Netherlands Foundation
For the Advancement of
Tropical Research

2004 *Please consult instructions and subsidy guide* **File number:**

Status:	**DC Fellowship - New Project**
1. **Applicant(s):** name and affiliation (not necessary to fill in address details again)	a. Marten Scheffer, Aquatic Ecology and Water Quality Management group, Wageningen University (Main applicant).
2. **Project title:** (including country in which the research will be carried out)	Effects of climate, nutrients and vegetation on the trophic cascade; a study of lakes along a latitudinal gradient in South-America
3. **Project outline:** (in case of subsidising the project, this description will be used in WOTRO yearbook and other WOTRO publications) Word count: 379	Freshwater of good quality is an increasingly limiting resource in the world. The majority of the water quality problems are related to high nutrient loading, which promotes excessive phytoplankton development. However, the risk of algal problems depends also on the potential of algal control through the food chain, the so-called 'trophic cascade'. Phytoplankton biomass can be kept low by zooplankton. However, when fish predation is strong, large-bodied zooplankters disappear and the zooplankton community structure shifts towards smaller-bodied species that are much less effective at controlling phytoplankton biomass. This insight is important as in temperate lakes it led to a novel way of water quality management called biomanipulation. It implies that fish density is reduced in order to promote an increase in the abundance of water fleas. Although it has been suggested that these insights may be used to fight excessive algal growth also in (sub)tropical lakes, there are indications that things work quite differently at lower latitudes. Our aim in this project is to find out how climate, nutrient load, and the presence of vegetation interact to affect the functioning of the trophic cascade at lower latitudes. We hypothesise that changes in the fish community structure occurring at warmer climates and at higher nutrient levels, reduce the average size of the zooplankton community implying a loss of top-down control of algae, which may be ameliorated by vegetation. To address our hypothesis we will sample 100 shallow lakes from Brazil to Argentina, and take sediment cores to reconstruct the history of a subset of them. We will use these data to analyse how climate (i.e. latitude) alters the way in which zooplankton community structure is related to the fish predation pressure and nutrient load. The results will help to understand the potential for biomanipulation as a way to control water quality changes with latitude. In addition, our envisioned results will provide an indication of the way in which climatic change may affect water quality and biodiversity of shallow lakes. Such lakes are the dominant lake type in most flat areas of the world including The Netherlands and large parts of the South American Continent. They are abundant in riverine and coastal zones where most of the population is concentrated, and intensively used for water supply, fish farming and recreation activities.

4.**Research environment**

a. Composition of the research group (indicate promotor):

- supervisor in the Netherlands
- supervisor in the country where the project is carried out:
- researcher:
- other researchers:

b. (optional) Participation in a Graduate School (´Onderzoekschool´)

Names and titles	Specialisations/universities	Financed by	Hours per week on the project
Prof. Dr. Marten Scheffer (Promotor and Supervisor in The Netherlands)	Aquatic ecology/ Wageningen University NL	WUR	4
Dr. Danilo Calliari (Supervisor in Uruguay)	Zooplankton trophic ecology/Faculty of Sciences. Universidad de la República, Uruguay	UdelaR	4
MSc. Gissell Lacerot (Researcher)	Zooplankton ecology/ Faculty of Sciences. Universidad de la República, Uruguay	UdelaR	36

	Dr. Néstor Mazzeo	Shallow lakes Aquatic Ecology/ Faculty of Sciences. Universidad de la República, Uruguay	UdelaR	1
	Dr. Felipe García-Rodríguez	Paleolimnology/ Faculty of Sciences. Universidad de la República, Uruguay	UdelaR	1
	Prof. Dr. André F. Lotter	Paleolimnology/Utrecht University NL	UU	1
	Prof. Juan César Paggi	Zooplankton taxonomy and ecology/National Institute of Limnology. Santo Tomé, Santa Fé, Argentina	INALI	1

5. **Previous** file number: (only in case of renewed application	none
6. Type and duration project: a. Type (PhD/Post-doc): b. Duration of the project: **c**. Proposed starting date:	 PhD project 4 years July 2004
7. **Detailed description of the project** including at least the following aspects: a. scientific significance/ innovative aspects b. hypothesis/research question c. research methodology d. history of the project e. co-operation with other national and international universities/research groups f. quality of formal institutional linkages with (inter)national policy making groups, NGO´s. Word count: 3475	Freshwater of good quality is an increasingly limiting resource in the world and South America is not an exception. Just like in temperate lakes, the majority of the water quality problems are related with an excessive nutrient loading. This does not only stimulate planktonic algae (phytoplankton) growth, but also produces a cascade of ecological effects resulting in strongly impoverished biodiversity of aquatic plants, invertebrates, fish and birds (Scheffer, 1998), not to mention the deterioration of the quality of water for human use. The proposed study focuses on shallow lakes, which are the dominant lake type in most flat areas of the world where they are closely linked to human societies. They are abundant in riverine and coastal zones where most of the population is concentrated, and intensively used for water supply, fish farming and recreation activities. They are also richly diverse habitats, with enormous importance for nature conservation. **The trophic cascade in temperate lakes** In addition to nutrient control, the indirect effect of fish on algae known as **'the trophic cascade'** has become one of the key-mechanisms to control excessive development of phytoplankton in temperate shallow lakes. Zooplankton filters the water, controlling phytoplankton biomass. Especially large bodied species such as those from the genus *Daphnia* ("water fleas") are tremendously effective in exerting this top-down control and their presence in a sufficient number can significantly increase water transparency. However, when fish predation is strong, these large-bodied zooplankters are the first ones to disappear and the zooplankton community structure shifts towards smaller-bodied species that are much less effective at controlling phytoplankton biomass (Brooks & Dodson, 1965). An application of this insight in temperate lakes is to reduce fish density in order to promote an increase in the abundance of water fleas, which then filter the water clear of phytoplankton, so-called "biomanipulation" (e.g. Lammens *et al*., 1990). Excessive **loading with nutrients** (**eutrophication**) does not only stimulate algal growth directly, but has also an indirect effect as it affects the trophic cascade (Jeppesen *et al*., 1996a). In shallow eutrophic lakes the high productivity leads to an increase in the flow of organic material to the sediments. This organic matter represents a food source for a wide variety of small animals including fish, which uses it as an alternative choice. This boosts fish biomass, which indirectly hammers back on the Daphnia, as all new-born fish focus on these

water fleas as food. Thus top-down control of algae by zooplankton is usually weak in such lakes, and as a result nothing stops the abundant algal growth stimulated by the high nutrient levels.

A particularly important factor affecting the trophic cascade in temperate shallow lakes is the presence of **submerged vegetation** (Timms and Moss, 1984; Scheffer, 1998). Although the situation may vary depending on the vegetation density and the fish-species involved, aquatic macrophytes act as a refuge for large zooplankton, thus reducing the cascading effect of planktivorous fish.

Why the trophic cascade may work differently in warm climates

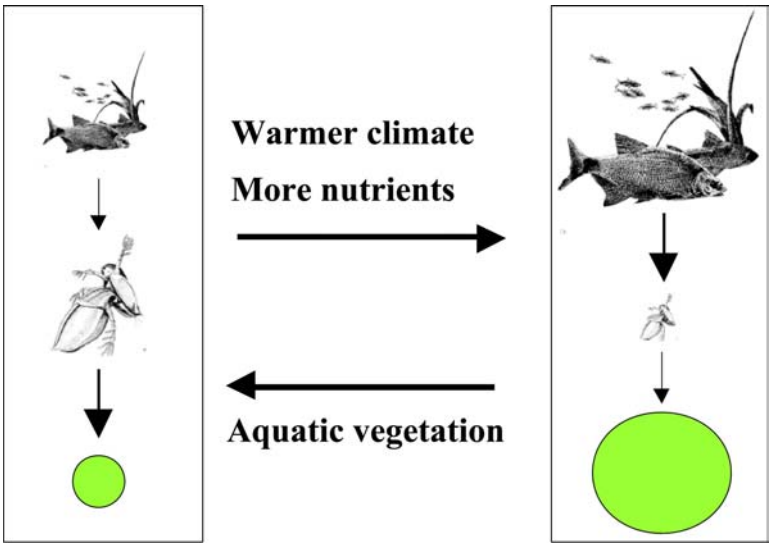
There are several indications that the trophic cascade theory developed for temperate lakes cannot be simply applied to (sub)tropical lakes. Recently, attention has been focussed on the observation that zooplankton species in tropical lakes and ponds are generally much smaller than in temperate zones and in particular large herbivorous zooplankton of the genus *Daphnia* seem less diverse or even absent at lower latitudes (Dumont, 1994; Gillooly & Dodson, 2000). As a consequence, chances for an effective top-down control over phytoplankton are likely to be diminished at lower latitudes (Crisman & Beaver, 1990; Fernando, 1994; Lazzaro, 1997; Pinel-Alloul *et al.* 1998). Several possible explanations have been suggested for the observed pattern. It could be related to a lower-upper thermal tolerance of these organisms (Moore *et al*., 1996). However, this explanation is flawed by laboratory experiments showing that large *Daphnia* are rather tolerant to high temperatures (Mitchell & Lampert, 2000). Another factor that could be involved is the quality of food for *Daphnia*, which may decrease towards lower latitudes as the relative share of cyanobacteria may increase at higher temperatures (e.g., Weyhenmeyer, 2001). Also, this seems unlikely to be the main explanation of the latitudinal gradient in top-down control as many low-latitude lakes are not dominated by cyanobacteria, but still lack large *Daphnia*. Probably the most important current hypothesis for explaining the lack of large *Daphnia* in tropical lakes is that the systematic shifts in the fish community with latitude are the key. In temperate regions most fish reproduce only once a year, leaving a period in spring in which there are few small (and hence planktivorous) fish, allowing large zooplankton to become abundant and filter the water clear of phytoplankton (Sommer *et al*., 1986). By contrast, many fish species at low latitudes reproduce more-or-less continuously (Fernando, 1994; Lazzaro, 1997; Pinel-Alloul *et al*., 1998) resulting probably in a continuously high predation pressure by young fish on zooplankton. There are many other aspects in which the ecology of the small omnivorous fish that dominate low latitude lakes differs from that of the relatively large cyprinids and other species that typically dominate eutrophic temperate lakes. This casts doubt on whether the large effects of nutrients and aquatic vegetation on the trophic cascade observed in temperate lakes will occur in low latitude lakes in a similar way.

Scientific significance of filling the knowledge gap

Despite an increasing interest in the functioning of low latitude lakes, (sub)tropical lakes are still poorly understood. Indeed, all of the hypothesised explanations of the lack of top-down control of algae in warm regions we discussed are based on local observations or reviews of existing literature. The systematic study of the trophic cascade in lakes along a large latitudinal gradient we propose is a novel and potentially powerful way to address these knowledge gaps. Resolving these questions is important, not only because water quality problems are severe in many of the systems we will study in South America, but also because the study of these lakes may help making a better prognosis of the potential effects of climatic change on temperate lakes.

Hypothesis and research questions

Our central hypothesis is that an increase in average temperature and nutrient level produce systematic changes in fish community leading to a reduction in the average size of zooplankton and a weakening of top-down control of phytoplankton, which can be ameliorated by the presence of aquatic vegetation.



This central hypothesis translates into five specific research questions:

1. Does the average body size of zooplankton (and in particular the cladocerans) diminish along the *climatic gradient* from temperate to tropical systems?
2. Does variation in the abundance of *planktivorous fish* along a latitudinal gradient explain much of the variation in zooplankton size structure?
3. Does the effect of *nutrient level* on apparent fish predation pressure on zooplankton change along the climatic gradient?
4. Does the effect of *vegetation cover* on apparent fish predation on zooplankton change along the climatic gradient?
5. Do fish kills induced by extreme meteorological events such as droughts have *cascading effects* on zooplankton size and phytoplankton biomass in low latitude lakes, as they do in temperate lakes?

Research methodology

We will address our hypothesis by analysing indicators of the state of the trophic cascade in a set of 100 lakes with different nutrient levels over a latitudinal gradient from Brazil to Argentina. In addition, we will use sediment cores from a subset of 10 lakes to reconstruct the history of variations in the state of the cascade in relation to changes in environmental conditions (Brodersen *et al*., 1998; Brendonck & De Meester, 2003).

Our approach may seem rather ambitious, but may in fact be realized as we will combine with an (already funded) parallel WOTRO project (W 84-549) starting in 2004 with a sampling program of the same lakes. Although this project will only formally start in next year, we have informally started preparations and enlarged the research team by setting up an informal network of five research groups along the latitudinal gradient of lakes who are eager to cooperate. We have had a first meeting at which we agreed on a data sharing protocol and a relatively extensive sampling schedule. The idea is that the PhD candidates of the parallel WOTRO project (W 84-549) and the project proposed here will have a strong data set to address their research hypotheses, while additional samples and information collected on this unique opportunity will be analysed by the various groups involved.

We will do the census in two periods. First we will sample from Montevideo southwards starting December 2004. Then we will sample from Rio de Janeiro northwards starting in July 2005 (see map at the end of the proposal). The two envisioned PhD students will be present at all samplings, but will be helped by local teams at all locations. Long distances are travelled by air. We will have one protocol, and except for the car and boat, we will use one set of equipment for all sampling.

We will collect information along two lines:

1. A one-time mid-summer **census** of the state and basic properties of a selected set of about 100 lakes.
2. Sediment **cores** of a representative subset of 10 of the censused lakes.

The census (1) of lake states will follow in short the following protocol. At each lake we will measure a temperature profile and take a top 5 cm sediment sample in the middle. Then the lake will be sampled along two perpendicular transects that run from one shore to the other. Each transect has 5 equidistant sampling points. At each point we will: Measure in situ: depth, Secchi depth, K_d, Chl-*a* (fluorescence), turbidity, oxygen; Collect 25 l water from throughout the water column with a 1m tube; Sample the sediment with a rake for macrophytes at 5 points around the boat. The 25 l water sample is then put in one of two containers depending whether macrophytes were present or absent so when the sampling is finished we will have two big containers with pooled water samples from each transect. We mix the containers and determine pH, conductivity, alkalinity. We then take from each container: 200 ml which we acidify for fixation to determine in the laboratory total-P and total-N; 200 ml fixed with lugol for phytoplankton identification and counting; We then filter an appropriate volume for suspended solids (SS) and inorganic SS determination. Filters will be kept cold and dried in the laboratory. Finally we filter 100 l water over a sequence of 60 micrometer and 20 micrometer sieves for zooplankton, which is preserved in 4 % formaldehyde. Fish will be sampled by means of 10 remote control jump traps as used at NERI in Denmark, placed in different habitats. The fish will be identified, measured, weighed and counted. We also make a digital picture of the catch, spread out on a board with scale raster.

Sediment cores (2) will be taken in a sub-set of 10 representative lakes. We will collect the top 2 meters from the centre of the lakes using a Livingstone core with piston system. In order to keep the work feasible within the current project we will focus on the analysis of zooplankton remains in the cores. The parallel project will take care of dating the cores (^{210}Pb and ^{137}Cs) and using simple chemical indicators for reconstructing macrophyte dominance and other aspects of lake state. Although, this does not have the resolution of a full paleolimnological approach, it will likely produce good hints on major changes in the lakes. For instance, work on Lake Apopka (Florida USA) which switched from clear to turbid half a century ago has demonstrated that the C/N ratio adequately indicates whether the lake was clear and vegetated or turbid and phytoplankton dominated (Schelske, 1999). The analysis of zooplankton remains in sediment records will only provide a qualitative picture of changes in fish predation pressure, this is because different zooplankton species are not deposited and preserved in the sediment in the same proportion as they appear in the lake water (Leavitt *et al*., 1994). Therefore we need transfer functions, which are equations describing the relationship between surface sediment samples of recent biological remains (zooplankton in this case) with the corresponding contemporary data on the variable of interest (e.g. fish biomass and nutrients) from a set of lakes (Jeppesen *et al*., 2001). To produce these functions we will analyse the top sediment samples of the 100 lakes and link the results to those of the census (1). Note that many more aspects (diatoms, pollen etc.) could be analysed from the cores. Although we expect to obtain important information from our superficial approach we will seek additional funding for a thorough analysis of the cores.

Analysis of samples will follow standard procedures. Zooplankton, which is our major focus, will be counted in aliquots following Paggi & De Paggi (1974) criteria. Zooplankton abundance will be expressed in organisms per litre. A minimum of 50 individuals of each species of microcrustaceans (copepods and cladocerans) will be measured to estimate its biomass using length/weight regressions published by McCauley (1984) and Bottrell *et al*. (1976). The most common rotifer species biomass will be obtained using Ruttner-Kolisko`s (1977) approach. Transfer functions for interpreting paleontological data will be obtained by calculating

zooplankton community optima (in abundance, biomass and size) in relation with planktivorous fish using weighted average regression and inverse deshrinking regression. In this way we will obtain the prediction formulas for estimating planktivorous fish biomass and abundance. The same procedure is going to be followed for the rest of the possible structuring variables. For the quantification of the zooplankton remains in the sediment, an aliquot will be processed according with Jeppesen *et al*. (1996b) method and the minimal number of individuals represented for each taxa calculated following the method of Frey (1986).

The research questions will be addressed using the two sets of data (*recent* from census and *palaeontological* from cores) in a complementary way (see schematic representation below). Changes in size structure of zooplankton with climate (question **1**) may be verified in a straightforward way from the set of recent data, but should also be reflected in the subfossil zooplankton communities found in the cores. Our (recent) fish data will be used in conjunction with the indicators of zooplankton size structure to address research question **2**. The hypothesized effect of nutrient level on the trophic cascade (question **3**) will be analysed from the recent data by checking how fish abundance and zooplankton size structure changes with total-P, and other indicators of nutrient level (including sediment) in our temperate versus low latitude lakes. The palaeontological data offers an interesting other cut at the same question, as they will allow us to reconstruct how apparent predation pressure (derived from zooplankton community structure) shifts during the eutrophication process at different latitudes. Similarly, we will be able to use both recent and palaeontological data to check if the effect of aquatic vegetation on the trophic cascades is reduced at lower latitudes (question **4**), as sharp shifts between vegetation dominated and vegetationless states which tend to occur in such lakes can be reconstructed well from sediment cores. Finally, the palaeontological data will allow us to scan for cascading effects of possible fish kills induced by extreme meteorological events at different latitudes (question **5**). Such kills due to desiccation of lakes or anoxia can be considered natural biomanipulation experiments, and may give us a clue to differentiate between (sub)tropical and temperate lakes responses to biomanipulation as a management measure.

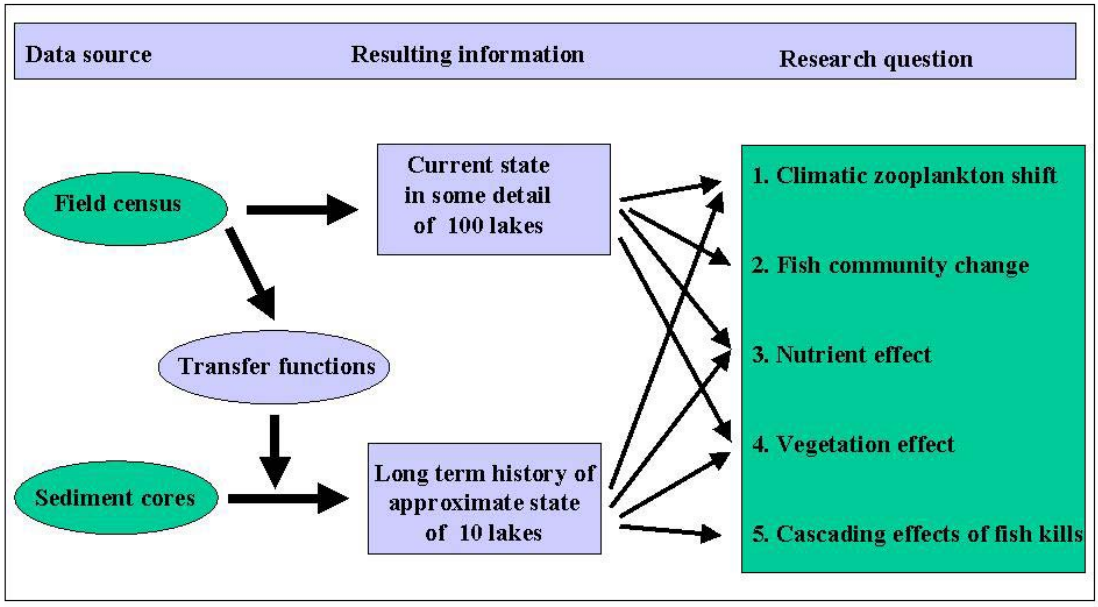


Illustration of the flow of information in the project. Transfer functions derived from the field census data are needed to interpret the sediment cores. The resulting two sets of information allow complementary approaches to three of the five research questions, while two remaining questions need to be answered from either recent or palaeo data.

History of the project and co-operation with other research groups

In 2002 Dr. Marten Scheffer travelled to Uruguay to give a course on the stability and restoration of shallow lakes. During this course several ideas for future co-operation on

research appeared. As a follow-up, the proposed researcher, Gissell Lacerot did an MSc with the Aquatic Ecology Group in Wageningen. This proposed project would allow Miss Lacerot to continue the central line of work started during her visit to The Netherlands. Importantly, the project would be conducted in co-ordination with two ongoing WOTRO projects of the Montevideo Faculty of Sciences and the Wageningen group (W 84549 and W 8455). This implies not only an efficient use of data, as outlined above, but also a connection to groups working on paleolimnology and other important expertise areas involved in the parallel projects. In particular, the Faculty of Sciences group has a history of collaboration with Xavier Lazzaro who is a specialist on Brazilian lakes and Dr. Vera Huszar, phytoplankton ecologist. The inclusion of these important researchers in the team ensures good access to the information needed and an efficient selection of the lakes. Moreover, we have already ensured the collaboration of other important experts in South America such as Dr. Felipe García-Rodríguez (paleolimnology) from the Limnology Section of the Faculty of Sciences Montevideo, Uruguay and Prof. Juan C. Paggi (zooplankton taxonomy and ecology) from the National Institute of Limnology, Santo Tomé, Argentina.

Institutional linkages with (inter)national policy making groups, NGO´s

The research group through the Faculty of Sciences of the Universidad de la República has formal institutional linkages with the main policy groups of the country. With the Minister of Environment, the National Environment Direction, the National Direction of Aquatic Resources and the Municipalities of Montevideo, Maldonado and Rocha, where the Uruguayan lakes object of study are located. The Faculty of Sciences group is also connected to UNESCO through financed projects and to regional NGO´s: Vida Silvestre (Uruguay)

References

Bottrell, H. H., Duncan, A., Gliwicz, Z. M., Grygierek, E., Herzig, A., Hillbricht-Ilkowska, A., Kurasawa, H., Larsson, P. & Weglenska, T. 1976. A review of some problems in zooplankton production studies. *Norw. J. Zool.* 24: 419-456.

Brendonck, L. and De Meester, L. 2003. Egg banks in freshwater zooplankton: evolutionary and ecological archives in the sediment. *Hydrobiologia 491: 64-84*

Brodersen, K. P., Whiteside, M. C. and Lindegaard, C. 1998. Reconstruction of trophic state in Danish lakes using subfossil chydorid (Cladocera) assemblages. *Canadian Journal of Fisheries and Aquatic Sciences 55: 1093-1103*

Brooks, J.L. and Dodson, S.I. 1965. Predation, body size, and composition of plankton. *Science. 150: 28-35.*

Crisman, T.L., and J.R. Beaver. 1990. Applicability of planktonic biomanipulation for managing eutrophication in the subtropics. *Hydrobiologia 200/201: 177-185.*

Dumont, H.J. 1994. On the diversity of the Cladocera in the tropics. *Hydrobiologia 272: 27-38*

Fernando, C.H. 1994. Zooplankton, fish and fisheries in tropical freshwaters. *Hydrobiologia 272: 105-123.*

Gillooly, J.F., and S.I. Dodson. 2000. Latitudinal patterns in the size distribution and seasonal dynamics of new world, freshwater cladocerans. *Limnology and Oceanography 45: 22-30.*

Jeppesen, E., Leavitt, P., De Meester, L. and Jensen, J. P. 2001. Functional ecology and paleolimnology: using cladoceran remains to reconstruct anthropogenic impact. *Trends in Ecology & Evolution 16(4): 191-198.*

Jeppesen, E., M. Søndergaard, J. P. Jensen, E. Mortensen, and O. Sortkjaer. 1996a. Fish-

induced changes in zooplankton grazing on phytoplankton and bacterioplankton: a long-term study in shallow hypertrophic Lake Søbygaard. *Journal of Plankton Research 18:1605-1625.*

Jeppesen, E., Madsen, E. A. And J, J. P. 1996b. Reconstructing the past density of planktivorous fish and trophic structure from sedimentary zooplankton fossils: a surface calibration data set from shallow lakes. *Freshwater Biology 36: 15-127.*

Lammens, E.H.R.R., Gulati, R.D., Meijer, M-L. and Van Donk, E. 1990. The first biomanipulation conference: a synthesis. *Hydrobiologia 200-201: 619-628.*

Lazzaro, X. 1997. Do the trophic cascade hypothesis and classical biomanipulation approaches apply to tropical lakes and reservoirs? *Verh.Int.Ver.theor.angew.Limnol. 26: 719-730.*

Leavitt, P.R., P.R. Sanford, S.R. Carpenter, and J.F. Kitchell. 1994. An annual fossil record of production, planktivory and piscivory during whole-lake experiments. *J. Paleolimnol. 11: 133-149.*

McCauley, E. 1984. The estimation of the abundance and biomass of zooplankton in samples. In: Downing, J. A. and F. H. Riegler (eds.), *A manual on Methods for the Assesment of Secondary Productivity in Fresh Waters,* Blacwell Scientific Publications, Oxford, London: 228-265.

Mitchell, S.E., and W. Lampert. 2000. Temperature adaptation in a geographically widespread zooplankter, *Daphnia magna*. *Journal of Evolutionary Biology 13: 371-382.*

Moore, M.V., C.L. Folt, and R.S. Stemberger. 1996. Consequences of elevated temperatures for zooplankton assemblages in temperate lakes. *Archiv für Hydrobiologie 135: 289-319.*

Paggi, J.C. and De Paggi, J. 1974. Primeros estudios sobre el zooplancton de aguas lóticas del Paraná Medio. *Physis (secc. B).* 33: 94-114.

Pinel-Alloul, B., A. Mazumder, G. Lacroix, and X. Lazzaro. 1998. Lake trophic food webs: Structure, function, interactions and spatio-temporal variations. *Revue des Sciences de l'Eau 11: 163-197.*

Ruttner-Kolisko, A. 1974. Plankton rotifers. *Binnengewässer Suppl. No. 26. Pp. 1-126.*

Scheffer, M. 1998. Ecology of Shallow Lakes. Chapman and Hall. London

Sommer, U., Gliwicz, Z.M., Lampert, W., & Duncan, A. 1986. The PEG-model of seasonal succession of planktonic events in freshwaters. *Archiv für Hydrobiologie 106: 433-471.*

Timms, R. M., and B. Moss. 1984. Prevention of growth of potentially dense phytoplankton populations by zooplankton grazing in the presence of zooplanktivorous fish in a shallow wetland ecosystem. *Limnology and Oceanography 29:472-486.*

Weyhenmeyer, G.A. 2001. Warmer winters: Are planktonic algal populations in Sweden's largest lakes affected? *Ambio 30: 565-571.*

8.**Detailed description of the relevance of the project for development of the country involved, including at least the following aspects:** a. usefulness of expected results for sustainable development, poverty alleviation, environmental control and the position of women; b. scientific capacity building; c. plans for dissemination of research results in scientific circles d. plans for dissemination of research results in policy circles; e. plans for dissemination of research results in other stakeholder circles. Word count: 526	**Usefulness of expected results** The population in the coastal planes of South America and its water consumption has increased rapidly over the past years, while the quality of aquatic resources is declining. Due to the absence of adequate management many aquatic systems have already been severely affected by pollution. Also, the hydrologic regime has been altered through water extraction, soil erosion and mechanical modifications. Many of those alterations act in concert to promote the development of nuisance algal blooms with detrimental consequences for human utility of these lakes. The results obtained will help to design strategies for algal control based on techniques used for temperate lakes, but tailored to (sub)tropical lakes. In addition the results will allow a glimpse of how climatic warming may affect top-down control of algal biomass. This project will also constitute an important contribution to the study of the zooplankton community diversity in lower latitude aquatic systems and especially in Uruguay were few zooplankton studies have been carried out. **Scientific capacity building** This project will allow the proposed researcher (Gissell Lacerot) to become a full expert in these important fundamental aspects of water quality research. In particular, the paleolimnological approach she will take, although a promising line of work in other countries, has no examples in Uruguay yet. On a more general level the project will contribute to the institutional scientific capacity building as it will give a boost to the young research group of the Limnology Section in the Sciences Faculty which was set-up only in 1996. Capacity building has always been an important focus of the group, and the courses organised by the Limnology Section and given by renown European scientists over the past years have already had a large impact on the quality of research in Uruguay and the neighbouring countries. We feel confident that this project which offers very good opportunities for participation by undergraduate students will add to the growing momentum of scientific capacity building. Along with the development of this work at least two undergraduate student thesis will be produced. Finally, this project will constitute an important contribution to the creation and strengthening of academic networks within South American and between South American and European groups as well as the implementation of databases for South American lakes and complementation of existing databases for European lakes. **Plans for dissemination of research results to policy and stakeholders** The Uruguayan research group has an excellent track record of being in close touch with local and national water quality authorities, as well as with other stakeholders such as drinking water companies and fisherman. The results will be disseminated through this vital network. Also, we aim to publish the key results of this research in general public magazines to promote non-formal dissemination of results. In addition, the results will be combined in a larger ongoing project along with information about other organisms, biodiversity, geography, hydrology and human activities in a GIS (geographical information system) that will be designed for easy access and use. In this system, using multicriteria decision aid the possible alternatives can be evaluated in terms of multiple non-commensurable criteria invoking different stakeholders with conflicting preferences for environmental planning.
9. How and where will the results of the project be **published:**	The results will be published as a Dutch style thesis containing the combined results and a general discussion, and also in peer reviewed journals and electronically. The journals included will be international: Journal of Plankton Research, Limnology and Oceanography, Trends in Ecology and Evolution, Journal of Paleolimnology

10. **Information on proposal development and history of the collaboration between the research groups involved**

(joint publications, joint supervision of projects)

The present proposal is inserted in an emerging network for cooperation in scientific research, which involves different institutions and representatives from Europe and South America. This network has been built during at least four-years of academic exchanges.

During the 8th International Conference of Sustainable Lake Management in Denmark in 1999, Dr. Nestor Mazzeo met Prof. Erik Jeppensen (University of Aarhus-NERI-Denmark), Prof. Marten Scheffer (University of Wageningen-The Netherlands) and Dr. Christina Branco (Universidad do Rio de Janeiro-Brazil). In this meeting, the group discussed the possibility of initiating an academic and research exchange programme focused on the principal differences in the structural and functional attributes of shallow lakes between tropical and temperate zones.

At the end of 2000, Prof. Scheffer lectured a postgraduate course entitled *Stability of alternative equilibria in shallow lakes and restoration implications* in Montevideo, Uruguay. In this activity, students from both Uruguay and Argentina participated. During this course several ideas for future co-operation on research appeared. As a follow-up, the proposed researcher, Gissell Lacerot did an MSc with the Aquatic Ecology Group in Wageningen financed by NUFFIC from The Netherlands.

During 2001, Prof. Vera Huszar (Universidad Federal de Rio de Janeiro-Brazil) visited Uruguay to take part in the examination committee of the MSc. Thesis: *Phytoplankton succession in a shallow lake under restoration* by Carla Kruk. Prof. Huszar actively joined the incipient network of combined Latin American and European Institutions. All the network members maintained an intense email exchange during 2001 to define the main research goals of the groups, the academic exchange programme and the potential sources for financial support.

During 2003 at the VIII Limnology Congress in Brazil, most of the Latin American members of the network got together and discussed the implementation of the objectives for the WOTRO proposal: “Climate induced shifts in South American Lake Ecosystems: Threats and Novel Restoration Perspectives (WOTRO 84-549), where the present proposal is inserted. **(see “Scientific networks in the local research area” for a list of the South American researchers involved)**

11. **A time table of the project:**
(per year and in months)

2004	**j**	**f**	**m**	**a**	**m**	**j**	**j**	**a**	**s**	**o**	**N**	**d**
Short visit to The Netherlands to collect relevant literature and finalise work plan							X					
Select the 100 lakes that will be sampled and collect existing data on relevant lakes								X	X	X		
Training and set of zooplankton remains analysis techniques								X	X			
Meeting in Montevideo with European and South American partners								X				
Test sampling of Uruguayan lakes										X	X	
Field sampling of southern loop lakes (see map)												X
2005	**j**	**f**	**m**	**a**	**m**	**j**	**j**	**a**	**s**	**o**	**N**	**d**
Field sampling of southern loop lakes (see map)	X	X										
Field sampling of northern loop lakes (see map)						X	X	X				
Analysis of the zooplankton water samples for the census database			X	X	X				X	X	X	
First undergraduate student project related to zooplankton diversity									X	X	X	X
Preparation of **manuscript 1**												X
2006	**j**	**f**	**m**	**a**	**m**	**j**	**j**	**a**	**s**	**o**	**N**	**d**
Preparation of **manuscript 1**	X	X										
Analysis of zooplankton remains in sediment samples for calibration and construction of the transfer functions			X	X	X	X						
Visit to The Netherlands for data analysis and preparation of **manuscript 2**							X	X				