Registration

1. Programme

a. Research:

A [ ] Open

B. Thematic
- [ ] 1. Poverty and hunger
- [ ] 2. Health
- [x] 3. Sustainable environment
- [ ] 4. Global relationships

b. Number of researchers

Ph.D. researcher(s): [2] NL/non-DC country: temporal employee (at NL institution)

[2] DC: [2] Net grant (living allowance)

[ ] Temporal employee (at NL institution)

Post-doc researcher(s): [ ] NL/ non-DC country: temporal employee (at NL institution)

[ ] DC: [ ] Net grant (living allowance)

[ ] Temporal employee (at NL institution)

c. Duration of the programme: 5 years

d. Country(ies) where the research will be carried out: Tanzania

2. Title

Exploitation or eutrophication as threats for fisheries? Disentangling social and ecological drivers of ecosystem changes in Lake Victoria, Tanzania (SEDEC)

3. Composition of the research group(s)

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c. Researchers' details

Two DC researchers for PhD 1 and PhD2 will be recruited from Tanzania. TAFIRI and UDSM have indicated the availability of two researchers for these studies but at this stage no full assessment was possible yet. The intention is to do an open selection procedure within Tanzania after granting of the proposal. Preference will be given to TAFIRI researchers in case of equal capabilities.

Two non DC researchers for PhD3 and PhD4will be recruited (inter)nationally in an open selection procedure after granting of the proposal.

d. Experts' details

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Research proposal

4. Summary of the research programme Word count: 344
(*Max. 400 words, add word count)*

Lake Victoria is the second largest freshwater lake and supports the largest freshwater commercial fishery in the world. **Eutrophication** and **fisheries** drive Lake Victoria's changing ecosystem with far-reaching consequences for exploitation patterns, livelihoods and trade. Yet, no attempt has been made to link the two processes to understand feedbacks in food webs, resource use patterns and trade. Our main objective is to unravel the social and ecological drivers of ecosystem change and to develop long-term strategies to deal with the risks of these ecosystem changes. The **working hypothesis is that continued eutrophication presents a much graver risk to the resource base and livelihoods of coastal populations than fishing pressure**. Initially eutrophication resulted in a higher carrying capacity for Nile perch, because food availability increased through enhanced primary production. This increased carrying capacity resulted in an apparent resilience of the exploited Nile perch stocks to increased fishing pressure. However, the compensation of increased fishing pressure by increased production could fail when eutrophication becomes too strong, because of increasing self-shading by algae and by an increasing anoxic hypoliminion, which can cause catastrophic fish kills. Optimal nutrient concentrations to support fisheries may have already been exceeded, which could negatively affect Nile perch biomass. The responses of the fishery to changes caused by increased eutrophication as well as the responses of Nile perch stocks to the combined impacts of size selective fishing and eutrophication will be researched in four inter-related projects that (1) analyse social factors that drive decision-making processes of individuals in the fishery; (2) analyse ecological factors, including size-selection, that drive decisions about spatial effort allocation by fishermen; (3) analyse the impact of eutrophication and Nile perch predation on food web structure, and (4) model the interactions and feedbacks resulting from eutrophication and fishery, as most likely factors driving changes in Lake Victoria's food web. Scenarios to assess management under non-steady state conditions will be developed in collaboration with international scientific experts and with regional and national government and research institutions. A networking NGO will be instrumental in communicating results to fishing communities and the general audience.

5. Description of the programme Word count: 2495
(*Max. 2500* w*ords, add word count)*

a. Rationale and background

Introduction

Lake Victoria is the second largest freshwater lake and supports the largest freshwater fishery in the world. Over the past 75 years, the lake became eutrophic due to deforestation, increased agriculture and urbanization[1]. This **eutrophication** caused a four to eight-fold increase in algal biomass and primary production[2,3]. In the 1980s the lake's food web changed from a complex fauna with many species to a simplified food web, dominated by three fish and one shrimp species[4]. This **regime shift** in the ecosystem drastically changed the resource base of the **fishery** with far reaching consequences for local livelihoods. Around 1960 fish catches were based on a wide range of mainly cichlid species but now, they are dominated by the introduced top-predator Nile perch (*Lates niloticus*). The changes in the lake ecosystem created new opportunities in the livelihoods of people around the lake. Many migrants were attracted to take up fishing, fish trade and fish processing[5,6]. As a result, the number of fishermen and boats is now seven times higher than in the 1960s and fish catches have increased by a factor 6.5. Nearly 1.3 million people depend on this fishing industry[6,7] for their livelihoods.

Development problem

Sustainable development of the Lake Victoria region is strongly linked to the sustainability of the fisheries and its resources. The fast increase in fishing pressure has convinced fisheries managers and researchers in the region that **over-fishing** is the most important threat to the fishing industry and that a collapse of Nile perch stocks is imminent if the increase in exploitation pressure is not halted[7,8]. Fisheries management focuses strongly on this aim: policy measures are implemented trough co-management arrangements with fishermen on the assumption that this would lead to sustainability. However, this assumption is completely based on the idea that Lake Victoria's ecosystem is in a steady state. This is most probably not the case: the lake is subject to **eutrophication** leading to increased primary production and fish productivity and thus to a higher carrying capacity for Nile perch stocks. We believe that this eutrophication may have compensated for the increased exploitation pressure. The major **risk,** however, is that this compensating effect will no longer function with further increases in nutrient loadings and that the latter could even become detrimental to fishery production. The fishing industry is hardly aware of the risk of increasing eutrophication and it will require a major change in the focus of fisheries management – including its information base, communication with stakeholders, co-operation with water quality managers and implementation of measures – to incorporate this risk in the design of effective ecosystem-based management to protect the fishery, its resources and the livelihoods of those dependent on them.

Stakeholders in the fishing industry

The changes in Lake Victoria's food web influence decision-making by individual **stakeholders** in their use of the lakes' resources. The economic success of the Nile perch fishery instigated attempts for an economic organisation of the commodity chain. To comply with EU food safety regulations, **filleting factories** trading on international markets (the Netherlands is one of the largest **importers of Nile perch**) constructed specific Nile perch landing sites. These sites are run by so-called **Beach Management Units (BMU's)** consisting of representatives of local **fishing communities** who collect taxes and are controlled by officers from the **Fisheries Division**. **Middlemen**, provided with means of transport but not employed by the factories, collect and transport Nile perch. These risk-takers determine the fish price at landing. In addition, they provide **fishermen** with loans for gears, boats and fuel in exchange for fish.

All these actors in the commodity chain have to deal with risks of seasonal and long-term fluctuations in catch, international trade (e.g., EU regulations already caused the closure of the fishery once), in fish quality standards (leading to higher rejection rates of undersized / spoilt fish) and so on. Yet, overfishing is seen as the major threat to the industry. Based on these views, Fisheries Management Organisations such as the **Lake Victoria Fisheries Organisation** *(***LVFO***,* Jinja, Uganda) and associated national fisheries management research organisations as the **Fisheries Division** and **TAFIRI** together with lake-wide projects, funded by EU (**Implementation of Fisheries Management Project (IFMP)** and its precursor) and by Worldbank (**Lake Victoria Environmental Management Project (LVEMP)**) have made great efforts to regulate the fishery. These efforts focussed on gear regulations (minimum/maximum meshes; banning of illegal gears) and on measures to regulate total effort. Measures were implemented in co-management arrangements with the **BMU's**. However, this approach is increasingly contested and emerging **NGO's** of fishermen call for a stronger involvement in the design of the management rather than in its implementation only.

Threats to the fisheries: eutrophication, over-fishing and selective fishing?

Increased nutrient loadings in Lake Victoria resulted in higher algal biomass[2] and in a taxonomic shift from green algae and diatoms to blue-green algae[9]. The higher primary production also resulted in higher organic sedimentation to the hypolimnion and this significantly increased the seasonal areas and volume of hypoxic and anoxic water layers below 20m depth[10]. The danger of these oxycline changes is demonstrated by regular catastrophic fish kills which are attributed to water turnovers when anoxic waterlayers mix with oxygen-rich surface waters[11,12]. On the other hand, the evidence for over-fishing of the Nile perch stocks can be contested, because average catch rates and standing biomass of Nile perch have remained remarkably stable over the past 30 years despite increased fishing effort. Also the annual average catch rates have remained stable since the late 1990s and fluctuate around 70-80 kg/ha, now resulting in ca. 3 tonnes per fisherman[13]. Moreover, average fish length in the stocks has not decreased, in contrast to what could be expected from an over-fished population and the highly selective fishery[13], targeting for fish of 50-85 cm. This apparent stability cannot be explained by the current stock assessment methods which uniformly indicate overexploitation of Nile perch stocks.

We believe that the carrying capacity of the lake and its fish productivity is stimulated by the Lake's eutrophication to an extent that it compensates for the increased fishing pressure. This is quite in contrast to the steady-state assumptions behind the stock assessment models which are commonly applied in Lake Victoria's fisheries management. Our hypothesis is supported by the increased biomass of shrimps and lakeflies[11,14,15], probably as a result of increased eutrophication. The extra amount of these prey organisms creates an additional food source for Nile perch, and this may explain the apparent resilience of the exploited Nile perch stocks to the increased fishing pressure. However, the same eutrophication may also pose a threat to the fishery. The compensation for increased fishing pressure by increased productivity could fail when eutrophication becomes too strong[16,1]. In shallow coastal areas, a further increase in nutrient loadings would lead to decreasing increments in primary production because of the increasing self-shading of algae[10]. In deeper pelagic zones, further eutrophication would expand the hypolimnetic anoxic water layers, thereby reducing the volume of productive habitats in the lake. All this would make an end to the increasing carrying capacity for Nile perch. Some reports suggest that optimal nutrient concentrations to support fisheries may have been exceeded already[10].

Finally, management regulations and fishing industry drive the fishery as well. For example, fish filleting factories require larger Nile perch and therefore large Nile perch are selectively harvested by the export fishery. This selective harvesting of Nile perch at the size at which it becomes piscivorous[11,17], could lead to the re-appearance of haplochromine species, in particular zooplanktivores competing with Nile perch fry[18]. This could possibly lead to an apparent reversal of the regime shift around 1980, which took place more than 30 years after Nile perch introduction[19], allegedly through to local depletion of haplochromine stocks - main competitors and possibly predators of Nile perch fry - through heavy fishing and eutrophication. The decrease of haplochromines may have contributed to a strong increase of adult Nile perch, which then decimated the remaining haplochromine stocks[11]. **The question is what conditions in relation to fishing pressure, selectivity of the fishery and eutrophication could result in a collapse of Nile perch stocks resulting in a regime shift to a new cichlid-dominated state.** Biodiversity could increase[18], though also the recovery of haplochromines may be more successful if eutrophication can be reduced[20]. In any case, a Nile perch collapse would represent catastrophic economic loss for the region, and a decrease or stabilisation of nutrient input would be a useful strategy for lake and fisheries management.

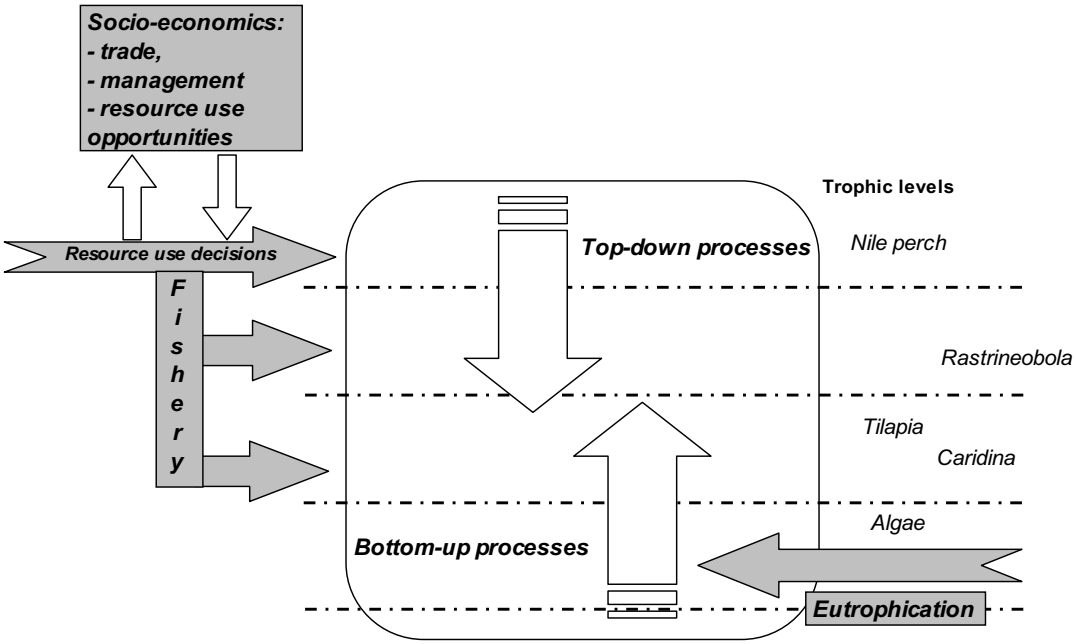

Figure 1. Top-down and bottom-up processes structure the Lake Victoria ecosystem. The ecosystem is represented by its various trophic levels in major fish species. The grey arrows are drivers that directly impact on the ecosystem at particular trophic levels. The fishery in its turn, is driven by trade demands while resource use opportunities are a main driver for choices made by the fishery community.

Research gaps: disentangling processes of fisheries and eutrophication

The changes in Lake Victoria's food web are driven both by top-down (e.g. fishing pressure influenced by trade and management) and by bottom-up processes (e.g. eutrophication) (Fig. 1). Both processes structure the food web and thus the resource base of the fishery. They certainly interact, but it is unknown to what extent they reinforce or compensate each other. Until today both processes were analyzed separately, resulting in different and often highly conflicting views on the direction and needs of fisheries and ecosystem management. Therefore, the real challenge is to understand and disentangle environmental and resource use interactions and feedbacks. Filling these knowledge gaps is essential for a proper assessment of the risks to the resource base and to propose solutions. That is why we propose an integrated analysis of all driving processes. **Our working hypothesis is that continued eutrophication presents a much graver risk to the resource base and thus livelihoods of Lake Victoria's coastal populations than fishing pressure.** The interactions and feedbacks of both drivers should be analyzed to enable development of long-term ecosystem management strategies to counteract their risks. With this the program addresses at least three of the four key areas in the Sustainable Environment theme (I, III and IV).

b. Programme outline

Two general questions will be addressed by the proposed project.

1. What are responses of the fishery to the changes caused by increased nutrient loadings?

Fishermen take decisions about the use of their resources based on (1) the socio-economic environment including trade possibilities and management restrictions and (2) the availability of resources. Limits to fish productivity due to continued eutrophication will be reached earlier

near urban centres and in enclosed shallow bays where water exchange is limited. As these areas are also places where fishing pressure is highest, effects of eutrophication and fisheries exploitation can only be distinguished if a comparison is made between sites with different pressures of both factors. Therefore, in the present project spatial differences in catch effort allocation and the contextual factors behind the history of fisheries will be carefully analysed to reveal the relative importance of both drivers in the decision making process regarding resource use.

2. What are the responses of the Nile perch stocks to the combined impacts of fishing and increased nutrient loading: when does eutrophication become deleterious to the fishery?

Predator-prey theory tells that, unless there are strong density-dependent effects in predator mortality rates, the biggest responses to changes in productivity will be in the abundance of top-predators in the ecosystem[21]. Further disentanglement of the impact of eutrophication and fishing can only be done experimentally by manipulating main links in the food chain. We will focus on the main link between shrimp and Nile perch to test impacts of changes in productivity.

From these general questions four sets of **integrated PhD studies** (Fig. 2) are proposed that relate to:

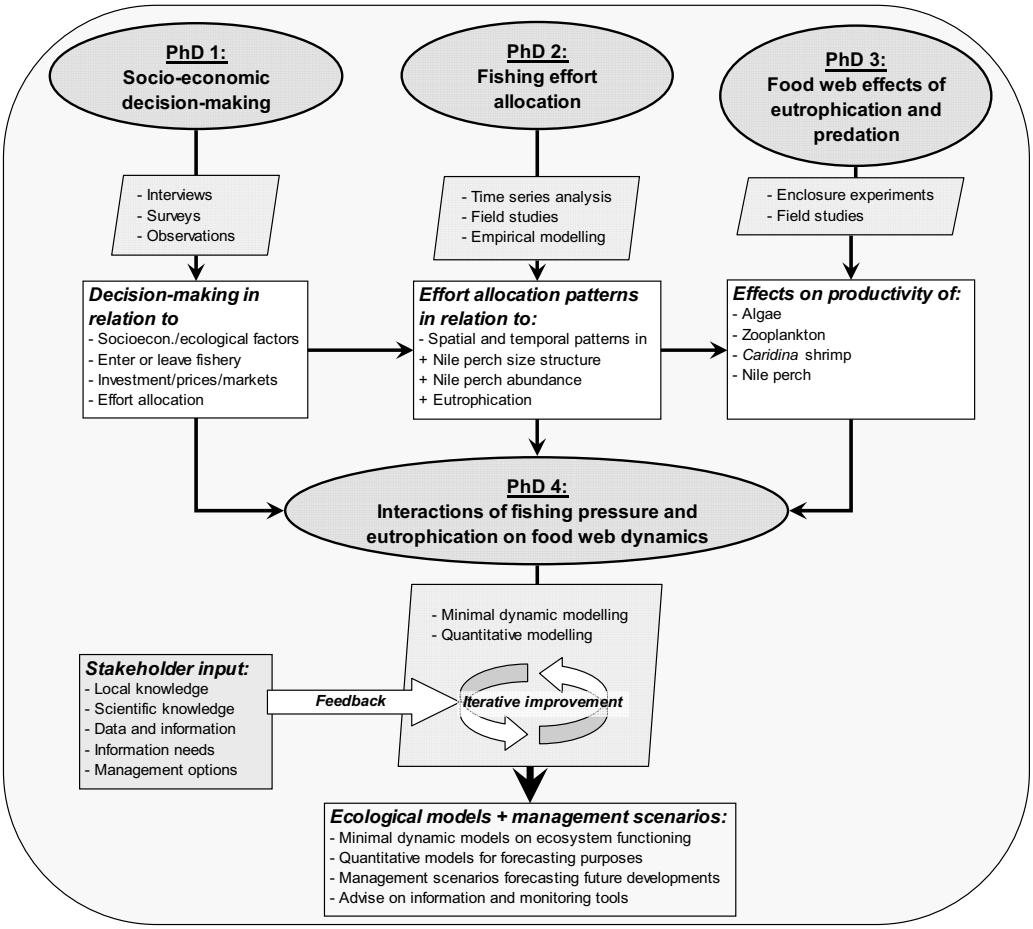

Fig 2. Relationships between the PhD studies in the programme. Ellipses:main processes on which each project focuses; tilted tetragons: research methods; rectangles: output information and data; arrows: information / data flows.Note the iterative improvement cycle in the modelling phase of PhD 4, in which stakeholder information is used to fine-tune the models.

(1) The **social factors that drive resource use decisions** of individuals in the fishery. The objective of this study is to elucidate social, economic and governance factors driving the decisions of fishermen and the resulting patterns and pathways in fishery resource use. The study also will contribute in understanding how local communities manage fish resources in relation to governance processes at higher levels.

(2) The **ecological factors that drive resource use decisions** of fishermen. The objective of this study is to understand the ecological driving forces in fishing effort allocation and to understand how selective fishing affects the size structure of Nile perch stocks and hence food webs.

(3) The **impact of eutrophication and Nile perch predation on food web structure**. The objective of this study is to understand the nature and extent of the effects of eutrophication on major pathways in the food web, involving Nile perch and its main prey.

(4) The **causal relations between fishing pressure and eutrophication on food web structure and the identification of management scenarios**. The objective of this study is to unravel interactions and feedbacks resulting from eutrophication or fishery as most likely factors driving changes in Lake Victoria's food web. This modelling study integrates and guides research in the empirical studies (1 to 3). Dominant interactions identified by the first three PhD's will be further explored to assess the risk of potential future regime shifts. Scenario studies based on the results of PhD's 1, 2 and 3 and on discussions with stakeholders (see 11 and 12) will show at which trophic levels management measures are most effective to reach the desired societal goals with regard to eutrophication, exploitation, food security, and trade.

A series of workshops for stakeholder consultation, process guiding and internal coherence building are planned throughout the program. Research and the workshops will be embedded within the existing consultations by *LVFO*, *IFMP* and *LVEMP* (see 11 and 12). The outcome of these workshops should help in answering **which short-term solutions for lake management are feasible and which long-term solutions are needed?** The current fisheries management instruments have a strong focus on regulating the fishery, in particular of Nile perch. This is mainly an export oriented industry, but local decisions on resource exploitation will be strongly influenced by both local and global economic opportunities. In addition, resources are also affected by land use and therefore a more balanced view on resource exploitation may be reached when environmental health and food security are added as conditions and goals of management. The program aims to contribute to such a view.

c. Interdisciplinary and integrative approach

Central to the program is the quest for (1) the **conditions leading to or following a Nile perch stock collapse** and (2) **early warning signals** indicating such a regime shift. Ecological conditions, researched in PhD 3 and 4 are framed by likely reactions of society to ecological changes researched under PhD 1 and 2. Early warning signals can be ecological (increased variance in catch rates or algal blooms) or social (reaction to spatial changes or increased catch variance). Continuous interaction between the four PhD students, their supervisors and regional scientists with long-term experience on Lake Victoria is required to formulate the most likely interactions and feedbacks that will be modelled in PhD 4. Integration of the four PhDs will be assured by organising meetings between students and supervisors already at the outset of the program and at least once per year during the program in which stakeholders will give feedback on conceptual and model development. Scenarios to avoid a regime shift will be explored during workshops that will be used as integrative learning environments: research results will be scrutinised from a scientific, experiential and policy perspective.

Description of the projects

(*Max. 500 words/project, add word count)*

a. Project 1 PhD 1 – 500 words

Title of project:	***Motives and strategies of fishermen driving choices in available fishery resources for food security, trade and export***
Name researcher:	
Name promoter/supervisor:	Van Dijk (promoter), Mwaipopo (local supervisor)
Start and end date project:	1 January 2008 – 31 December 2011

Description:

Fishing pressure is determined both by the demand for fish at local and export markets and by the decisions of local fishermen how to respond to this demand. Fishermen take their decisions whether or not to invest in fishing gear, or in and time and effort of fishing, based on a wide range of economic, socio-cultural and ecological factors These decisions largely determine the pressure on the available fish stocks

Over the past decades fishing communities changed fundamentally in size, composition and organisation concurrent to fast changes in the lake ecosystem. The current changes in the nutrient load of the lake and the foodweb structure are both cause and effect of human pressure. They create at the same time risks and opportunities for local fishermen and their dependents. They also shape the decision-making on the exploitation and the management of the fish resources. The decisions are further embedded in social and political relations within riparian communities, relations fishermen maintain with middlemen, traders, and local and national management structures through customary, co-management arrangements and the Ministry of Natural Resources and Tourism

To identify the major drivers behind increasing fishing pressure a study on decision-making of fishermen with respect to fishing activities and investments in fishing equipment will be made. Having identified the determinants of actual and potential fishing pressure they can be targeted by measures and policies to promote the sustainable management of the lake. Fishermen navigate between opportunities offered by local and international markets, ecological opportunities offered by the lake ecosystem and .opportunities and constraints embedded in local governance structures and co-management arrangements currently in force around the lake.

The proposed PhD study will answer the following questions:
(a) How do socio-cultural, historical and environmental factors drive decision-making at the level of individual fishermen?
(b) Which decisions and driving factors at different levels of varying scale (research community, local community, regional authority, national government, and markets) are relevant for understanding these decisions.
(c) Which pathways of resource use arise out of these decisions and determine fishing pressure on the lake?
(d) How are these pathways related to varying levels in eutrophication and composition of the fish stock both in time and in space?

The methodological framework used has been designed for analyzing decision-making under conditions of high ecological and economic risk[23,24]. It focuses on the interaction between decisions, social, ecological factors, available assets, institutions, and knowledge. It takes into account that decisions of fishers and related actors such as traders are determined as well by previous (investment) decisions that co-determine their manoeuvring space and possibilities to change their livelihood.

The analysis will identify:

1. social, economic and governance factors driving the decisions taken by fishers and fishing communities and the resulting patterns in fish resource use.
2. the ways in which local communities manage fish resources in relation to governance processes at higher levels;
3. the way in which actors allocate their time over fishing and other activities and fishing effort in space investigated by PhD2.

b. Project 2 PhD2 – 502 words

Title of project:	***Effort allocation and the impact of eutrophication and fishing on the size structure of the Nile perch stocks.***
Name researcher:	
Name promoter/supervisor:	Verreth, Nagelkerke, van Zwieten, Mgaya
Start and end date project:	1 January 2008 – 31 December 2011

Description:

Selective fishing on Nile perch >60cm could weaken predation on haplochromine stocks[11,21,25] potentially leading to a state with low Nile perch stocks. However, we hypothesize that the fishery alone will not be able to reduce Nile perch stocks to levels leading to such a shift, because, before it can happen, fishermen will have reverted to other resources if catches become too low[26,27]. But if large Nile perch is also negatively affected by the impacts of eutrophication[28] - hypoxic conditions in deep and in hypereutrophic shallow waters - stock collapse may indeed occur. Disentangling the effects of fishery and eutrophication on stock abundance is therefore essential to understand and influence the food web processes in Lake Victoria.

An important aspect of the fishery is **effort allocation**, which will be strongly driven by the availability of large Nile perch. Effort allocation depends on two processes at different temporal and spatial scales: (1) long-term changes in numbers and types of gear used; and (2) short-term changes (seasons, days) in fishing activity, driven by encounter rates with patches of fish. Most fishing effort now takes place near urban centres in relatively shallow areas (<20m), which causes deeper areas to be essentially refuges for Nile perch. However, also impacts of eutrophication on Nile perch are expected to be spatially differentiated: in coastal areas eutrophication will be stronger, while in deep waters distribution is constrained by the seasonal movements of the oxycline. Changes in abundance of fish will drive fishing effort allocation within the limits of economic and physical variables as travel distance and weather but also the oxycline (setting depth of nets!) and algal blooms[29,30]. At the scale of individual locations catch may be independent of past local fishing effort, but may be more strongly determined by changes in fish availability. On an aggregated scale this will lead to patterns of co-variation between catch, effort and eutrophic state. By combining four types of studies patterns of effort allocation can be related to stock availability and factors indicating eutrophication:

1) **Reconstruction of historical effort allocation:** spatial analysis of past frame-surveys and through systematic interviews with fishers (with PhD1)
2) **Empirical study** on location choice, size structure and species composition in the catch in relation to eutrophication. Current allocation will be studied at four sites (with PhD3) with different levels of fishing effort and eutrophication status through (a) daily logbooks with a large sample of fishermen and a limited number of detailed GPS studies, (b) experimental gillnet fishing providing fishermen with fleets of gillnets with a range of mesh sizes to examine selection and recruitment patterns.
3) **Time series analyses** of historical experimental trawler surveys to characterise changes in Nile perch stocks and size distribution since the Nile perch boom. In co-operation with TAFIRI tri-annual lake-wide trawl surveys will be extended to the specific research sites of this study. The result will be a
4) **Deductive empirical model** to examine location choice and effort allocation in relation to eutrophication status and size structure of Nile perch.

c. Project 3 PhD3 – 466 words

Title of project:	***Impact of eutrophication status and fisheries on major pathways in Lake Victoria food webs: a combined experimental and field study approach.***
Name researcher:	
Name promoter/supervisor:	Verreth/van Donk, Nagelkerke/Vijverberg
Start and end date project:	1 January 2008 – 31 December 2011

Description:

In this sub-project we attempt to elucidate relative impacts of **eutrophication** and **predation** on the biomass and production in Lake Victoria's food web. This will help us to disentangle the effects of eutrophication, leading to a larger carrying capacity for Nile perch, and of increased fishing pressure. We hypothesize that progressively increasing eutrophication beyond the presently observed levels, will not lead to a further increase of primary production, and thus will not further compensate for increased fishing pressure. We will **combine experimental and field studies**.

In the **enclosure experiments** we will focus on a simplified food web, consisting of Nile perch feeding on *Caridina* shrimp[31,32], which, in turn, feeds almost exclusively on detritus[33,34]. Experimental enclosure studies are performed in order to separate effects of eutrophication and predation and to enable us to increase the range of eutrophic states beyond the range presently observed in the field. Enclosures (six of 100 m^2 each) will be subjected to nine different treatments following a two-factorial design with three levels of nutrients as a measure of eutrophication (lower than, equal, and higher than the lake's average) and three levels of biomass (zero, medium and high) of Nile perch as a measure of top predation. Differential impacts of predation and eutrophication will be investigated in further detail by a nested design[35], in which smaller 'bags' (0.1 – 5 L) are inserted in the larger enclosure, containing the same water quality and prey organisms, but excluding predatory organisms These will be constructed in a shallow part of the lake near the TAFIRI Laboratory, where nutrient levels are lower than the lake's average. Enclosures will be repeatedly used in time, with treatments assigned randomly in time and to enclosures. Primary production, algal biomass and taxa

composition, size structure, biomass and production of shrimp population and zooplankton community, and water transparency will be measured as output variables.
Because enclosure experiments are not without risk of failure, we have chosen for a relative small number of enclosures (6) and a long study period (3 years), permitting many series of experiments

Field studies at stations with different fishing pressure and eutrophication levels will be performed in order to validate whether the results from our enclosure studies are comparable to observations from the real food web of Lake Victoria. During a February 2007 visit to the area we were already able to select four such stations. At these stations the same output variables will be measured as in the enclosure studies. Fish biomass and size structure will be in measured with experimental gill-netting and (lakewide survey) trawling in co-operation with PhD 2.

The results of this sub-project on the relationship between eutrophic state and carrying capacity for Nile perch are important input for PhD 4, whereas water transparency and chlorophyll content data will be useful information for PhD2.

d. Project 4 PhD 4 – 517 words

Title of project:	***The effects of fishing pressure, eutrophication and their interactions on the Lake Victoria food web and its exploitation: analysis and management scenarios***
Name researcher:	
Name promoter/supervisor:	Scheffer/Mooij,
Start and end date project:	1 january 2008 – 31 December 2011

Description:

We aim to enhance insight in the combined effects of fishing pressure and eutrophication on the Lake Victoria food web with models that will be closely linked to available data. We will develop models that can plausibly explain the past dynamics, and subsequently use those models to explore possible future scenarios for the lake

Our working hypotheses are that (1) competitive interactions and predator-prey dynamics in the complex size-structured community of Nile perch, cichlids, tilapia, dagaa, shrimps and their planktonic and benthic food sources cause the system to react in a non-linear way to changes in nutrient loading and fisheries. A possible explanation for the regime shift that took place in the 1980's, decades after its introduction, is that Nile perch recruitment initially was controlled by cichlid predation and competition, but could suppress cichlids once this control was weakened by eutrophication. This is a mechanism of much interest that has been suggested not only for Lake Victoria[11] but also for collapse of other commercial fish species such as cod[21,36]. We will then develop hypotheses on how a future increase in eutrophication, in combination with (selective) fishing would affect Nile Perch and other key components of the foodweb. (2) Continued eutrophication would have two types of effects. Firstly, it would lead to a larger volume of anoxic water and thereby decrease the habitat of both Nile perch and its main prey organism *Caridina*. Secondly, increased eutrophication would lead to an overall increase in productivity. Information on the second aspect will be generated by PhD3.

We will approach the problem in two complementary ways to deal with well known caveats of quantitative ecosystem modelling. First we will explore *minimal dynamical models* that grasp the essence of some major driving forces that have been suggested to govern the dynamics of

the system. Subsequently, we will employ two elaborate quantitative models that describe effects of eutrophication and fisheries and can be used for evaluating management scenarios. Those models will be modifications of two elaborate models that we developed earlier: the individual based fish community model *PISCATOR*[37] and the lake ecosystem model *PCLAKE*[38,39]. These models are complementary in their approach. PISCATOR allows us to analyze feedbacks in the size-structure of a multi-species fish community. PCLAKE offers the possibility to look deeper into interactions between the biological community and nutrient dynamics. Sophisticated techniques for sensitivity analysis, parameterization and validation will be used for those relatively complex models[40].

Importantly, our models will allow the best possible use of the data obtained in the empirical PhD projects, and promote the development of a common theoretical framework. Specifically, PhD3 will provide information on effects of eutrophication on productivity. Fishing pressure will be modelled in close cooperation with PhD 1 and 2. The individual based model PISCATOR will be used to model choices of fishermen in response to fish distribution and other important factors such as regulation and socio-economical aspects in a dynamic way. We will organize cooperation in constructing and analyzing the model as well as the interpretation of the results with project partners and stakeholders (see section 11).

6. Timetable of the programme

Activities	Deliverables	2007		2008				2009				2010				2011				2012		remarks
		3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	
Project activities																						
Research																						
PhD 1																						
Preparation/course work	Research proposal & methodology & workplan for field research			■	■	■																
Field research 1	Data sets						■	■	■													
Preliminary analysis	Adjustment of research plan, first article/paper									■												
Field research 2	Data sets										■	■										
Analysis of data sets	Identification of driving factors for fishery												■	■	■							
Cross-checking data in the field	Validated data set															■						
Write-up of thesis	4 articles, plus synthesis chapter												■	■	■	■	■	■	■			
Thesis defence	Completed PhD thesis																		■			

Activities	Deliverables	2007		2008				2009				2010				2011				2012		remarks
		3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	
PhD 2																						
Preparation, literature study, research plan	Research proposal & methodology & workplan for field research																					
Logbook development – gillnet survey with fishers	Logbook ready fishermen trained																					discussions with fishermen on results
Historical effort data collection and analysis	GIS maps of effort allocation																					
Effort allocation study	Data sets																					
Experimental gillnetting	Data sets																					**Lundgren nets**
Exp. Gillnet with fishers	Data sets																					**Fleets of gillnets**
Trawler surveys	Data sets																					**RVExplorer (dependen ton schedule)**
Analysis historical experimental catch data	Analysis Nile perch stocks/size-structure																					
Data analysis	Identification of effort allocation patterns and impacts selective fishing on NP stocks																					
Write up scientific papers	4 articles written																					
Write-up thesis	Synthesis chapter & thesis written and defended																					

Activities	**Deliverables**	**2007**		**2008**				**2009**				**2010**				**2011**				**2012**		**remarks**
		3	**4**	**1**	**2**	**3**	**4**	**1**	2	3	**4**	**1**	**2**	**3**	**4**	**1**	**2**	3	4	**1**	**2**	
PhD3																						
Preparation enclosures																						
Literature review, research plan	Research proposal including methodology and work plan for field research																					
Set-up lab	Equipment bought and installed																					
Enclosure experiments	Data sets																					
Field studies	Data sets																					
Data analysis	Identification of major food web patterns																					
Writing scientific papers	4 Articles and synthesis chapter																					
Writing thesis	Completed PhD thesis and defence																					

Activities	Deliverables	2007		2008				2009				2010				2011				2012		remarks
		3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	
PhD 4																						
Model formulation related to past development	Conceptual model																					
Workshop with project members and experts	Main interactions																					
Model development and analysis	Draft model																					
Feedback from experts and stakeholders	Feedback																					
Further model improvement	Model																					
Evaluation with experts and stakeholders	Model tested																					
Model formulation related to future development	Conceptual model																					
Workshop with project members and experts	Main interactions																					
Model development and analysis	Draft model																					
Feedback from experts and stakeholders	Feedback																					
Further model improvement	Model																					
Evaluation with experts and stakeholders	Model tested																					
Workshop with policy makers	Scenario review																					
Write-up scientific papers	4 Articles and synthesis chapter																					
Write-up thesis	Completed PhD thesis and defence																					

Activities	Deliverables	2007		2008				2009				2010				2011				2012		remarks
		3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	
MSc Studies	4 MSc studies per PhD																					
Programme activities																						
Preparatory activities																						
SIL meeting (presentation and discussion of proposal)	Proposal discussed by international scientific audience																					
Identify and contracting PhD students	4 students contracted																					
Project agreements with TAFIRI and collaborators	Project agreement																					
Project agreement on communication an dissemination	Project agreement																					
Advisory committee	Advisory committe ready																					
Kick-off workshop																						Supervising teams the Netherlands/Tanzania, PhD's. Two day workshop to be held in Tanzania
Cross-check and adjustment of research plans																						
Monitoring milestones:																						

Workshops - stakeholders						■					■				■							
Advisory committee meetings	Reports; advice					■					■				■							
Website/WIKI development	Website/WIKI developed	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Publications:																						
Scientific articles by PhD	16 Articles – 8 published in international peer reviewed publications							■					■				■				■	
Scientific article(s) integrated	Book? Special publication?																				■	Supervising teams, PhD, Advisors, Stakeholders
Non-scientific articles										■				■				■				
PhD Thesis	4 PhD theses																		■			
MSc Theses	16 Msc theses								■	■	■	■	■	■	■	■						
Dissemination and communication milestones:																						
Stakeholder meetings	Reports					■					■				■				■			
Conference presentations	Abstracts, power points						■					■				■				■		

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7. Partnership and track record (*Max. 2 pages)*

a. Previous collaboration

Vijverberg with **Nagelkerke** PhD project Eshete Dejen on 'Ecology and potential for fishery of the small barbs (Cyprinidae) of Lake Tana (Ethiopia) (1999-2006) - INCO-DEV project FISHSTRAT (2002-2003) Sabbatical project 'Fish communities and foodwebs of 9 Ethiopian lakes (2004-2005). **Van Zwieten**, **Verreth**, **van Dijk** and **Scheffer** RESCOPAR – Rebuilding Resilience of Coastal Populations and Aquatic Ecosystems, Wageningen University INREF (2006 – 2010); **Van Zwieten** and **Kolding:** Research co-operation between CMI, WU, University of Bergen funded by NORAD on effort development in African freshwaters (1997-2002); Knowledge in Fisheries Management EU-INCO Dev project (2001 – 2005); Improving Productivity in Tropical Lakes and Reservoirs, CGIAR Challenge Program (2005 – 2006); **Van Zwieten, Kolding**, **Mgaya** and **Hecky** with various scientists involved in **LVEMP**, **LVFO** and **TAFIRI** on the Regional Synthesis of Fisheries Research and Management, LVEMP/Worldbank (2005); **TAFIRI** in various projects with **ECOVIC**, **TIFPA**, **LVFO, LVEMP** and **Division of Fisheries**. **Janse** and **Scheffer** and **Mooij**: PhD project lake modelling; **UDSM** with **TAFIRI, LVFO,** and **LVEMP:** capacity building, advise, scientific working groups **Janse** and **Mooij**: NWO project adaptations of PCLake model to various systems; **Janse** with **TAFIRI** and others: biodiversity and poverty modelling; **Van Dijk** with **Mwaipopo** University of Dar es Salaam, Faculty of Arts and Social Sciences

b. Workshop

After preparations in January 2007 in Mwanza by **WU**, **TAFIRI**, University of Dar es Salaam (**UDSM**) and Lake Victoria Fisheries Organisation (**LVFO-secretariat**), representatives of the **Division of Fisheries** (Ministry of Tourism and Natural Resources); LVFO-Secretariat; the Tanzania Industrial Fishing and Processors Organisation (**TIFPA**); the Water Quality Laboratory (**WQL**); the Lake Victoria Environmental Project (**LVEMP**); the East Africa Community Organisation for Management of Lake Victoria resources (**ECOVIC**) and the UDSM convened at TAFIRI in Mwanza on 9 February 2007. **Results**: (1) all endorsed the project developed by TAFIRI and the WU (2) signed the project document and (3) sent in Letters of Support. **Conclusions**: (a) stakeholders could have been solicited earlier in the process, but acknowledged that the time limits to write the proposal precluded this; (b) Addressing the issue of the relation between fisheries and eutrophication was urgent, timely and related to discussions on the impact of fisheries held in the region between stakeholders; (c) The combination of disciplines and fundamental research questions was seen as useful and contributing and informing (applied) research work already carried out by the various institutions involved; (d) The research should aim to incorporate stakeholders' views; (e) The proposal should indicate how it can complement and supplement other projects on the lake such as LVEMP and IFMP; (g) Additional and complementing research in Kenya and Uganda should be sought to gain regional impact. **Remarks** on the proposed research (a) the project should take into consideration the dynamics of the fisheries (b) there is need to relate oxygen uptake to fish sizes (c) there is need to bring in the history of the fishery for instance the effect of market forces (d) information from Fish Processors on the state of the stocks (size structure) differs from experimental trawl surveys (e) the project should aim at building capacity at both technical and infrastructural levels (f) the project should involve a much wider range of stakeholders and thus benefit from the expertise and views in the region (g) eutrophication and fisheries are important drivers of ecosystem changes but it is difficult to manage eutrophication. Concerns were raised as to what (fisheries) management measures could be implemented to address eutrophication

c. Partnership

Verreth overall scientific and management responsibility; experience experimental approaches (Phd3); **Ngatunga** Tanzania program co-ordinator; stakeholder involvement; **Katunzi** field project manager; **van Dijk** supervision of PhD1; co-ordination with PhD2; **Nagelkerke**; co-responsible for the supervision of PhD1 and PhD2; experimental fishing **van Zwieten**: co- supervision of the PhD2; set-up effort allocation study and experimental fishing, day-to-day project management; multidisciplinary interaction; **Mgaya** co-responsible supervision of PhD2; experimental field ecologist; **Nagelkerke** supervision of PhD3; **van Donk**: co-supervision PhD3; **Vijverberg** co-supervision PhD3. Experimental food-web study using cosms, measurement of primary production

and phytoplankton community respiration (cosms and Lake habitat); establishing, start–up of the cosm (research) at the lake site; the training of PhD3 and assistants; **Chitambwewe/Mroso**, assistance in limnological field work and experiments; **Tamatamah/**(later **Radhia**): limnologists, advise. **Mooij:** co-supervision PhD4; re-development of PCLAKE for the Victoria situation in cooperation with **Janse** of the RIVM; **Scheffer**: supervision of PhD4; re-development of PISCATOR for the Victoria situation.

Capacity strengthening collaborating partners and end users

TAFIRI: two DC candidates employed; 4 MSc trained; **UDSM** – 2 MSc trained; collaboration in research. **Dutch scientific and development community** – 2 NL/non-DC students; 8 MSc trained; **TAFIRI**, **LVFO**, **TIFPA**, **Fisheries Division**, **WQL** experience in stakeholder involvement in scientific research; integrated approach complex research questions; sharing of information between stakeholders; management advise on eutrophication and fisheries. Co-operation between institutions: responsible for the three field work PhD's is always a WU/NIOO and a TAFIRI/USDM person. **ECOVIC** is responsible for aiding in dissemination and communication with local stakeholders in co-operation with **TAFIRI** and the project direction

d. Recent publications

Amarasinghe, P.B. & J. **Vijverberg.** 2002. Primary production in a tropical reservoir in Sri Lanka. Hydrobiologia 487: 85-93.; Verschoor, A.M., J. Takken, B. Massieux & **J. Vijverberg.** 2003. The Limnotrons: a research facility for experimental community and food web research. Hydrobiologia 491: 357-377; Dejen, E., **J. Vijverberg**, **L.A.J. Nagelkerke** & F.A. Sibbing. 2004. Temporal and spatial distribution of microcrustacean zooplankton in relation to turbidity and other environmental factors in a large tropical lake (L. Tana, Ethiopia). Hydrobiologia 513: 39-49.; De Leeuw, J.J.; **L.A.J. Nagelkerke**, W.L.T. van Densen, M. Holmgren & P.A. Jansen & **J. Vijverberg** (2003) Biomass size distributions as a tool for characterizing lake fish communities. Journal of Fish Biology 63:1454 - 1475.; M.C.J. Verdegem, **L.A.J. Nagelkerke**, M.A. Wahab, A. Milstein & **J.A.J. Verreth** (2006) Growth, production and food preference of rohu Labeo rohita (H.) in monoculture and in polyculture with common carp Cyprinus carpio (L.) under fed and non-fed ponds. Aquaculture 257: 359 - 372.; **Katunzi, E.F.B**, J. Zoutendijk,.T. Goldschmidt,.J.H. Wanink & F. Witte (2003) Lost zooplanktivorous cichlid from Lake Victoria reappears with a new trade. Ecology of Freshwater Fish 12: 237-240.; **Katunzi, E.F.B**., van Densen W.L.T, Wanink, J.H. and Witte, F. (2006) Spatial and seasonal patterns in the feeding habits of juvenile Lates niloticus (L.), in the Mwanza Gulf of Lake Victoria. Hydrobiologia 568:121-133; Moss, B., D. Stephen, D. M. Balayla, E. Bécares, S. E. Collings, C. Fernández-Aláez, M. Fernández-Aláez, C. Ferriol, P. García, J. Gomá, M. Gyllström, L.-A. Hansson, J. Hietala, T. Kairesalo, M. R. Miracle, S. Romo, J. Rueda, V. Russell, A. Ståhl-Delbanco, M. Svensson, K. Vakkilainen, M. Valentín, W.J. Van de Bund, **E. Van Donk**, E. Vicente & M.J. Villena (2004). Continental-scale patterns of nutrient and fish effects on shallow lakes: synthesis of a pan-European mesocosm experiment. Freshwater Biology 49: 1633-1649.; Rahman, M.M.; Van De Bund, W.J. & **E. Van Donk** (2004) Effects of fish and nutrient additions on food-web stability in a charophyte-dominated lake. Freshwater Biology 49: 1565-1573; **Van Donk, E.**, M.P. Grimm, P.G.M. Heuts, G. Blom, K. Everards & O.F.R. Van Tongeren (1994). Use of mesocosms in a shallow eutrophic lake to study the effects of different restoration measures. Arch. Hydriobiol. Ergeb. Limnol. 40: 283-294.; **Scheffer, M.**, S. R. Carpenter & B. De Young (2005). Cascading effects of overfishing marine systems. Trends in Ecology & Evolution 20:579-581.; **Scheffer, M**., S. R. Carpenter, J. A. Foley, C. Folke, & B. Walker (2001). Catastrophic shifts in ecosystems. Nature 413:591-596; Van Nes, E. H., E. H. R. R. Lammens, & **M. Scheffer.** 2002. PISCATOR, an individual-based model to analyze the dynamics of lake fish communities. Ecological Modelling 152:261-278; **Van Dijk, H.** & M. de Bruijn (1999). Insecurity and Pastoral Development in the Sahel. Development and Change 30: 115-139.; **Van Dijk, H**. & M. de Bruijn (2003) Risk positions and local politics in a Sahelian society: the Fulbe of the Hayre in Central Mali. In: African Environment and Development Rhetoric, Programs Realities (W G Mosely & B. I. Logan, eds), Ashgate, pp. 140-160.; **Van Dijk, H**. & M. de Bruijn (2005) Introduction: Climate and Society in Central and South Mali. In: Sahelian Pathways. Climate and Society in Central and South Mali (M. de Bruijn et al., eds.), Leiden African Studies Centre, ASC Research Reports 78/2005, pp. 1-15; Van Oostenbrugge, J.A.E., E.J. Bakker, W.L.T. van Densen, M.A.M. Machiels, **P.A.M. van Zwieten** (2002) Characterising catch

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e. NWO research funding

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9. Management and Monitoring and Evaluation

(Max. 500 words, add word count) 491 words

The **Project Board (PB)** is the basic unit of decision making and consists of one representative of each partner institution. The PB is responsible for scientific, political and administrative strategy of the project.

The **Steering Committee (SC)** is responsible for the daily coordination of the project, and receives a specified mandate by the PB to handle finances, planning and control cycles and external communication. The SC consists of J. Verreth (project director: overall program responsibility), B. Ngatunga (project director Tanzania - overall responsibility for activities in Tanzania). Both are assisted by P. van Zwieten and E. Katunzi for day-to-day management of project activities in the Netherlands and Tanzania. The program director Tanzania will be responsible for coordinating the organization of workshops, act as "problem owner" for the logistics and local arrangements of the PhDs and for the provision of infrastructure. He also liaises to ECOVIC for dissemination to local communities.

An external **International Advisory Committee (IAC)** consists of 3 external experts who will critically assess project developments, review scientific output, attend workshops and advise on general program strategies whenever appropriate. The IAC reports to the PB and to the SC.

Financial planning and control will be carried out by the financial controller of the Dept of Animal Sciences at Wageningen University (WU-ASG). For activities in Tanzania, financial control will be carried out by the Financial Controller at the TAFIRI station in Mwanza, who reports to the controller at WU-ASG, who reports to SC.

The **scientific progress monitoring and evaluation** of the project will be conducted by the group of supervisors in the Netherlands and Tanzania, under coordination of the PB. Quality and progress of each PhD project will be assured trough the establishment of a **PhD supervision team (per PhD)** which meets at least biannually (and further each time considered as necessary). All PhD studies will be carried out within the quality assurance systems of the graduate schools where the PhD students will be registered (WIAS, WIMEK, CERES). An important tool is the *Training and Supervision Plan* which has to be submitted for approval by each PhD student within the first 3months of his/her assignment to the Graduate School. It is the backbone for progress monitoring of the PhD training. The PhD student and his supervisors will submit an annual progress report on activities and results to the SC.

External communication will be coordinated by the Steering Committee. To avoid that the scientific program is politically damaged by uncontrolled communication, all communication memoranda with policy implications must receive approval by the Tanzanian Project Director. Dissemination activities will be reported annually under the responsibility of the project director in Tanzania, who will also be responsible for the agreements with LVFO, TIFPA and ECOVIC and other stakeholders regarding these activities.

The PB, together with SC, will convene annually after the annual workshop to evaluate the progress of the project, with regard to overall scientific objectives, milestones, obtained results and communication and dissemination activities.

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Key summary

I. Scientific significance

a. Overall objective program

To understand and disentangle environmental and fisheries resource use interactions and feedbacks of Lake Victoria, in an integrated analysis of major driving processes to develop scenarios for an assessment of the risks to the livelihood resource base with a focus on Nile perch. To propose, discuss and communicate solutions to ecosystem based fishery management. Two sets of research questions: (1) what are responses of the fishery to the changes caused by increased nutrient loadings (2) what are responses of the Nile-perch stocks to the combined impacts of fishing and increased nutrient loading and when does eutrophication become deleterious to the fishery?

b. Assumption/risk

Assumption: Local studies are representative for the Lake. Risk: Other contextual factors - like demography, politics - and environmental factors - like climate change (temperature, rainfall - might become a risk if they change faster or stronger than known to and assumed to be normal.

Specific Objective 1: To understand and disentangle interactions and feedbacks in the fisheries of Lake Victoria with a focus on Nile perch.		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Responses of the fishery to the changes caused by increased nutrient loadings?	1a. Scientific results presented at 4 Int. Conf. 1b. 8 publications in refereed journals 1c. 2 Ph.D. thesis published 1d. 8 MSc thesis available	MSc studies, PhD studies, local and regional workshops, scientific meetings
2. Responses of the Nile-perch stocks to the combined impacts of (selective) fishing and increased nutrient loading	2a. Scientific results presented at 4 Int. Conf. 2b. 8 publications in refereed journals 2c. 2 Ph.D. thesis published 2d. 8 MSc thesis available	MSc studies, PhD studies, local and regional workshops, scientific meetings

Specific Objective 2: To assess risks to the resource base, and discuss and communicate solutions to ecosystem based fishery management.		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Early warning signals of a regime shift (stock collapse) are identified	- Integrated scientific publications 1a. Ecological conditions (PhD2, 3, 4) and likely reactions of society (PhD1, 2) identified 1b. Early warning signals identified.	- PhD research; interactions between PhD researchers, supervisors and advisory team - local/ regional workshops, (international) scientific meetings
2. Improved tools for an ecosystem based-monitoring of the eutrophication and fisheries	2a. The administrative bodies involved in NRM understand the relevant information and can devise monitoring tools. 2b. The local/regional scientific organisations dispose of improved knowledge on NRM. 2c. International scientific community takes note of approach	2a. Local and regional workshops, website 2b. Deposition of all relevant reports and studies with the institutions involved (TAFIRI, LVFO), data deposition at LVFO. 2c. Peer reviewed publications

c. Overall objective **PhD1**

The objective of this study is to identify social, economic and governance factors driving fishers' decisions and the resulting patterns and pathways in fishery resource use. Furthermore it will contribute to the understanding of the ways in which local communities manage fish resources in relation to governance processes at higher levels.

d. Assumption/risk

Assumption: a study on decision-making of fishers will give insight into which ecological, economic and institutional factors have most influence on their decisions to engage in fishing. Detailed analysis of their behaviour will give insight into how fishers weigh and perceive these factors and translate these into choices for labour and capital investments, preferences for specific species and type of fishing gear, as well as marketing channels and labour and institutional arrangements to organize the fisheries.

Specific Objective PhD1: To determine the major driver(s) behind increasing fishing pressure through a study of decision-making of fishermen with respect to fishing and investments in fishing equipment as the principal determinant of actual and potential fishing pressure		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Identification of economic socio-cultural, historical and environmental factors that drive decision-making at the level of individual fishermen.	1. driving factors identified and their relative importance assessed and communicated through participation in scientific and dissemination meetings and publications 2. detailed description of fishermen's pathways of resource use communicated through participation in scientific and dissemination meetings and publications	Detailed studies of decision-making processes and life-history reconstruction of investment decisions through surveys, in-depth interviewing and observations
2. Forces and driving factors at various scale levels (research community, local community, regional authority, national government, and markets) relevant for understanding these decisions	1. Governance processes and market networks described and analysed and communicated through participation in scientific and dissemination meetings and publications 2. Identification of main forces at supralocal level driving fishermen's decisions and policy alternatives, communicated through participation in scientific and dissemination meetings and publications	Investigation of the linkages between fishermen's decisions and higher order governance processes, linkages between fishermen, market partners, government officials and market and marketing structures through in-depth interviewing, network analysis, surveys and observations

e. Overall objective **PhD2**

The objective of this study is to understand the ecological driving forces in fishing effort allocation and to understand how selective fishing affects the size structure of the Nile perch stocks.

f. Assumption/risk

i. Dominant processes in the food web affecting Nile perch are the bottom-up effect of increased carrying capacity for Nile perch production resulting from increased eutrophication, and the top-down effect of fishery selectively removing large Nile perch. Other potential effects in the food web involving haplochromines, Tilapias and/or *Rastrineobola* are taken into account in as far they are covered by the experimental gillnet and trawler surveys and in co-operation with the field studies of PhD3.

ii. Both the effort allocation study and the experimental gillnet data collection require good co-operation with fishermen. Two of the collaborators in this project (van Zwieten, Kolding) have had extensive personal experience with data collection in co-operation with artisanal fishermen in Zambia (Lake Mweru, Bangweulu, Kariba), Botswana (Okavango), Egypt (Lake Nasser), Vietnam (Red River Delta) and Indonesia (Mahakam Delta). It requires careful explanation and education of fishermen and fishing communities involved (3-6 months), but it is unrivalled in the quality and amount of spatially detailed data and information that can be obtained. In time the data collection for the effort allocation study precedes that of the gillnet survey as the latter requires longer preparation and trust building. In publishing data care should be taken that the co-operation is acknowledged, but that the privacy of the persons involved is not in any way compromised. Furthermore care should be taken that data collection from fishermen is not of an extractive nature: information that is based on data fishermen have provided is to be thoroughly discussed with them.

iii. Historical data (effort and trawler surveys) are available through TAFIRI, the Fisheries Division and LVFO. Cleaned time series of trawler survey data from Tanzania are available digitally from 1970 to 2005 albeit with gaps in the 70-ies and the 90-ies. With LVFO and their partner institutions in Uganda and Kenya it may be discussed if similar series from these two countries can be used for analysis for comparative purposes. Effort data are available from frame-surveys. Recent frame-surveys (since 1998) are well documented but at this stage it is unknown what is still available from earlier surveys apart from aggregated statistics. In that case historical analysis will depend to some extent on interviewing knowledgeable fishermen (in cooperation with PhD1). TAFIRI has researchers with a long term experience (personal and professional) in the fishery.

Specific Objective PhD2 : Understand the ecological driving forces in fishing effort allocation and to understand how selective fishing affects the size structure of the Nile perch stocks.		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Empirical model relating fishing effort allocation decisions to eutrophication status and size structure of Nile perch – input to scenario studies	1. Historical data of effort are present 2. Good contacts between staff of the University of dare s Salaam, TAFIRI, Fisheries Division and fishermen at the fours sample sites identified are present and will aid in setting up this study. The involvement of local staff conversant with fishermen will aid carrying out of the monthly collection of logbooks.	1.A reconstruction of historical effort allocation, by analysing past frame-surveys and through ethnographic interviews (with PhD1) 2. An empirical study on location choice, size structure and species composition in the catch in relation to eutrophication status. Current allocation will be studied at four sites (with PhD3) with different levels of fishing effort and eutrophication status through the use of daily logbooks with a large sample of fishermen as well as a limited number of detailed GPS studies. 3. Empirical modelling to examine location choice and effort allocation in relation to eutrophication status and size structure of Nile perch.
2. Time series and model analyses of characterising changes in Nile perch stocks and size distribution since the Nile perch boom – input to lake models	1. Historical data of trawler surveys are present. Regular lakewide surveys carried out by TAFIRI extending the database to the period of this research program and the research areas are done. 2. Good contacts between staff of the University of Dar es Salaam, TAFIRI, Fisheries Division and fishermen at the four sample sites identified are present and will aid in setting up this study. The involvement of local staff conversant with fishermen will aid carrying out of the monthly collection of daily size-based catch data.	1. Time series of historical experimental trawler surveys to characterise changes in Nile perch stocks and size distribution since the Nile perch boom. In co-operation with TAFIRI the tri-annual lakewide trawl survey will be used to take additional limnological and fishsamples in research areas. 2. Experimental gillnet fishing providing fishermen with fleets of gillnets with a range of mesh sizes to examine selection, and in addition local growth and recruitment patterns

a. Overall objective **PhD3**

The overall objective is to elucidate relative impacts of predation (top-down effects) and eutrophication (bottom-up effects) on Lake Victoria's food web

b. Assumption/risk

i. We assume that the dominant processes in the food web affecting Nile perch, are the bottom-up effect of increased *Caridina* shrimp, production resulting from increased eutrophication, and the top-down effect of fishery removing Nile perch. This does not take into account other potential effects in the food web involving haplochromines and/or *Rastrineobola*,. We chose not to include other fish species because it would increase experimental complexity and because especially *Rastrineobola* does not survive handling. Moreover, the *Caridina* – Nile perch components of the food web are by far the largest. We hope to enlighten the role of these fishes with the field studies.

ii. Since the size of the enclosures is limited we have to use small Nile perch (<30 cm).We assume that these are representative of all Nile perch up to 60 cm, because their dominant food is similar until they reach that size. This assumption seems fair given literature on the diet of Nile perch in Lake Victoria

iii. Working with large (100 m^2) enclosures is risky. Wind induced wave actions my damage the enclosure walls and it will be difficult to remove all the fish before stocking it again.

iv. We assume that in the field study the Nile perch population at particular stations is characteristic for that habitat*, i.e.* that the home range of the Nile perch is limited to that specific area. This is probably true for the smaller Nile perch (up to ca. 60 cm), but may not be true for large Nile perch.

Specific Objective @: Elucidate relative impacts of fisheries (top-down effects) and eutrophication (bottom-up effects) on Lake Victoria's food web		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Biomass and production estimates of food web components (detritus, algae, zooplankton, *Caridina*) at different levels of eutrophication and Nile perch biomass in an experimental setting.	1. By using six enclosures used repeatedly in time 72 experiments are possible. With a minimum of three replicates for each of the nine treatments this leaves room for compensation in case of experimental failure due e.g. to weather conditions. In case there are no failures the number of replicates can be increased to increase the statistical reliability of the experiments. 2. Enclosures can be built near the guarded terrain of TAFIRI, ensuring safety of the experimental setup 3. Design and building of the enclosures will be advised by W. Hecky who is an internationally recognized specialist in this field.	A two-factorial **experimental** enclosure study, with three levels of nutrient level (measure of eutrophication) and biomass of Nile perch (measure of fishery pressure) as main factors. These nine treatments will have at least three replicates, resulting in at least 27 experiments.
2. Biomass estimates of food web components and primary production measurements from lake habitats with different fishery pressure and eutrophication levels. Data will be similar to those from the enclosure experiments, but now under more realistic field conditions and with the addition of other fish species. This enclosure-independent information will enable the valuation of the experiments and an integration of the experimental results in the analysis of the Lake Victoria food web as a whole.	1. Five relevant sampling stations were already identified and we are able to sample all food web components relatively easily. The involvement of local staff will guarantee the timely analysis of biological samples.	**Field studies** of stations with different fishery pressure and eutrophication level will yield the same output data as the enclosure experiments, but in a more realistic setting and completed by biomass estimates of food web components that will not be involved in the experiments (Such as haplochromines and *Rastrineobola*)

c. Overall objective **PhD4**

The objective of this modelling study is to unravel the role of eutrophication and fisheries in driving past changes in the Lake Victoria foodweb, and subsequently use the models to predict the future response of the ecosystem to different scenarios of fisheries and eutrophication.

d. Assumption/risk

We have two key assumptions in this project:
1) We assume that we can use information from the other subprojects, existing time series from the lake, and general knowledge about key processes in aquatic ecosystems to construct a set of models that realistically explain the past dynamics of the system.
2) We assume that we can use the resulting models to predict future dynamics of the system.

Those assumptions imply several risks. A general risk in all ecological modelling enterprises of this character is that it is difficult to know whether a model produces the right results for the right reasons. It is easy to fit complex models to any time series. However, if the assumed causality in the model is wrong, it is a poor basis to make future predictions. To control this risk the best we can we work on three different lines of independent models, as explained earlier.

A more subtle risk is the possibility that fish species in the lake are subject to rapid evolution. If key species have changed considerably over the last years, and keep evolving in the near future, this implies that a model based on past dynamics may have limited use when it comes to predicting future dynamics of species.

Specific Objective PhD4 : to unravel the relative impact of eutrophication or fishery as the most likely factors driving changes in Lake Victoria's foodweb by integrating and guiding research in the empirical studies		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. A set of models that can reproduce past dynamics on the basis of realistic formulations	1. Good concordance of simulated dynamics with observations on the past dynamics of the ecosystem 2. Approval of the assumptions and formulations of the model by experts within and outside the project team	• Workshops with project members and invited experts to formulate the models • Sensitivity analysis, parameter optimization and simulations as well other techniques to analyze the model. • Workshops with project members and invited experts to discuss the plausibility of the results and possible weaknesses or false assumptions. • several iterations of the last two activities to converge to the best possible model
2. Predictions of the future development of the fish community under different scenarios of eutrophication and fisheries	1. Acceptance of the credibility of the predictions by scientists in the project 2. Acceptance of the predictions as useful aids in guiding practical governance of the lake	• Workshop with project members and invited experts to decide on relevant scenarios of eutrophication and fisheries (+ perhaps also climatic scenarios if this seems important) • Simulation of predicted future dynamics of the lake under the scenario's, and uncertainty analysis • Workshop with scientists in the project to discuss credibility of predictions • Workshop with policy makers to explain results and invite feedback

II. Relevance for development

a. Overall objective

Contribute to elucidate conflicting views on the fisheries and water quality management of Lake Victoria and propose solutions for short and long-term ecosystem management on a local and regional level to ensure the continuance of livelihood options of people involved in the fishery sector. The insights yielded by the programme on the complex relations between the two main driving factors for ecosystem change and their relation with (potential) changes in fish stocks, may provide the basis for the development of new policy options on the long and short run.

b. Assumption/risk

i. Though eutrophication is viewed as a problem by many, for stakeholders in the fishing business the real risk is overfishing. This driver has had limited effect on the discourse on fisheries management and policies up to now. Discussions on the potential impact of both phenomena have been done in separate fora. Through clarifying the relation between the two, new dimensions can be added to this ongoing discussion.

ii. The problem of management of African fisheries is generally is viewed as a problem of enforcement of measures. However, as has been argued the scientific basis for taking measures (effort or gear related, spatial) is often thin, based on inherited common-sense notions, or, perhaps, flawed assessments or wrong interpretations of developments based on the best available knowledge in the region. Over the past two decades much effort by policy makers, management and industry has gone into creating awareness of the importance of and agreeing on fishery measures and in institutions to carry them out (e.g. BMU's). The messages that may come out of the present research work may be counter-intuitive to some of these measures, perhaps are difficult to grasp, and may even exacerbate conflicting views.

iii. The sheer size of the Lake Victoria fishery, the magnitude of the export earnings from Nile Perch and the number of people dependent on the fishery make any discussion about ecosystem change and changes in management regimes very sensitive. Current practices of the different stakeholders are also related to vested interests in trade and management. Earlier presentations of the main hypotheses of this proposal for an audience of Lake Victoria scientists and politicians invoked strong reactions. The real challenge for the program therefore will be to **assist in creating an open-minded discussion platform for stakeholders in research management and the industry** where the consequences of the research results can be discussed freely and lead to propositions for real solutions. Communication on workshop results in particular on policy and management consequences will need to be carefully monitored and needs consensus of all participants before distribution.

iv. Taking up proposed solutions by policy makers on a Lake wide basis may take much more than the project can hope to achieve. Therefore, an important aim is to embed the project into larger fora (existing large projects like LVEMP, IFMP and institutions like LVFO) that are able to take up the results. It is therefore highly significant that these stakeholders at this stage already support this research programme.

v. The project may be viewed as "merely" a Tanzanian affair. This was pointed out during the preparation of the proposal as well as the stakeholder workshop. However, there are important scientific considerations to have all PhD's in one place, also given the limitations of the budget. Our explicit aim will be to define companion projects in Kenya and Uganda, within the framework of the institutions mentioned or companion institutes in these countries, in which related subjects or comparative work can be carried out.

vi. This programme will for the first time systematically address the position of the local fishermen and their perceptions of the fishery. Any solution focusing on management of the fishery will need insight in the decision-making strategies (and the variety in these) and the way in which the fishery is organized to address the real issues and to guarantee a fair distribution of benefits and costs of policy changes.

Specific Objective 1: contribute to elucidate conflicting views on the fisheries and water quality management of Lake Victoria		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Contribution to elucidate conflicting views on the fisheries and water quality management of Lake Victoria	1. Stakeholders acknowledge each others understanding of the ecosystem 2. Stakeholders value each others view and information base on the resource 3. Stakeholders can agree on main processes affecting the Lakes resources	1. Workshops 2. Dissemination and communication with people involved in the fishing industry
2. Insight in the dynamics and driving factors of the fishery in relation eutrophication will help to identify policy options	1. driving factors identified 2. causal chains identified 3. policy options identified	1. research 2. workshops 3. dialogue with stakeholders

Specific Objective 2: recommend solutions for short and long term ecosystem management of Lake Victoria on a local and regional level.		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Insights, knowledge on the conditions under which regime shift resulting in or from a Nile perch stock collapse could take place in relation to eutrophication and fishing	1a. Incorporation of insights and knowledge in monitoring instruments aimed at ecosystem management at relevant research institutions (e.g. TAFIRI and LVFO)	1a. PhD research and workshop with stakeholders; 1b. Promote Involvement of stakeholders in monitoring
2. Contribution to the development of monitoring instruments for ecosystem based management using insights in early warning signals indicating a potential regime shift in relation to eutrophication and fishing.	2a. Early warning signals related to ecological (increased variance in major indicators) or social (reaction to spatial changes or increased catch variance) defined.	2.a. PhD research and workshop with stakeholders; 2b. Promote Involvement of stakeholders in monitoring

Specific Objective 3: contribute to expanding insights gained from this project to relevant institutions in other riparian countries of Lake Victoria		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Additional (comparative, complementary) studies instigated in Kenya and Tanzania	1. At least two – four additional studies defined, funding acquired (on ecological modelling, e.g. fisheries ecology and management, aquatic ecology/limnology, and on aspects related to livelihoods, governance and/or international trade).	1. Development of proposals with relevant institutions in Kenya and Tanzania in co-operation with LVFO 2. Acquisition of funding

III. International (multi)stakeholder collaboration

a. Overall objective

Contribute to elucidate conflicting views on the fisheries and water quality management of Lake Victoria and propose solutions for short and long term ecosystem management on a local and regional level.

b. Assumption/risk

Specific Objective 1: Capacity building, training		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Training of students	1a. 2 DC and 2 Dutch PhD students trained 1b.16 MSc students trained – 6/8 DC	1a. PhD study 1b. MSc studies – Acquisition of funding
2. Training of TAFIRI staff	2a. TAFIRI staff trained (limnological analysis, fisheries data acquisition and management)	2a. On the spot training

Specific Objective 2: Networking		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Scientific co-operation	1a. New collaborative research projects defined	1a. Proposal writing parallel to planned workshops
2. Transdisciplinarity	2a Contribution to fisheries management policy based on less top-down networks and recent scientific results 2b. Public private partnerships established	2a. Stakeholders involved in research and in workshops. 2b. Contact industry and invite at workshops.

Specific Objective 3: Follow-up activities		
Expected main results (Max.2)	Quantitative and/or qualitative success factors	Activities/methods
1. Public-private partnership with e.g. ANOVA (Dutch fish Importer); NUTRECO (= Feed Industry); CARREFOUR.	1a. ANOVA is represented at project workshops 1b. Follow-up activities identified with ANOVA, NUTRECO and CARREFOUR	1a Workshops, discussions 1.b. Proposal development
2. Comparative and complementary studies instigated in Kenya, Tanzania and Uganda in co-operation with local and regional institutions	2. At least 2 additional studies defined, funding sought and acquired.	2a. Development of proposals with relevant institutions in Kenya and Tanzania in co-operation with LVFO 2b Acquisition of funding

12. Summary communication plan

I. Key stakeholder (scientific/non-scientific) involvement

Target group (TG)	Main objectives	Main results	Main activities and methods	Success factors
TG 1: Civil society organisations and EU, Worldbank Projects (LVEMP2, IFMP)	1a. Establish contacts between program with civil society organisations through ECOVIC (NGO's and CBO's) including BMU's 1b. Dissemination of research results	1a. Contacts established with civil society organisations in Tanzanian research regions. 1b. Research results known to civil society organisations	1.a Contract a local office (ECOVIC) for communication to riparian communities. 1 b. Invitation of key civil society organisations at workshops 1c. Local language flyers: project goals and methods, and 1d. results, and potential solutions.	1a. Key civil society members know about the project and 1b. take part in workshops 1c,d. Flyers printed and disseminated
TG 2: Processing industry:	2a. Industry uses is aware of the dangers of continued eutrophication for the fishing industry	2. Tanzanian Fish Processors Association, ANOVA address eutrophication in their communications on the sustainability of the fishing industry	1a, 1b, 1c and 1d. 2a. Contact industry together with consumers green label organisations 2b. Invite for project workshops	2a. Industry at workshops 2b. Industry considers sustainable NRM a market strategy.
TG 3a: Tanzanian research and management institutions TG 3b: Regional research and management institutions	3a. Involve and enhance the capacity of primary stakeholders in the management of the natural resource base 3b. Necessity to improve waste water management for fishing industry known	3a. LVFO considers eutrophication an issue affecting the fishery resource base 3b. Mwanza city Council and communities in LV watersheds Tanzania consider waste water quality also a fisheries issue.	1a, 1b, 1c and 1d. 3b. Invite for project workshops 3c. Send the scientific publications	3a. Representatives at project workshops. 3b. Fishery research approaches, policies of fisheries management and of management of eutrophication processes have changed.

II. International research collaboration (networks, platforms, institutions)

Target group	Main objectives	Main results	Main activities and methods	Success factors (Max.2 / objective)
LVFO, LVEMP 2, and VICRES (Lake Victoria Research Initiative, Inter University Council of East Africa)	1a. Contribution to development of monitoring tools 1b. Defining complementary research projects in Kenya and Uganda 1c. Contribution to integrated research program of the LVEMP2	1a. LVFO scientists conversant with results of the research program 1b. Embedding research program in research program project 1c. Complementary research projects defined 1d VICRES funding acquired (E50,000)	1a. Workshops, e-mails. discussions 1b/c. Discussions, proposal development 1d. Contact and proposal development	1a. Monitoring tools defined 1b/c. Proposals developed Close links between researchers on common themes Exchange of data and results 1d. Funding acquired
University of Waterloo, University of Bergen, other European Universities	1. Further development of long term research program on productivity of fisheries	1. Interest in research program by international research institutions (CGIAR, WorldFish) and scientific community (SIL)	1. Discussions at seminars workshops and conferences 2. Combined proposal development	1. Proposals developed and submitted (e.g. EU FP7)
International Scientific Org. dealing with great lakes research and management incl.: -UNESCO-IHE - Tanzanian, Kenya and Uganda universities and research institutes; - CGIAR institutes (WorldFish Center)	1. Scientific (peer) review of proposed methods and intended results of the current proposal 2. Contribution to international discussion on causes and consequences of the combined impacts of eutrophication and productivity changes in tropical great lakes 3. Information exchange PCLAKE modelling for Lake Victoria (UNESCO-IHE, MNP) Global Biodiversity Modelling project	1. Proposal reviewed 2. Awareness of research work carried out Contributions made (papers, presentations at international gatherings) 3. Collaboration with UNESCO –IHE, MNP	1. Presentation of project proposal at SIL meeting' special workshop of the GLFC (Great Lakes Fishery Commission) on the relation eutrophication and fisheries 2. Website with web logs of students (possibly a WIKI) 3. Contacts between scientists involved in both modelling efforts	1. Clarity on success factors / pitfalls of proposed methodology 2. website and web logs running and visited; contacts between scientists; information exchanged

III. Scientific output

Target group	Main objectives	Main results	Main activities and methods	Success factors (Max.2 / objective)
DC PhD students	1. To complete PhD studies	1. PhD study completed	1. See proposal by PhD study	1. 2 PhD studies successfully defended and published
Dutch PhD students	1. To complete a PhD studies	1. PhD study completed	1. See proposal by PhD study	1. 2 PhD studies successfully defended and published
MSc students	1. 4 MSc students trained per PhD	1. 16 MSc students trained	1. MSc students (DC and/or Dutch) enrolled at relevant courses of WU 2. Funding acquired for MSc students	1. - 16 MSc theses - 16 training programs successfully completed
Global Scientific community	1. Review and publication of research results 2. Information of global scientific community	1. Publication in double peer reviewed journals. 2. Posters, abstracts, oral presentations; the various PhD studies will have different audiences	1 Publication of research results in relevant scientific journals and at gatherings. 2.a Organise special sessions at international conferences (AEHMS, SIL, GLOW). 2b. Dedicated seminar on Lake Victoria at Wageningen University (final workshop)	1. 12 papers published in peer reviewed journals 2a. In total 16 presentations of research results by PhD and by associated senior staff in proceedings of int. conf.. 2b. Seminar proceedings published in a book

IV. Popular communication and dissemination

Target group	Main objectives	Main results	Main activities and methods	Success factors (Max.2 / objective)
Fishermen, Fishing communities, BMU's Fishing organisations Fish Producer Organizations, Local Government (Mwanza and relevant Lake districts)	1. Information of stakeholders 2. Dissemination of results	1. Relevant stakeholders informed	- Flyers in Swahili and English at district offices (each 1000 copies two sided full-colour); distribution in region; Text provided by team leader, adapted and edited by ECOVIC, printed in Lake region, distributed by ECOVICT - Full colour posters in Swahili and English at research site; composition research team and ECOVIC; printed etc. in NL. - Support of radio and television programs for awareness raising. - Organisation of thematic drawing/writing competition at primary schools in Participating Lake communities (The lake is important because . .) - Organisation of a one-day seminar in participating fishing communities - Presentation at global scientific seminars and publication in double refereed journals (research budget) - Preparation of radio and television programs together with ECOVIC	- Flyers printed and distributed - Posters printed and distributed - Radio program broadcasted - Drawing competition held, drawings published on website - Winning pieces published in newspapers, website
Stakeholders representatives and relevant policymakers in research areas	1. To embed the project in the local context and to obtain support and back-up from relevant stakeholder groups and policymakers for the project	1. Quarterly workshop at the research site; 2. Annual workshop with selected stakeholders and relevant policymakers (in co-operation with LVFO, IFMP and LVEMP) 3.Publication in booklets and in flyers for policymakers, stakeholders.	- Quarterly workshop at the research site; - Annual workshop with selected stakeholders and relevant policymakers (in co-operation with LVFO, IFMP and LVEMP	- Annual and quarterly workshops held and reported (on website)
The Netherlands/Global community	1. Information results Netherland & global scientific community	1. Awareness of LV problematic and solutions Neth./Blobal informed	- Website with web logs of students; possibly a WIKI - Quarterly electronic newsletter - 1 Newspaper article major Dutch Newspaper	- website and web logs running and visited -quarterly electronic newsletter running and read