake and the catchments area, and on fisheries and restocking possibilities and potential. The sources included published and unpublished work, articles from the internet, relevant journals and departmental reports as well as NGOs reports.

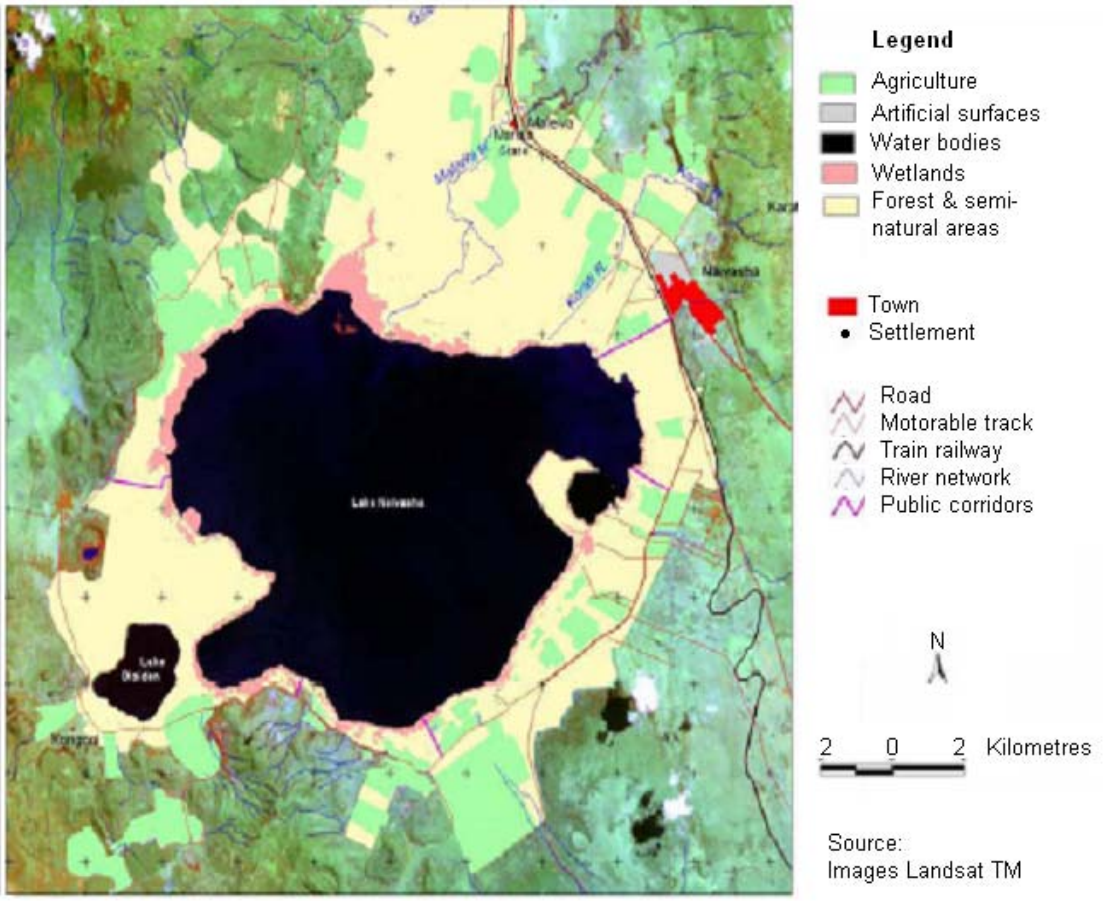
A questionnaire was given to 30 fishermen, 10 fish traders and 15 representatives of various stakeholders (Table 1); 33 interviews sheets were returned. In-depth interviews were carried out in order to gather information in a more private setting. Focused group discussions were used because some stakeholders especially, among fishermen and fish traders have limited reading and writing skills. Focus groups comprised of 5-10 people from various stakeholders and the discussion lasted for 2 to 3 hours. The discussions included an assessment of (i) species preferences and their potentiality for being cultured and reared in captivity, as well as their acceptability by farmers and consumers (ii) local support for the project and their attitude and adopting such kind of a project (iii) availability of land/soil quality/easiness of digging ponds and (iv) availability of markets and threshold for market prices.

Table 1 : List of stakeholder and mode of gathering information from them

	Information sourcing		
stakeholder	Interview	focus discussion group	Numbers
Fishermen	X	X	23
Fish traders	X	X	8
Consumers		X	5
Floriculturist	X		2
Horticulturist	X		4
Municipal			
LNRA	X		1
LNGG	X		1
KMFRI	X		2
Fisheries Department	X		4
KWSTI	X		2
University	X		3

Source: Mageria, 2006

Figure 1: Map of Lake Naivasha



Results

Context

Lake Naivasha is a shallow freshwater lake approximately 160 km^2 (Figure 1). The Lake lies in semi-arid zone with a rainfall of between 500-700 mm and high surface evaporation of 1336 mm.yr^{-1} (Richardson & Richardson, 1972). The Lake was found to support a diversity of activities (Fig 3), such as intensive agriculture under irrigation. This is one of the main foreign exchange earners and employs more than 300,000 people. The lake's water quality and levels have reduced due to agricultural activities; land degradation, pollution and environmental deterioration were distinguishable within the lake basin. These activities were found to have increasingly stressed the Lake leading possibly to the fish catches decline and to a negative water budget especially during dry season (Table 2).

The distribution of the soils and the underlying rocks in and around L. Naivasha is complex as a consequence of past influences: intensive variation in climatic condition, volcanic activities (Sombroek *et al* 1980). Earlier workers (Ongweny, 1973; Rachillo, 1977; Gaudet, 1977; Gaudet & Melack, 1981) described the soils of rift valley as light grey to brown to pinkish non-calcareous soils. The lake catchments are situated in fertile and productive Western Aberdare's ranges and Kinangop plateau. The high human population density and forest clearing from settlement has resulted in extensive catchments degradation and changes in land use.

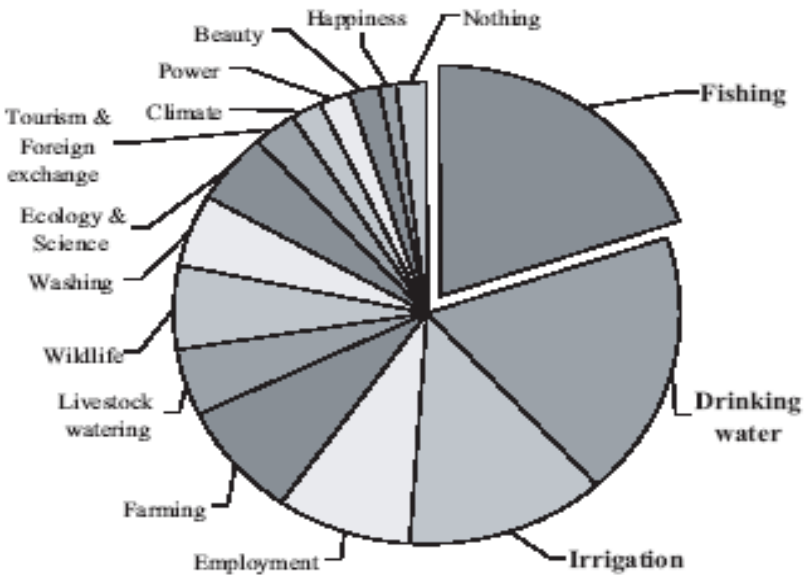


Figure 2: Importance of L. Naivasha water natural resources (*source Hickley, 2004)*

Paleoclamatic studies have revealed historical fluctuations from a deep lake discharging to the south through Njorowa gorge to a complete desiccated lake (Richardson & Richardson, 1972; Washbourne, 1967). Water levels in Lake fluctuate due to rainfall, high surface evaporation rate, underground drainage and water use. The natural fluctuations were either due to drought causing lake water level to drop or to heavy rains increasing lake water levels for example during 1998/9 from the El Nino phenomena. Water abstraction for irrigation has become a serious problem both at the Lake and in catchments areas. The newly emerged flower sector provides high social and economic benefits without accounting the environmental cost of water use and pollution. Owning to the semi-arid conditions, the water abstraction from the lake by these farms for irrigation and domestic use was estimated to be over 70 million m^3 in 2005

Table 2: Annual water budget of L. Naivasha (in million M^3)

	Wet Conditions	Mean conditions	Dry conditions
Inputs			
Direct rainfall over the lake	140.8	72.9	45.0
Malewa River	378	153	53
Gilgil River	74	24	3.3
Karati River	6.5	2.1	0.28
Ungauged area of the watershed	117	77.9	34.2
Seepage in	54	54	32
Total Input	**771.1**	**383.9**	**167.7**
Output			
Loss due to evapotranspiration	38.5	26.7	21.9
Evaporation loss	229	183.5	177.8
Seepage out	54	54	32
Abstraction (Estimated)	33.8	44.6	53.2
Total Output	**355.3**	**308.8**	**284.9**
Balance	**+415.8**	**+75.1**	**-1877.2**

Source:: LNRA, 1999.

The lake has submerged macro flora including various species of C*eralophyllum demersum, Najas pectinara* and *Patomogeton spp.* The lake and its' surroundings support a high diversity of animals especially birds (400 species) and several species of macro and micro invertebrates. Invasive aquatic plants have colonised the Lake such as *Eichornia Crassipes, Salvinia molesta* and *Pistia straliates* and cause problems. These problems range from navigation impediments, obstruction of light penetration, to reduction of Lake Shoreline areas suitable for fish breeding.

Along its Eastern and Northwestern shores, the lake is fringed by *Cyperus Papyrus* and *Typha domigensis* with a large papyrus swamp in the North encompassing the mouth of the affluent rivers. The shoreline vegetation is composed of *papyrus-typha* swamp and further away from the shoreline is *acacia xanthophloes.* Most of the lake is surrounded by riparian land defined as the 100 meters between owned land and backside of the vegetation fringe. The frontier land beyond the riparian zone is used for agriculture (horticulture and floriculture), settlements (laborers working in agricultural farms), game sanctuary, range-land and forest. Very few locals own land next to the Lake.

This riparian land is under the custodian of Lake Naivasha Riparian Association (LNRA) which is an NGO formed in 1927. It is a diverse group composed of landowners, business and conservation organizations working together to manage the use of Lake Naivasha's resources and its environs in a sustainable manner. On this land no permanent buildings are allowed, but grazing and cultivation is allowed.

Recently Lake Naivasha was designated "Wetland of International Importance" where the mandate to manage the site resides with the local community, i.e. a Ramsar site according to IUCN/LNRA (2005). Therefore any form of development initiative in the site has to be accepted by the community since they are the custodian of the lake.

Fishery of Lake Naivasha

Lake Naivasha originally contained only one endemic species *Aplocheilichihys antinoni* which was last recorded in 1962. This species is believed to be extinct as a result of new species introduction (Elder *et al* 1971). Over 10 fish introductions have been made since 1925, and only 3 have successfully established a fishery in the lake – *Oreochromis leucostictus* (Bleu spotted tilapia), *tilapia zillii* (Red belly tilapia), *micropterus salmoides* (black bass) (Muchiri & Hickley, 1991). The three formed the Lake Naivasha commercial fishery as well as sport fishing (KMFRI, 2002). Recently in 2001, the common carp *(Cyprinus carpio)* has invaded the Lake after escaping from fish farms in the catchments areas. Today common carp is one of the major commercial species being landed from the Lake contributing over 70% of the total catch. This new species has changed the whole fishery as evidenced by changes in species catch composition. It has interfered with the ecosystem and species such as *Micropterus salmoides* have become vulnerable.

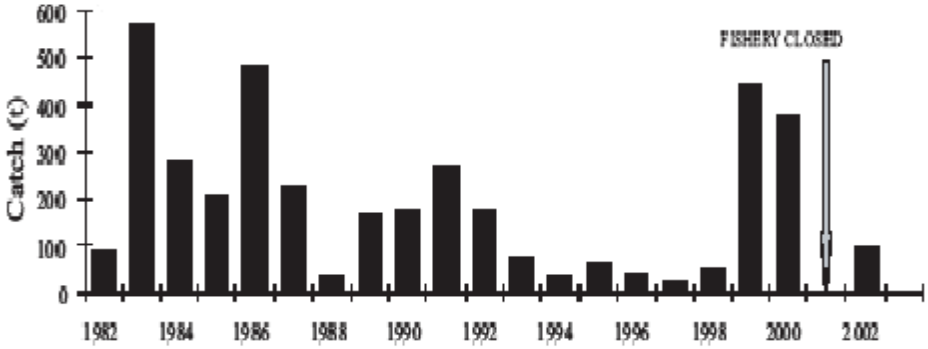


Figure 3: Lake Naivasha fish landings 1982-2002.

Source: *Fisheries*

department, 2004

Over the years there have been great fluctuations in the amount of fish landed from Lake Naivasha (Fig 3). The fluctuations were either due to drought causing the lake's water level to drop hence supporting less fish or due to heavy rains increasing the lake's water level and boosting the fish catches. Annual catches show that the impact of above mentioned factors has continued to affect the fish population leading to closure any fishing activity in year 2001. This was after a serious decline in catches that has lead to reduction of the number of licensed fishermen to just about 40. Nonetheless, effort by the Fisheries Department and other stakeholders seems neither effective nor efficient enough to avoid the depletion of the Lake fishery resources.

Illegal fishermen pose a serious problem negating the efforts by Fisheries Department of controlling the fishing effort. They use illegal nets/mesh size, fish in protected areas and fish during closed seasons. The illegal catches of hundreds of people are not included in the estimated landing. Though part of the increased demand is attributed to declines in subsistence fisheries yields (Fisheries department Annual Report, 2004).

The lake's fish production has declined tremendously almost 15 fold from 1150 metric tonnes in 1970 to only 66 metric tonne being harvested now (Hickley *et al.*, 2004). The decline is attributed to habitat destruction due to damage of the papyrus cover, decline in water level and over-predation of macrophytes by introduced crayfish (Hickley *et al.*, 2002).

Market for fish

Data on fish import in the region are not available, but the past catches of 1,150 ton were all consumed by a population of 300.000 people (<4kg capita^{-1} year^{-1}). The gap between past consumption and present catches is over 1,000 ton, while the population increased. At present the flower sector alone employs over 300,000 people, and it may be estimated that over 1 million fishconsumers live around the Lake. Moreover lake Naivasha is centrally located to serve the demand for fish in the neighbouring urban centres. Two main cities with close to 1 million people are at less than 2 hours drive over a bitumen road. In general the infrastructure in the region surrounding Lake Naivasha is good.

Thus a very conservative estimate of the immediate market demand is 1,000 tonnes of fish per year, of which landings cover only 7%. Globally the consumption of fish is 17.8 kg capita^{-1} year^{-1} and is expected to rise to 30-40 kg within 5 decades (FAO, 2002). Taking again a conservative estimate the potential market of 2 million people would at least need 20 million kg or 20,000 tonnes of which the official fishery landings from Lake Naivasha cover less than 1 %. The region relies on fish brought from other regions (Lake Victoria) to meet the growing consumer demand for fish. Among the present fish from the catches, the consumers have a specific preference for black bass, then tilapia and in last place carp. However, carp is gaining recognition.

Stakeholders Analysis

The results presented are an overview from the answers obtained to the interviews, during the focused discussion groups and the personal visit/ judgment. Stakeholders were found to have diverse interest on Lake Naivasha resources (Table 3). The LNRA is the only organization regrouping several stakeholders, but it has a say on the riparian

zone only. During the period of our fieldwork a first general stakeholders meeting was held to discuss the possibilities of a sustainable management of the Lake's resources.

Table 3 : Stakeholders interest on the Lake resources

Stakeholders	Particular needs and interest
Large and small scale farms	Floriculture/horticulture / agriculture production for local consume and exportation
LNRA, the NGO having custody over the riparian zone	Research, conservation/ protection, education-training awareness and management-policies and data collection
Kenya Wildlife Service	Research, conservation/ protection, education-training awareness and management-policies and data collection
Fisheries Department and Kenya Marine & Fisheries Institute	Research, conservation/ protection, education-training awareness and management-policies and data collection, fishing
Fisher folk	Fish, Fishing , Food , water for domestic use
Town council	Community service
Local community	Livestock production, irrigation social and cultural activities.

Source: Mageria, 2006

The overview shows that there several common problems threaten the Lake (Table 4). These problems can be classified and divided into core problems and symptoms. The stakeholders singled out the agricultural activities taking place around the Lake as cause for the habitat degradation and the runoff from agricultural farms in the catchments area as cause of the excessive nutrients loading (siltation). Respondents agreed that for Lake Naivasha to stand the test of times, something needs to be done to alleviate the impact of some of these problems. In their own opinion, everybody who has interest in the Lake plus it catchments should be made wholly responsible for it sustainable development. This will create a sense of ownership and therefore participate in saving the Lake from the "tragedy of the commons". It emerges clearly that almost all these problems are as a result of uncoordinated sustainable exploitation of the lake resources and selfishness among stakeholders.

Table 4: Major problem prioritization in Lake Naivasha

Problem/threats	Respondent				Severity ranking
	Agree	uncertain	disagree	total	
Water abstraction	20	8	15	53	**
Illegal fishing*	47	5	3	55	***
Habitat degradation	45	2	8	55	***
Pollution	37	3	15	55	**
Siltation	40	15	-55	55	***
Species introduction	37	15	2	55	*

**These are activities carried out by fishermen who have not been licensed to do fishing by the authorizing agent (Fisheries Department). Included also is use of prohibited fishing gears and mesh sizes as well as fishing during closed seasons and in fishing in protected areas.*
Source:: Mageria, 2006

Too much fishing pressure was identified as another major problem in the lake and it has continued to affect the fishery. Illegal fishermen were found to be using illegal fishing net and mesh sizes and to be fishing in protected areas and in closed seasons. These groups of fishermen outnumber the legal fishermen hence increasing the fishing pressure tremendously. A number of these illegal fishermen are seasonal migrating from the catchments areas and other areas when there is a crop failure. The lake also supports a large number of fish eating birds suppressing the fish population further.

The third highly ranked problem was siltation. Majority of respondents believe that siltation is the cause of the increased water turbidity observed in the Lake especially during wet and rainy season. The light penetration becomes limited thus affecting the functioning of the lake ecosystem. Siltation also caused habitats degradation subsequent to sediment deposition thus affecting the vegetation cover and consequently loss of breeding and feeding grounds for fish. The increased siltation is supposed to be caused by erosion due to habitat degradation in the catchments areas and the Lake surroundings. The degradation of the catchments areas can be traced back from poor land use practises, farming practises and intensification of small-scale farming. The recently invaded Common carp might also contribute to increase water turbidity due to its feeding habit.

One of the buffers that used to filter out some of the sediment is the papyrus, but most of this has been cleared for agriculture. The remaining papyrus cover is protected by the LNRA, but nevertheless encroachment and clearing continues. This subsequent habitat degradation diminishes the scarce suitable breeding grounds for fish and thus not able to maintain a fish biomass leading into declining catches. Additional degradation of the papyrus covers comes from overgrazing when used as pasture during dry seasons. This problem of habitat degradation compounded with water abstraction and pollution, have adversely affected the fishery of Lake Naivasha.

Pollution was identified as a major cause of the decline in fish catches as a result of habitat degradation and loss of breeding grounds. Fishermen accused the horticulture, flower growers and municipal for polluting the waters, thus altering the ecosystems (Fig. 4). Majority of those interviewed had the sentiment that, the water quality within the Lake appears to have declined, although the levels of contaminants and fertilizers are regards to be very low. Contaminants levels in the lakes water have not been comprehensively researched on, but the little that has been done suggests that the current levels are not alarming to cause any serious effect on flora and fauna of the Lake.

Aquaculture prospective

The assessment shows that Lake Naivasha basin provides some opportunities for aquaculture development, due to its unique climatic conditions, physical, biological and economic developments in the region. Some culturable species which can be easily reared, propagated and cultured at farm level are already available: *Oreochromis leucostictus*, *Tilapia zillii*, and *Cyprinus carpio*; the reproduction of *Micropterus salmoides* is somewhat problematic. These three species have the potential to increase fish production through use of available culture technologies and available opportunities in the region.

Water-based aquaculture

Lake Naivasha is ideally suited for water-based aquaculture through exploring a number of culture systems. Water-based systems involve using the lake's water to rear fish either directly or indirectly using enclosures such as cages and pens. However, cage culture was not viewed as an option in Lake Naivasha because of its' shallowness. Pen culture could play an important role in open water fisheries development of Lake Naivasha. Pen culture could be set up in existing water bodies by use relatively simple technology. Their initial costs may be considerable; their operating costs are relatively low with or without supplementary feeding. Pen culture of larger areas, e.g. papyrus land serving as buffer for sewage water, managed by a group might be an option that is at present propagated in South and SE Asia.

Water-based systems could provide an entry point for landless people, seasonal fishermen and poor fishers to farm fish. It is an effective way of utilizing open water fisheries resource that can achieve fish and provide economic efficient livelihoods

Major constraints towards establishment of water-based aquaculture include insecure access to water bodies, protection of riparian land and shoreline, risk, and fingerling supply and ownership. The suitability of water-based culture system and realisation of this potential towards aquaculture development is governed by, access to lake's water, availability of land and permission granting by LNRA to use riparian land, fingerling supply and cooperation among stakeholders.

Land-based Aquaculture

Land-based aquaculture is poorly developed in the region. Very few fish farmers are found in the catchments areas, but around the lake there are no fish farming activities. The probable explanations could be: i) lack of land as most of the suitable land is under horticulture and floriculture and the remaining is under LNRA; ii) water access and availability; iii) soils with high sand content and poor water retention capacity for pond construction; iv) lack of knowledge and technical know-how in fish farming; v) high cost for pond construction and fingerling acquisition, and vi) people are not ready to take risks. Although there is a lot of potential on the catchments areas, this potential has not been fully exploited due to competition for land with other agricultural activities especially the horticulture farming.

However, there is still some potential around the lake if large agriculture farms can agree to integrate fish farming in artificial wetlands designated to reduce pollution from waste water originating both from farms and people. But from the responses obtained the large specialised farmers are not willing to divert their line of interest which is solely on either flower or horticulture production. This constrains land-based aquaculture development around the lake.

A second option would be the introduction of finger-ponds in the riparian zone that is continuously increasing due to the receding water level. Finger-ponds are a relatively new technology whereby finger-like extrusion from the lake shoreline into the land is constructed and filled with lake's water. This seems an opportunity to make use of land adjacent to the shoreline and riparian land that has a lot of potential. However this option requires an authorization due to protection of riparian land by the LNRA management act.

A third option is the development of fish farming in the various smaller communal water bodies around the Lake and in the catchments areas. Most of those water bodies do not contain fish and present an excellent potential of restocking them with fish under communal management agreements. Potential also exists for use of irrigation systems and of land unsuitable for agriculture such as swamps.

The main potential that does exist for this kind of aquaculture development is to integrate fish farming with other agricultural activities in catchments areas. Quite some private farms have ponds on their land for multiple uses, but fish production is not yet part of it. Also in Asia, at the time of their construction most ponds were not intended to contain fish, but at present the produced fish contribute an essential part of their livelihood (Manjurul et al, 2004). Land-based aquaculture has considerable potential in lake Naivasha basin catchments areas as agricultural land can profit from fish culture through the synergies of integrated farming practice (Muendo, 2006).

Knowledge and awareness were found to be too inappropriate if at all available. This has influenced the pace of land based aquaculture development in the region. Establishment of land-based aquaculture would be a big challenge in Naivasha basin because: the region is semi-arid thus water availability in terms of quality and quantity is not guaranteed and turning to bore hole water would be too expensive for locals. Moreover, evaporation rates are very high and that would mean constant water supply, which might turn out to be costly and expensive. Another constraint identified was land availability; the results shows that very few people own land and if they do other factors mentioned above come into play.

Restocking of the Lake

Fish production from the lake is viewed as too low when compared with similar lakes due to lake's ecological changes and flora & fauna composition. In the region water resources are naturally productive and conducive for fish rearing. Some scientist believe that potentially the fish production can be boosted by introducing new species to fully utilise the under utilised niches; but this would need a thorough ecological assessment and this approach was and the introduction of new species is still not favoured by many. This leaves open the other option of restocking the lake with already existing species for instance *Micropterus salmoides* whose population have been greatly affected by invasion of the lake by *Cyprinus carpio* and habitat degradation.

Most of the researchers highly recommend restocking the lake with such as *Micropterus salmoides* and *Tilapia spp* whose population has dropped significantly as reflected in daily catches from the Lake. Restocking will overcome the phenomenon of recruitment limitations occurring when natural supply of juvenile fails to reach the levels allowing optimum use of carrying capacity of the ecosystem and with time it will enhance the spawning biomass of some species to a level that can provide regular substantial yields. Restocking with cultured juveniles could only be considered when there is good evidence that the stock, or part of the stock, is either at a chronically low level, or consistently limited by recruitment. However, this information was and is still missing, thus justifying more research in this area. The cost-benefit of using cultured juveniles to rebuild the stock to a productive levels (restocking), or to increase productivity, must be assessed and compared to other sources with potential to achieve the same objective. However before restocking is initiated it are prerequisites to rehabilitate and restore degraded habitats, to reduce illegal fishing activities and to minimise pollution. Success of restocking will depend on the good will, support and corporation among stakeholders.

Hatchery Prospects

The assessment showed that in the whole of Lake Naivasha region there is no hatchery for fingerling production. The few potential farmers would rely on other farmers or on a government hatchery; both are at more than a day drive over 150 kilometres of very bad roads. This makes the availability and supply of fingerlings one of the factors contributing to poor aquaculture establishment in the region.

Brood stock is easily available from the lake or other well established hatchery farms in the country. However, lack of competent skilled hatchery personnel was identified as a major constraint and that could mean having some people trained beforehand. Training becomes a crucial component for the establishment of both the hatchery and the aquaculture in the region. Hence it is evident that both land-based and water-based aquaculture development around the Lake could depend on hatchery establishment for their fingerling needs. Hatchery could thus serve as the starting point for aquaculture development in the region.

There are good sites for hatchery establishment coupled with good environmental and climatic condition for the species being targeted for propagation. However, institutional embedding and management of the hatchery remain the biggest challenge. Two possibilities were identified: the establishment of a private hatchery or the upgrading of a non-used facility.

Establishment of a new hatchery

A private developer in the region has volunteered to offer a parcel of land where a new hatchery could be constructed. The sites physical location and water availability is ideal couple with security and management. To realize this, an agreement/ memorandum of understanding need to be developed first, in order to spell out how local community and other interested partners will be incorporated. However, this option was not viewed as feasible immediate option due to ownership and lack of clear guidelines as to how local community will be involved. As a result this was left out for further consultation and as an open opportunity for further expansion of hatchery development in the region.

The costs for a new complete functional state-of-the art hatchery are estimated at € 50,000. However, various options exist to start on a smaller scale in the vicinity of existing private infrastructures.

Rehabilitation of already existing hatchery facility

The second possibility is the rehabilitation of KWSTI-annex that was established in 1986 as a fisheries training facility and contains a hatchery unit. The KWSTI-annex has never been used due to some institutional problems and ownership. Initially when it was being established it was meant to serve the needs of and be shared by the two departments i.e. Fisheries and Kenya wildlife service which were by then under one ministry. Later in early 1990s they were separated and one become a government parastatal (KWS) and since the annex is on their land it become very complex. Since then there has been problem in the facility ownership between the two departments. Currently, it serves as a sanctuary and is being used for wildlife and ornithological studies.

The annex is about 50 acres and is situated 3 kilometres from Naivasha town. It has rearing ponds, a hatchery raceways and facilities such as fish processing unit, boat building, gear technology, quality control and inspection units. It also has offices, classrooms, a library, a bacteriological laboratory, a fish processing laboratory, a net-shed, a boat-building yard, aquarium tanks and a kitchen for sensory evaluation. These facilities

after having stayed non-operational for the last 20 years are in very bad shape having undergone a lot of dilapidation. Rehabilitation of the already existing structure is relatively easy than looking for a suitable site and constructing one. Another advantage is that site and land is not a problem and the LNRA has supported reviving the structure located in the riparian zone. The costs are estimated at €50,000 for partial rehabilitation that will see hatchery unit function (Annex 1), and €440,000 to turn the KWSTI-annex into full scale centre with training and extension services (Mageria, 2006).

Cost benefit Analysis for running the hatchery for one year

The present market price for fish is 200 Ksh or 2.2 Euro per kg of fish live weight. Aquaculture can produce fish for this price at a good profit margin. The market demand for cultured fish was estimated to be at least 1,000 ton per year. This can be provided by 1,000,000 fish of 1 kg. For a start we propose to invest in a hatchery of 100,000 fingerling per year.

With a production capacity of 100,000 fingerling per year the hatchery could be able to sustain it own operation and to run economically (Table 5). For the hatchery to make a price during first year of operation the price of fingerlings has to be Ksh2.50 higher than other government hatcheries and Ksh0.50 higher than in private hatcheries at 150 km. The price is fair as transportation cost at fish losses will drop if farmers acquire their fingerlings locally.

Table 5 Estimates of operating cost and revenue from the rehabilitated KWSTI-annex hatchery (capacity 100,000 fingerlings/yr) and cost for extension work.

	Description	Euro
Fixed cost	Cost of investment 5 % of € 37,200	1860
	Motorbike for extension work	1000
	Labour cost (1 technician, 1 skilled and 1 unskilled)	400
Variables cost	Brood stock, sex ratio of 1:5 male to female	400
	Feed; Ksh1200 for 100kg at feeding rate of 2%BW *	1200
	Chemicals , disinfectants and other equipments	500
	Oxygen cylinders	100
	Packaging materials and equipments	300
	Maintenance of the facility (1% of of € 37,200)	375
	Fuel for and maintenance cost of motorbike	1000
	Contingencies, 5% operating cost	265
Total cost per year		7,400
Revenues	100,000 fingerling of 5 centimetre at Ksh 7.50 pp	7,500
Net margin 1st year		100

** €1≈100 Kenya Shillings)*

The cost for training of technicians was not included in the budget. If a trained technician and skilled labourer can not be recruited in Kenya, motivated persons can be trained on a USAID project in Uganda. Funding the cost of transport and travel allowances for such training should not be a problem.

SWOT analysis

The SWOT shows that the region has several strength and excellent opportunities for aquaculture development (Table 6). There is a potential market for at least 15 million kg or 30 million marketable fish of 0.5kg. The threats most relate to the sustainable use of Lake Naivasha for fishery.

The main weaknesses for aquaculture development are the lack of a local hatchery, of know-how and information, and of credit facilities. Although the knowledge gap is constraining aquaculture we postulated that by providing the fish hatchery with an extension service this weakness can be overcome. A USAID project in Uganda offered to train the technical staff without cost for fee and lodging; only transport and pocket money need to be covered. If equipped with a grow-out pond, the fish hatchery could also serve as a demonstration and training centre. The credit facilities not only relate to the start-up of the hatchery, but mainly to micro-credits that have to be available for farmers interested to stock their pond, for landless to start a finger-pond, for communities to restock small water bodies or for groups to manage and stock net-enclosed parts of the Lake and it's surrounding wetlands. In view of the weak financial situation of most farmers, the focus should be on low-external input technologies to prevent failure of the introduction of aquaculture.

Table 6 The results of fieldsurvey summarized in a SWOT table.

Strengths	**Weakness**
• Good availability of natural and man-made water bodies • Naturally productive waters in the Lake • Huge market for both farmed and wild fish species • Good infrastructure to a main markets • Culture species available in the region • Moral support from local community and other locally based organisations	• Lack of training and extension services • Lack of local hatchery and fingerlings • Large part of the local community are poor • Poor access to credits • Majority of the fisher folks are foreigners • Limited access to the Lake water as shore land is owned by few or protected. • Poor organisation of the rural community reinforces the resource conflicts.
Opportunities	**Threats**
• Water pools in catchments areas • Integration of fish ponds on farms in catchments area • Finger-pond development on shores • LNRA has a say on shore land. • Non-functional hatchery available • Wetlands and papyrus areas can be made productive with fish farming and for breeding/ nursing of wild fish • Consultation between stakeholders of the Lake resources started recently.	• Drought and erratic weather conditions • Habitat degradation in the Lake and on catchments areas. • Lake's water level fluctuations, affect the fishery and water availability • Competition between different users for water and land resources causes tensions • Outsiders moving into the region in search for jobs and turn into fishing • Insecurity on individual and community properties in the region.

Discussion

The assessment of Lake Naivasha's situation confirms the degradation of the lakes resources. The degradation is apparent through: disappearance of the local fish species; decreased water level leading to enlarged shores; decreased area of wetlands and area covered with papyrus; increased turbidity; decreased fish catches. Consultation between stakeholders on the management of the Lake's resources started, but until this becomes successful the restocking of the lake does not seem useful, unless to equilibrate the species composition.

At first the natural restocking should be enhanced by improving the fish breeding grounds around the lake and in its catchments. Before any restocking is done the following actions need to completed: (1) rehabilitation of degraded habitat and their restoration; (2) elimination of illegal fishing (poaching and use of illegal gears); (3) guaranteeing survival of the released juveniles by release in protected breeding grounds.

In view of the market opportunity there is definitely potential to develop aquaculture in and around Lake Naivasha. In the vicinity of the lake the soil characteristics limit the opportunity for aquaculture, but the use of nets in the lake and its' surrounding wetlands, as well as the introduction of finger-ponds on the enlarging riparian land are opportunities. Net-enclosure could also be used in other water communal water bodies in the Naivasha basin, but communal management after stocking fish is perhaps a better option. Another prospect lays in the development of artificial wetlands integrating fish farming on horticulture and floriculture farms for the water purification. The water-based systems carried out in the lake and large communal water bodies provide good options for landless and for underemployed fishers and mitigate effect of fishing pressure on the lake fishery. Land-based aquaculture has considerable potential for development through small scale pond fish farming on the catchments areas. Soils are less sandy and several farms already have multipurpose ponds that however do not contain fish.

Though the non-functional KWSTI-annex facility represents an opportunity for hatchery establishment, we believe that rehabilitation of a government structure does guarantee the take-off of aquaculture in the region. We suggest that a small private hatchery provided with an extension task should be initiated to get aquaculture off the ground in this region. The hatchery's mission will be to provide suitable quantities and qualities of fish fingerlings for fish farming on catchments areas and riparian land. On a broad perspective the hatchery might serve the community by providing education programs on aquatic resources and conservation. This could also create conditions for a sustainable restocking of the common water bodies.

Conclusions and recommendations

The SWOT analysis demonstrates that Lake Naivasha region present some strengths and opportunities for aquaculture development and its' promotion could improve the fishery status of the lake and provide means of livelihood. To achieve this positive contribution of aquaculture, two main actions reducing weaknesses have to be undertaken: (1) provision of the seed of the desired species at the appropriate time, and (2) access to credit facilities and information. Two opportunities to establish a small hatchery for the provision of fingerlings are to rehabilitation the KWSTI-annex or to identify a suitable partner within the lake vicinity and construct one. We advise to identify a private partner ready to invest land, time and money. NUTRECO Holding NV could assist in the identification of complementary funding in a bilateral public private partnership. The hatchery should have an extension assignment. The Kenyan government could support the initiative, also by investing in extension and training for aquaculture.

Based on our preliminary assessment and results from the fieldwork, on capabilities, potential and opportunities of developing aquaculture in and around Lake Naivasha, I recommend:

- To start a small scale hatchery with capacity to provide extension services;
- To identify partners that make micro-credit available and accessible;
- To make available riparian land for ecological sound aquaculture;
- To put in place a participatory management plan together with law enforcement for the sustainable exploitation of Lake Naivasha resources.

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Annex 1. Budget and costing for making annex hatchery unit operational

Activity	Description of activities	Total cost(€)
Objective1: **Rehabilitation of hatchery**		
1.	Site clearing and fencing	1,000
2. 3 Rearing ponds 25mx15m	Reconstruction work that involve -re-cementing the bottom - dykes and outlet -drainage cannels and pipe fitting -Enclosing with a mesh (sides and top to keep of birds and other predators	5,270
3. 4 Race ways(15x2m)	Reconstruction -re-cementing the bottom - dykes and outlet -drainage cannels and pipe fitting -Enclosing with a mesh (sides and top to keep of birds and other predators	3,610
4. 4 Circular tanks (diameter 4m; depth 11/2m)	Reconstruction -re-cementing the bottom - dykes and outlet -drainage cannels and pipe fitting -Enclosing with a mesh (sides and top to keep of birds and other predators	2,410
Renovation of Drainage Systems		
5. Main Drainage	Re-excavation Re-cementing Building broken sections Piping fitting valves	4,250
6. Water work/source	-Bore hole drilling (optional) -Pumping water from the Lake (optional) -Construction of holding tank -Piping and drainage -Water quality.	10,000
Brood stock acquisition		
7. Land based aquaculture	- *Oreochromis niloticus* - *O. leucostictes* - *T. Zillii* - *C. gariepinus* (to be investigated (EIA)	100 100 100 100
8. Restocking	- *Micropterus salmoides*	100
9. Breeding materials and facilities	-incubators -trays -Gas cylinders	1,000
Husbandry		
10. acquisition	-Feeds -medicine and chemicals - personnel acquisition - artificial wetland construction	1,200 500 10,000 1,000
Buildings Small office and store	-Office furniture -Painting and wiring -communication -stationeries -Computer	5,000
In house hatchery	-Redesigning and restructure one of the room in the main building and be converted into an in-house hatchery. Piping and incubators fitting	4,160
Totals		**49,900**

€1≈100 Kenya Shillings