EAGLES and COBAFISH Follow-up Committees (March 27th, 2013)
Programme

Place of venue:
Offices of the Belgian Science Policy
Louizalaan 231 Avenue Louise
1050 Brussel | Bruxelles
Rooms A and B

Agenda:

9h30 – 12h00: EAGLES

Invited experts: M. Schmid (Eawag, Switzerland), P. Servais (ULB), K. Muylaert (UGent)

9h30 – 9h40 Introduction: Objectives, teams and work packages (J.-P. Descy)
9h40 – 12h15 Main results of the WPs
(5 or 10 min of presentation followed by 5 min of discussion)

WP1 Exploitation of existing data

- **9h40-9h50** Database, data mining and data management (A.V. Borges)

WP2 New data acquisition and WP4 Statistical data analysis

- **9h50-10h05** Mixolimnion monitoring and statistical data analysis (F. Darchambeau)
- **10h05-10h15** Update on remote sensing (Y. Cornet)
- **10h15-10h25** Fish surveys and fisheries (J.-P. Descy)
- **10h25-10h40** Carbon pathways through the planktonic food web (S. Bouillon, C. Morana)
- **10h40-10h55** Carbon and nutrient cycling (A.V. Borges, F. Darchambeau)
- **10h55-11h10** Sediment cores (S. Bouillon, E. Verleyen, L. André, C. Delvaux)

WP3 Laboratory studies

- **11h10-11h20** Diatom cultures, nutrient and light requirement, Si isotopic fractionations (E. Verleyen, L. André)

WP4 Modeling

- **11h35-11h50** Climate simulations (W. Thiery)
- **11h20-11h35** Lake hydrodynamic and ecological simulations (F. Darchambeau)

11h50 Discussion and outcomes

12h15 – 13h00: Lunch

13h00 – 16h30: COBAFISH

Invited experts: K. Muylaert (UGent), Gilles Lepoint (ULg)

13h00 – 13h10 Introduction: Objectives, teams and work packages (E. Verheyen)
13h10 – 15h25 Main results of the WPs
(10 or 15 min of presentation followed by 5 min of discussion)

WP1 Carbon sources, cycling and aquatic metabolism

- **13h10 – 13h30** Carbon reservoirs, source of carbon and metabolism (A.V. Borges, S. Bouillon, F. Darchambeau, C. Teodoru)
- **13h30 – 13h45** Si sources and contributions of diatoms to primary production (L. André)

WP2 Aquatic floral and faunal diversity

- **13h45 – 14h00** Diversity and abundance of aquatic primary producers (C. Cocquyt, F. Darchambeau)
- **14h00 – 14h15** Utility of the DNA barcoding approach to increase the speed of reliable taxonomic identification in fishes of the Congo Basin (E. Verheyen)
- **14h15 – 14h30** Diversity of fish community (J. Snoeks, T. Moelants, E. Verheyen)

WP3 Ecosystem trophic structure

- **14h30 – 14h45** Fish stomach content analysis (T. Moelants)
- **14h45 – 15h00** Isotopic food web analysis (S. Bouillon)

15h00 Coffee break
15h30 Discussion and outcomes

Projet East African Great Lakes Sensitivity to changes (EAGLES)

Compte-rendu de la réunion du Comité de pilotage local – Gisenyi 7 juillet 2011

Etaient présents :

Alberto V. Borges (Université de Liège, Belgique), François Darchambeau (Université de Liège, Belgique), Tamara Garcia Armisen (Université Libre de Bruxelles, Belgique), Marie Herman (Katholieke Universiteit Leuven, Belgium), François Laenen (Université de Liège, Belgique), Marc Llirós Dupré (Facultés Universitaires Notre-Dame de la Paix, Belgique), Patrick Mambo-Leo (Coordinateur/ECN Sud-Kivu, RD Congo), Pascal Masilya (Institut Supérieur Pédagogique de Bukavu, RD Congo), Rose Mukankomeje (Rwanda Environment Management Authority, Rwanda), Jean-Claude Ndorimana (Ministry of Agriculture and Animal Resources, Rwanda), Léonce Ngirinshuti (Université Nationale du Rwanda, Rwanda), Laetitia Nyina-wamwiza (National University of Rwanda, Rwanda), Jean-Yves Saliez (Coopération Technique Belge, Rwanda), Natacha Tofield Pasche (Rwanda Ministry of Infrastructure, Rwanda), Parfait Yongabo (Université Nationale du Rwanda, Rwanda), Diego Zurdo (Délégation Union Européenne, Rwanda)

1. Présentation du projet

François Darchambeau ouvre la réunion du Comité de pilotage à 10h30 par une brève présentation du projet EAGLES. Celle-ci détaille les partenaires du projet, en donne les objectifs et détaille les différentes tâches du projet.

2. Membres du Comité de pilotage local

Rose Mukankomeje propose que le Comité de pilotage local soit renforcé par la présence d'un représentant de la Direction générale de la Recherches et/ou du Climate Change Observatory du Ministère de l'Education. De même, Pascal Masilya propose de renforcer le Comité de pilotage par la présence d'un représentant de l'Inspection Provinciale de l'Agriculture du Sud-Kivu et du Nord-Kivu.

3. Fonctionnement du Comité de pilotage local

Certains membres présents du Comité de pilotage regrettent de ne pas mieux connaître le projet, au-delà de la présentation qui en a été faite. Il est ainsi proposé d'envoyer la description complète du projet à tous les membres du Comité de pilotage. De même, le rôle précis des membres du Comité de pilotage devrait être précisé au sein de termes de référence et d'un plan d'action.

4. Transfert des résultats du projet aux gestionnaires locaux

La discussion poursuivie permet de mettre en évidence les retombées potentielles du projet pour les gestionnaires locaux. Natacha Tofield Pasche insiste pour que le projet donne accès à l'ensemble des résultats obtenus pendant le projet. Il est rappelé que ce point fait l'objet du deliverable 2.1 du projet.

Il s'avère que des résultats sont principalement attendus par les gestionnaires locaux dans le domaine de la pêche. Ainsi, le projet devrait pouvoir aider à définir les quotas de pêche de l'espèce *Limnothrissa miodon* pour les deux pays riverains. De même, une meilleure prévisibilité de l'importance des stocks est attendue en fonction de la production planctonique annuelle, ce qui pourrait permettre une meilleure préparation des campagnes de pêche.

Cependant, plusieurs difficultés liées au domaine de la pêche apparaissent, dont l'absence de coordination des politiques à l'échelle régionale et l'absence de collecte de données fiables sur les résultats des pêcheries. Bien que le projet EAGLES ne vise pas à proposer des solutions pour résoudre ces deux points, les experts du projet pourraient néanmoins aider à mettre en place, avec les autorités locales, les procédures et les outils permettant le développement de ces politiques.

5. Suivi du Comité de pilotage et recommandations

Le Compte-rendu de cette réunion, de même qu'une copie de la présentation faite et du projet écrit, seront envoyé à tous les membres du Comité de pilotage. Des termes de référence et un plan d'action pour le Comité de pilotage sera élaboré par le coordinateur du projet, en accord avec les partenaires. Il est également suggéré qu'à l'avenir les réunions du Comité de pilotage aient des thématiques/objectifs définis à l'avance et seulement les membres du Comité de pilotage pertinents à ces thématiques/objectifs soient convoqués. De par les discussions qui ont eu lieu le 7 juillet 2011, les thématiques/objectifs suivants ont été identifiés :

- Exploitation du gaz CH4
- Ressources halieutiques et pêcherie

- Changements climatiques et écologiques

Les 2 partenaires locaux (ISP – RDC & UNR – Rwanda) identifieront l'ensemble des entités locales et les thématiques associées qui sont susceptibles d'intervenir lors des prochaines réunions du Comité de pilotage. Cette liste sera communiquée au coordinateur du projet dans le courant de 2011.

Eagles follow-up committee (December 7th, 2011)

Programme

Place of venue:
Offices of the Belgian Science Policy
Louizalaan 231 Avenue Louise
1050 Brussel | Bruxelles
Room A « Christian de DUVE »

Agenda:

10h00 – 12h00: Plenary session
Invited expert: P. Servais (ULB)

- 10h00 – 10h05: Short introduction (F. Darchambeau)
- 10h05 – 10h20: Website and database (A.V. Borges)
- 10h20 – 10 h 40: First results of field mission 2011
    - 10h20 – 10h40: Microbial biodiversity (T. Garcia-Armisen & M. Llirós)
    - 10h40 – 11h00: C biogeochemistry (C. Morana)
    - 11h00 – 11h15: Denitrification rates (F. Darchambeau)
    - 11h15 – 11h30: CH_4 oxydation rates (A.V. Borges)
- 11h30 – 12h30: Sedimentology results
    - 11h30 – 11h45: Survey of sampled cores (E. Van de Vyver)
    - 11h45 – 12h00: Pigments (F. Darchambeau)
    - 12h00 – 12h15: Stable isotopes (C. Morana)
- 12h15 – 12h30: Modeling (N. Van Lipzig)

12h30: Lunch
14h00 – 16h00 : Specific meetings

- *Meeting 1: Planning of the field mission 2012*

This session will focus on the research planned for the first field campaign of the project and on logistic aspects. The discussion will benefit from presented results.

- *Meeting 2: Modelling*

This session will deal with the effective coupling between climate and hydrodynamic models. The time period of past, present and future simulations will also be defined accordingly with modellers (KUL and ULg) and paleolimnologists (Ghent U).

Report: Some notes

Modelling the regional climate

Nicole Van Lipzig presented summary of the PhD of Wim Thiery, who recently started at KULeuven. The aim of his PhD is to improve model performance for tropical lakes in a regional climate model. Therefore we can hopefully deliver improved climate simulations for present, past and future for EAGLES. Computational cost is an issue: there is a trade-off between resolution and time period of simulation. Therefore, a computationally cheaper method, namely physically-based statistical downscaling will be used to gain insight in uncertainties in climate scenarios.

Methane oxidation

Alberto Borges presented CH_4 oxidation measurements obtained in April 2009 (late rainy season), October 2010 (early rainy season), and June 2011 (dry season), at two stations (Ishungu + Kibuye/Gisenyi). Maximum CH_4 oxidation rates occurred at the base of the oxycline, and in oxic conditions. CH_4 oxidation rates followed a first-order relation with CH_4 concentrations. In sub-oxic and/or anoxic conditions CH_4 oxidation rates decreased down to undetectable levels. CH_4 oxidation rates correlated with $\delta^{13}C$ POC, indicated that the very negative $\delta^{13}C$ POC at the oxycline is partly or totally related to methanotrophs. Methanotrophic production measured by δ^{13} CH_4 additions (KUL) compared reasonably well with CH_4 oxidation rates measurements by natural abundance kinetics (ULg). CH_4oxidation for the three cruises and two stations (Ishungu + Kibuye/Gisenyi) averaged 19 mmol m^{-2} d^{-1}. This corresponds to a methanotrophic production ~5 to ~10 mmol m^{-2} d^{-1}, which is high compared to typical particulate primary production ~15 to 50 mmol m^{-2} d^{-1}.

Carbon biogeochemistry

The dissolved primary production is relatively high in Lake Kivu, accounting for roughly 50% of the total carbon incorporation by phytoplankton. At equivalent productivity, dissolved primary production is higher in L. Kivu than in other temperate lakes, consistent with the environmental conditions of tropical freshwater ecosystems enhancing phytoplankton excretion. The excreted compounds (DOCp) are rapidly assimilated by heterotrophic bacteria, highlighting strong interactions between phyto- and bacterioplankton. However, assessed by MAR-CARDFISH, the major phylogenetic groups of bacteria are not equally involved in the processing of DOCp, and they also show different patterns of uptake between ^{3}H-leucine and freshly produced DO^{14}Cp, used as labeled substrate. Chemoautotrophic and methanotrophic net production in the anoxic hypolimnion (ie. oxygen-free zone above 60m depth) accounted respectively for +/- 5% and +/- 15% of the epilimnetic primary production in June 2011, constituting thus a significant carbon flux.

Sediment – stable isotope analysis

The first 25 cm of the G4 core can be divised in three different zones, based on their carbon and nitrogen composition. In the most recent sediment (0-6 cm) we observe an accumulation of carbonate with a possible surface waters origin, as indicated by its carbon and oxygen isotope signature. In this first zone, the C:N ratio of organic matter increase linearly with depth. In the second

zone (6-21 cm) the inorganic carbon concentration is comparatively much lower, and its stable isotope signature indicate another origin for carbonate (deep waters ?)

Summary of the work plans at end of the meeting

KULeuven

1. Model evaluation of Flake and the CCLM-Flake coupled model
2. Runs for the present-day climate (2000-present) up to a resolution of 7 km and – if possible – up to 3 km (maybe only for a selected season)
3. Develop statistical downscaling method based on the runs, described under point 2. The relevant meteorological parameters that need to be downscaled are: near-surface temperature, humidity and wind, downward shortwave and longwave radiation, cloud cover and precipitation. Also a technique for the regional precipitation is needed as regional precipitation determines how active the sublake springs are and this – in turn – influences upwelling speed.
4. Produce time series for the past (some selected period from 1750 to present, based on the analysis of the paleo-proxies) of using the method under 3. Possibly different driving GCMs can be used. Francois will use these timeseries to drive his lake model and produce the proxy data that than can be compared with the measured proxy data in the sediments.
5. The same approach, or dynamical downscaling can be done for the future.
6. Only Francois Darchambeau will work with our data

UGent and RMCA: Paleoproxies

Objectives

1. Testing the hypotheses related to teleconnections between general climate events and past productivities
   - ➔ look at year-by-year (or time-averaging windows) co-variations between general climate index and paleoproductivity proxies (pigments, diatom cc, BSi cc, *Si isotopes*) for the period from (1850)1900-2000 (0-20 cm depths, resolution 0.25 cm)
2. Observe in the sediments long-term changes (1750-2000), draw some hypotheses for explaining these. If some (selected time periods) are related to climate changes, look at how climate changes (check literature) influence past productivities.

⇨ GCM outputs statistically downscaled

3. Validating the GCM by using paleoproxies (on time frame defined from point 2)
4. Look at the GCM for validating variations of precipitations during the XXth century in East-Africa

Long-term relationships between salinity and precipitations? How a change in precipitation will be related to salinity changes in surface waters? (+ influence on nutrient budget)

Check with Kelly Ann the availability of samples from core Kivu10-4

Validation Workshop: « Biological Baseline Study » *Synthesis and recommendations*

Thursday 30th and Friday 31st July 2015

The workshop has been divided in two parts and 4 sessions. The first part (session 1) was devoted to the Biological Baseline Study (BB) itself; the second part provided support to the study from other experts and insight from other studies carried out on Lake Kivu (session 2), as well as research and fish management experiences on Lake Victoria and Lake Malawi (session 3), and finally from the Regional Research Platform on Lake Kivu (session 4).

Introduction

In her general introduction about Lake Kivu and Lake Kivu Monitoring Programme (LKMP), Augusta Umutoni, Programme Manager, has explained the main physical and chemical characteristics of Lake Kivu: a strongly stratified lake, with several steps of density gradient, which make the lake very stable, and an important amount of gases in its deep waters, mainly methane and CO_2. She explained the main activities of the LKMP, including the different component of monitoring and inspection to be carried out on the extraction platforms. She also mentioned the wish of the LKMP to build a data base that might gather data from different horizons dealing with researches on the lake, along with a data sharing policy. She expressed the hope to have a regulatory authority on the lake, including Rwanda and DRC.

Session 1: "Biological Baseline Study"

The first session was devoted to the study carried out in the framework of the Biological Baseline (BB), on limnology plankton in the **pelagic zone** of the lake, at two sites located off Gisenyi and off Kibuye, as requested by the LKMP. Fish stock estimations were carried out in the whole lake in most campaigns.

In its presentation on the general view of lake biological baseline assignment, Prof Jean-Pierre Descy explained that, because of deep re-injection of the degassed water, the **effects of gas extraction on the surface waters won't be seen at short term but well on long term. Without caution, the ecosystem of Lake Kivu might be heavily impacted** by the exploitation of methane gas. The two years of the BB study aimed at putting in place monitoring techniques and assess them for long term use.

He insisted also that other environmental changes can affect the lake: climate change has also an impact, which he demonstrated later in the day.

The study focused on plankton, as it feeds the fish, and fish, as it is important to ensure the sustainability of fisheries on the lake. Primary production was also considered, i.e. the production of phytoplankton, and the exportation of organic matter to the deep waters of the lake. This is particularly relevant as 1/3 of methane is produced from organic matter, which is essentially produced from phytoplankton in the surface waters where photosynthesis occurs; the other 2/3 are produced from the transformation of CO_2 coming from deep underwater sources.

A large part of the BB study was devoted to **capacity building** and a large part of the budget to buying **equipment**, including floating platforms from which sampling has been carried out.

An important step was also the **synthesis of existing data up to 2012**, with the construction of a data base and with the edition of the book "Lake Kivu: Limnology and biogeochemistry of a tropical great lake" (Descy et al., 2012; http://www.springer.com/us/book/9789400742420, e-version available).

He mentioned also that, while the BB study was a monitoring project mainly based on observations, parallel research projects, within the same period, looked at understanding processes: EAGLES (East African Great Lakes Sensitivity to changes; www.eagles-Kivu.be) and MICKI (Microbial processes in Lake Kivu; http://www.urbe-fundp.be/micki.htm), for instance, looking at understanding carbon and nutrient transformations through various microbial activities at the interface between oxic and anoxic waters (between 50 and 90 m), . Fish studies were also undertaken, in particular the collection of detailed fish statistics on the Rwandese side of the lake, as well as studies on the competition between the sambaza and the recently introduced *Lamprichthys tanganicanus* (Masilya, 2011; Masilya et al. 2011). .

J.-P. Descy insisted on the fact that Lake Kivu is particularly interesting for researchers as infrastructures exist to carry out research, which is not always the case on other East African great lakes.

As explained Edouard Rugema, the BB study allowed to gather a data base of 48 CTD profiles, to establish the **physical and chemical characteristics of the upper part of the lake**, above the "chemocline" situated at 60 m, where an increase of salinity prevents surface and deep waters to mix. The upper part of the water column (the mixolimnion or biozone) is occupied by living organisms that rely on oxygen (microbes, phytoplankton, zooplankton and fish), whereas the deep anoxic waters harbour only microbes using different sources of energy (for instance, methanogenic microorganisms that produce methane from CO_2 and organic matter)

Nutrient analyses were also carried out in samples from the mixolimnion. Among other things, they showed limitation of phytoplankton growth by phosphorus most of the time, with at times co-limitation by nitrogen.

On the **phytoplankton** composition in the BB, J.-P. Descy explained that when water is mixing down to 60 m (in the dry season), nutrients, which are in high concentration in the deeper layers of the mixolimnion during the stratified rainy season, become available for the phytoplankton. And in fact we can see peaks of phytoplankton in the dry season. There is nevertheless an important variability, influenced by climate change, as shown later (from EAGLES research).

It is also important to note that in Lake Kivu, a significant share of phytoplankton is made of very small and very large phytoplankton, which are not directly available for the zooplankton.

HPLC analysis allowed to process numerous samples in a short time, and provide a direct assessment of the abundance and composition of phytoplankton at the phylum/class level. HPLC allows measuring the concentration of various pigments present in phytoplankton cells. Chlorophyll-a (Chl*a*) is a proxy of the biomass of phytoplankton, while other pigments are used to distinguish the main groups of phytoplankton. It is a useful method that allows automated analysis of numerous samples, allowing examination of vertical distribution of the phytoplankton, and of variations over time, thereby increasing the temporal and spatial resolution of phytoplankton studies. Microscope observations, on the other hand, are hardly adequate for high-resolution monitoring, as they are time consuming.

Unexpected changes were observed over the monitoring period. Since 2012, much higher abundance of green algae than in the past has been observed. As evidenced from microscope examinations, these green algae were mainly composed of desmids, possibly not edible by zooplankton. Daily partial mixing may have occurred more intensely in the recent years, explaining the maintenance of these relatively large algae. A clear trend of increase in Chl*a* in the long term was also observed, probably driven by slight changes in weather conditions. The same trends have been observed in the southern part of the lake (EAGLES data).

This shows that substantial changes can occur, from other factors than methane extraction, and that monitoring of the water column for several years is necessary to show changes. This implies that monitoring of the lake may be needed for decades, and that parallel observations, namely on

meteorological and limnological conditions, will be needed to provide evidence of possible impacts of methane exploitation vs. other environmental changes.

In conclusion

- **Methods are reliable and should be used in the future**
- **Data are totally comparable with previous ones as the same techniques were used!**
- **Results from both monitoring sites, located off Gisenyi and Kibuye, are very similar**
- **Beyond monitoring, detailed data analysis remains to be done, in particular by crossing CTD and phytoplankton data**
- **Sometimes, microscope examinations are needed to identifications at genus/species level, allowing more detailed interpretation of ecological changes.**

For **zooplankton**, the list of species comprised almost all those recorded in previous studies; only two species were not observed in 2012-2014, which can be explained by the mesh size used, which was adequate for copepods, but not for all small zooplankton. The formulas from Darchambeau et al. (2012) were used to calculate biomass from counting of individuals. Considering the mesh of the net used, only copepods and cladocerans were considered for biomass estimates. Zooplankton biomass followed grossly the seasonal variation, with maxima recorded in the dry season, although variation from this pattern was observed, possibly resulting from sampling errors or from heterogeneous distribution of copepods in the water column.

For the future, it is **suggested to acquire a Laser Optical Plankton Counter (LOPC)**, which will allow improved records of zooplankton spatial and temporal variations, and possibly speed up sampling operations.

To estimate the **amount of organic matter produced at the surface that is exported to deep waters,** sediment traps were installed at 90 m, suspended from the platforms, and the accumulated organic matter collected once a month. This allowed to determine the sedimentation rate and to look at its variation through time. This rate allowed to estimate the proportion of the plankton production (PP) that is exported to the deep water ("export ratio"), fuelling the methane production in the sediment. This is important, as so far there is no satisfactory explanation to the methane increase between 1974 and 2004 (Schmid et al. 2005). The export ratio was on average 8% but varied a lot during the monitoring period, probably depending on phytoplankton composition, as not all groups sediment similarly. This is important for the prediction of what might happen in the future. For instance, an increase in nutrients input to the mixolimnion – likely to occur from methane harvesting, depending from re-injection depth (see Wüest et al. 2012) will likely have an impact on phytoplankton composition and biomass, which in turn might affect the ecological quality of the lake, but will not result in an increase of production (Descy et al. 2012). Again, monitoring of methane plant operation is needed, and **the compliance to the management prescriptions is required (see Wüest et al. 2012).**

It was also mentioned that a model have been now developed to calculate PP from chlorophyll-a, water transparency and phytoplankton composition (Darchambeau et al. 2014). There is thus no need any more to measure PP.

Comparison of old and recent PP data shows that there is no significant difference, while variability exists. Internal nutrient loading contribute for a major part to the nutrient budget of the lake (Pasche et al. 2012), with external inputs from watershed and rivers contributing 15-20 % of the nutrient budget. Therefore, a great effect of an increased input of nutrients to the pelagic zone form increasing population and activities in the watershed is not likely to affect the lake's nutrient budget to a great extent, whereas an impact on the littoral zone may be expected.

In complement to monthly monitoring, **continuous data acquisition,** from mooring lines deployed from the platforms, is quite interesting. Loggers connected to various sensors were deployed from 0 to 70 m to measure temperature (every 10 m), and chlorophyll *a*, phycocyanin (proxy for

cyanobacteria biomass, useful to be measured as it is an important phytoplankton group), and oxygen (at 10 m depth), with data recorded every 5 minutes. Data were downloaded every month from Oct. 2012.

Dysfunctions were faced, and the software for downloading the data didn't work properly due to errors generated by sensor failure.

Temperature profiles at high temporal resolution are nevertheless interesting as they shows diel patterns in stratification: during the day, stratification sets in in the top first meters, depending on solar radiation, and at the end of the night, there is mixing of this layer due to cooling. This is a phenomenon already known in tropical shallow lakes. This is probably through this daily mixing that large phytoplankton cells can be maintained in suspension. Note that phytoplankton actually function at this daily time scale.

Chlorophyll a and phycocyanin results were not totally satisfactory: the phycocyanin sensor is not sensitive enough and shouldn't be used anymore, while chlorophyll a is a very good indicator but faced problem due to malfunctioning of the sensor, due to damaged connections and calcium carbonate deposits on the sensor surface. In the future, careful calibration of this sensor should be done, for instance using pure cultures of algae and /or chlorophyll a standards. It is also possible that variations resulted from vertical migration of phytoplankton at a daily time scale.

Oxygen is interesting as it shows the metabolism of the lake, which depends on photosynthesis and respiration during the day, with decline during the night as there is no photosynthesis and only respiration (of all organisms). It is a very good parameter to show the effect of an increase of nutrient, which would lead to higher amplitude of dissolved oxygen variations. This may also affect the thickness of the de-oxygenated layer in the mixolimnion during the rainy season, affecting the distribution of zooplankton and fish. Gross primary production could be calculated from oxygen measurements.

Note that a loss of sensitivity of the oxygen sensor was faced, due to missing calibration and other technical problems.

In conclusion

- **Mooring lines provided mixed results: the equipment was not totally reliable**
- **Temperature is very important, and could provide valuable short-term data on the stratification and mixing pattern**
- **Dissolved oxygen measurement is useful for short-term assessment of PP and of lake metabolism**
- **Fluorometers for chlorophyll *a* and phycocyanin provided disappointing results, which however may be improved by careful calibration.**

Temporal and spatial variations of the stock of *Limnothrissa miodon*, the sambaza, have been studied by Alice Muzana, under supervision by Dr Jean Guillard. The aim was to (1) contribute to the assessment of ecological status of the lake, (2) provide recommendation to decision makers, (3) be a reference to monitor changes.

The hydroacoustic method was used, as it is a standardized method for fish stock estimation in water bodies. It does not allow to identify fishes at the species level, but the fish catches and experimental studies have shown that the sambaza largely dominates in the pelagic zone.

It has been shown that the southern and western basins are more productive than the eastern and northern basins, while no seasonal pattern was noticed. The unimodal size distribution supports the fact that there is only one species in the pelagic zone (up to now). The vertical distribution of the fish varies: in the dry season, we found fish up to 60m; in the wet season, up to 40 m. This can be related to the oxygen depletion that occurs as a result of thermal stratification. Comparison with previous data was done, allowing long term comparison of the stock estimation and showing that the stock did not vary over several decades, as also suggested by Guillard et al. (2012) and Snoeks et al. (2012).

In conclusion

- **Globally the fish stock is stable**
- **No significant variation with time was observed during the monitoring period**
- **The southern and western basins are more productive, regardless of season**
- **Vertical distribution is homogenous, but varies seasonally with the depth of the mixed, oxygenated layer**
- ***L. miodon* reproduces all along the year**

Perspectives

- **There is a need of further studies, to show (1) the extent of development of *Lamprichthys tanganicanus* and (2) the way it is interacting with *L. miodon***
- **Analysis and continued monitoring of the fishing effort is necessary**
- **Regular monitoring by hydroacoustic surveys should be carried out twice a year**
- **There is a need of re-assessing the production/biomass ratio (P/B) for *L. miodon***

The **Biological Baseline data base** is presently available on the website of the University of Namur, along with previous data, as requested in the contract, and most data from the EAGLES project can be made available on request. The access to the baseline data base is restricted, and the password is available from the LKMP team. The final report of the EAGLES project will be available at the end of this year. The data relevant to the lake's monitoring would then be transfer to LKMP, after agreement by other EAGLES partners. It has also been stressed that environmental data should be made public after a while, possibly with access on request.

Validation and synthesis of recommendations

The Biological Baseline Study has been **validated**.

The following recommendations have been provided:

Long term monitoring, over decades, will be needed to see potential changes due to gas extraction, as changes may not be seen at short term. It is also to be noted that changes have already occurred: for instance, substantial variability of the dry season phytoplankton maximum occurred between 2002 and 2010, as a result of variations of the regional climate (Darchambeau et al. 2013).

For plankton monitoring, it has been shown that

- Methods are reliable and should be used in the future
- Data are totally comparable with previous ones as the same techniques were used
- Results from both monitoring sites in Rwanda were very similar
- Beyond monitoring, detailed data analysis remains to be done, in particular by crossing CTD and plankton data
- For phytoplankton, microscope examination may sometimes be necessary for more detailed identification (at genus or species level), in order to allow interpretation of variations at the class level as provided by the analysis of marker pigments.

It is therefore recommended to pursue the phytoplankton monitoring. It might be interesting, for a finer monitoring of plankton variations, to monitor one reference site more frequently, e.g. from the Gisenyi platform.

For zooplankton, it is suggested to use a Laser Optical Plankton Counter (LOPC), which may improve the knowledge on zooplankton distribution and will speed up data collection. Using the LOPC during the hydroacoustic surveys would allow to examine relations between the distribution of fish and that of their main prey.

The monitoring of settling organic matter on a monthly basis for a year is also recommended, using the sediment traps, but these measurements may not be necessary every year, at least as long as there is no great change in plankton biomass and composition.

While recommended, continuous data collection from mooring lines should benefit from a revision of the equipment, probably needing intervention of the manufacturer. Recordings from the phycocyanin sensor shouldn't be pursued as the sensor is not sensitive enough. Otherwise,

- Temperature is very important, and could provide valuable short-term data on water column dynamics
- Dissolved oxygen measurement is useful for short-term assessment of PP and for the monitoring of the lake's metabolism (photosynthesis – respiration balance and amplitude); calibration of the sensor should be performed frequently
- Disappointing results of the fluorometer for Chl*a* might be solved after the whole mooring line would be revised and working properly; on site calibration should be performed, from lake water and/or with adequate standards, with comparison with pigment analysis by HPLC.

For the hydroacoustic surveys, the following recommendations can be made:

- There is a need of further studies, to show (1) the extent of development of *L. tanganicanus* in the pelagic zone and (2) the way it is interacting with *L. miodon* (after careful review of the existing data; see Masilya 2011).
- There is a need for monitoring the fishing effort, on the long term and on both sides of the lake (i.e. in Rwanda as well as in DR Congo)
- Regular monitoring by hydroacoustic surveys should be carried out twice a year
- There is a need of re-assessing the production/biomass ratio (P/B) for *L. miodon*

It has been recommended that the BB data base will be physically transferred to LKMP. Transfer of a complete data base, including also the relevant results from concomitant research project EAGLES, will be done once this project will be validated and upon approval of EAGLES scientific partners.

It is recommended to the LKMP to build a robust database to gather Lake Kivu monitoring and scientific data. This should allow dissemination of data, and making them available for further use. To provide the access to such an invaluable data base will thus be highly appreciated and will generate interest from the international scientific community.

LKMP members are highly encouraged to pursue exploiting the data, as well as communicating at international conferences and publishing their results, while it is requested to obtain permission from the scientific partners and from the consultant of further use of data.

It is also recommended to the LKMP monitoring team collaborate with scientists from universities and research centres, both for technical and scientific support. LKMP should inform the scientific community about availability of facilities, laboratory and equipment, and access to those by international scientists should be considered as a valuable win-win perspective.

The representative of the MINEDUC insisted on the need and importance of sharing information. She expressed also her wish of a larger collaboration of experts with a larger public of students and the scientific community.

Session 2

The 2nd session was devoted to other studies carried out on Lake Kivu, both on pelagic and littoral zones.

Dr Guy Périat, from the Teleos consultancy, did the fish baseline for KivuWatt and told us about the first standardised gill net sampling in Lake Kivu, which was successful. Results comply with hydroacoustic data but give more information on biodiversity and fish ecology. As sampling was carried out till 30 m depth, unexpected fish communities were found at 30 m. Potentially 24 new species were found. Genetic analyses would be needed to confirm it. A monitoring of fish in littoral zone was proposed, in 4 bays, within 4 years' time lapse.

It is interesting to note that *L. tanganicanus* has been found in the pelagic zone but not in great numbers. The sambaza was more abundant in the pelagic zone and a few were found in the littoral zone. *L. tanganicanus* was found in rocky zones while the sambaza is mostly found close to tributaries.

A detailed analysis of two *Haplochromis* species was presented and discussed by Ph. Munyandamutsa.

Elisée Gashusi presented results of a study dedicated to the localisation and chemical properties of the subaquatic ground water discharges (SGD). There are different types of ground sources entering the lake. Some water are hydrothermal, warm and saline waters, while others are fresh and cooler water. The deep sources create a slow upwelling in Lake Kivu, allowing for the main input of nutrients to the pelagic zone of the lake. Lake conductivity and temperature have been said to be a product of episodic geological events within the lake, claiming again for the importance of monitoring.

The EAGLES project, carried out in parallel with the BB study, and partly sharing some data with it, looked at existing data, new ones, laboratory experiments, analysis and modelling. Prof J.-P. Descy provided us the main results relevant for our workshop. In particular the analysis of past studies showed that plankton production in Lake Kivu is in a range comparable to that of the other Great Rift lakes, and that the trophic transfer efficiency between phytoplankton and zooplankton is in a normal range. By contrast, the rate of ratio of fish production to zooplankton production is very low, suggesting that there is a bottleneck between zooplankton and fish. This suggests that any increase in phytoplankton production – which may result from an increased nutrient input to the surface waters - may not necessarily result in an increase in fish production. Predicting what would happen is difficult, however, as several ecosystem processes may be affected, but most probably, as observed in all cases of eutrophication in lakes, a degradation of water quality would be observed, and the fish habitat would be altered.

The project also worked on methanotrophic bacteria, situated in the oxycline (zone of oxygen decrease with depth), which take up and oxidise the methane which diffuses from the deep water; consequently almost no emission of methane from Lake Kivu to the atmosphere is recorded, which is in stark contrast with the very large amount of methane in the deep waters.

Phytoplankton biomass peaks, general recorded in the dry season, showed a lot of variability in the long term. Good relationships between Chl*a* variation and global climate indices have been found (Darchambeau et al. 2013).

One of the EAGLES teams conducted extensive studies on the use of remote sensing to assess surface Chl*a*, water transparency and temperature. For Chla, significant uncertainties remained despite careful model calibration, but weekly aggregation of the data provided results in the range observed in the field, suggesting a possible application of remote sensing for monitoring the lake status in the future.

Fish statistics are quite important to be compared with fish stock estimates by hydroacoustics. Till now, a detailed 3-year data collection has been done on the Rwandese part (by L. Nyinawamwiza's team from UR-CAVM). They showed that the sambaza still contributed the largest fraction of the pelagic fishery. Such data are presently missing on the Congolese part of the lake. Obviously, collection of fish statistics should be carried out on both sides of the lake, in order to determine possible effects of the fishery on the fish stock variations, as well as an impact of changing lake conditions on the fishery.

During the discussion, the issue of fish introductions in Lake Kivu was discussed. The advice of the experts was that the introduction of *L miodon* can been considered as a success, whereas it is rarely the case for introduction on other lakes. Nobody can foresee what can happen from introductions. In addition, the experts said that Lake Kivu has probably reached its highest fish yield and couldn't produce more. It was added that Lake Kivu did not contain any pelagic fish before the introduction: therefore, introducing a planktivorous fish as the sambaza was the only way to develop a fishery. Several changes may have occurred from this introduction, but careful analysis of the available data show that large uncertainties remain as to the extent of those changes.

Session 3

Session 3 was devoted to experiences of research and management of other lakes.

An ongoing research on use of satellite images to assess Chl*a* was presented by Dr William Okello. Dr Olivia MKumbo and Dr Steve Donda talked about the experience of fish management respectively on Lake Victoria and Lake Malawi, with information of institutional structure, functioning, activities, and management challenges.

Session 4

Finally the Context, history, objectives and way forward of the regional research platform and of its subsidisation programme by LKMP has been presented.

References

Darchambeau F, Borges AV, Sarmento H, Leporcq B, Isumbisho PM, Alunga G, Masilya PM, Descy J-P (2013) Teleconnections between ecosystem productivity and climate indices in a tropical great lake. Geophysical Research Abstracts, 15:EGU2013-9919-1.

Darchambeau F, Isumbisho M, Descy J-P (2012) Zooplankton of Lake Kivu. In Lake Kivu, Limnology and Biogeochemistry of a Tropical Great Lake. Springer, Aquatic Ecology Series, Vol. 5, 107-126

Darchambeau, F., Sarmento, H. & Descy, J. P. 2014. Primary production in a tropical large lake: The role of phytoplankton composition. The Science of the total environment. 473-474, 178-188, p. 178-188

Descy J-P, Darchambeau F, Schmid M (2012) Lake Kivu Research: Conclusions and Perspectives. In Lake Kivu, Limnology and Biogeochemistry of a Tropical Great Lake. Springer, Aquatic Ecology Series, Vol. 5, 181-190.

Descy J-P, Darchambeau F, Schmid M (2012) Lake Kivu: Limnology and geochemistry of a tropical great lake. Aquatic Ecology Series, Vol. 5, Springer. 190 p.

Guillard J, Darchambeau F, Mulungula PM, Descy J- P (2012) Is the fishery of the introduced Tanganyika sardine (Limnothrissa miodon) in Lake Kivu (East Africa) sustainable? Journal of Great Lakes Research 38: 524-533.

Masilya MP, Darchambeau F, Isumbisho M, Descy J-P (2011). Diet overlap between the newly introduced Lamprichthys tanganicanus and the Tanganyika sardine in Lake Kivu, Eastern Africa. Hydrobiologia 675: 75–86.

Masilya, P. (2011). Ecologie alimentaire comparée de Limnothrissa miodon et de Lamprichthys tanganicanus au lac Kivu (Afrique de l'Est). PhD thesis, University of Namur, Belgium, 212 p.

Pasche N., F.A. Muvundja, M.Schmid, A. Wüest, B. Müller (2012). Nutrient cycling in Lake Kivu. In Lake Kivu, Limnology and Biogeochemistry of a Tropical Great Lake. Springer, Aquatic Ecology Series, Vol. 5, 31-45.

Sarmento H, Darchambeau F, Descy J-P (2012) Phytoplankton of Lake Kivu. In Lake Kivu, Limnology and Biogeochemistry of a Tropical Great Lake. Springer, Aquatic Ecology Series, Vol. 5, 67-83.

Schmid M, Halbwachs M, Wehrli B, Wüest A (2005) Weak mixing in Lake Kivu: new insights indicate increasing risk of uncontrolled gas eruption. Geochem Geophys Geosyst 6 (7): Q07009. doi:10.1029/2004GC000892.

Snoeks J., Kaningini B., Masilya M., Nyinawamwiza L., Guillard J. (2012). Fishes in Lake Kivu: Diversity and Fisheries. In Lake Kivu-Limnology and biogeochemistry of a tropical great Lake. Aquatic Ecology series, Springer 5, 127-149.

Wüest, A., L. Jarc, H. Bürgmann, N. Pasche, M. Schmid. (2012). Methane formation and future extraction in Lake Kivu. In Lake Kivu, Limnology and Biogeochemistry of a Tropical Great Lake. Springer, Aquatic Ecology Series, Vol. 5, 165-180.

EAGLES kick-off meeting – 2010, 22th December

Were present: Jean-Pierre Descy, Bruno Leporcq, Marc Llirós (U Namur), Elie Verleyen (Ghent U), Luc André (RMCA), Tom Akkermans (KUL-Nicole van Lipzig), Steven Bouillon, Cédric Morana (KUL-Bouillon), Yves Cornet (ULg-Géomatique), François Darchambeau (ULg-UCO)

FNRS-FRFC 2011/2013

Santa Claus visited recently Namur and Liège's Chemical Oceanography Unit with a positive answer from the FNRS reg. a new FRFC-project entitled "Microbial diversity and ecological processes in Lake Kivu, Eastern Africa". The project additively involves Pierre Servais (ULB)'s lab Ecologie des Systèmes Aquatiques. So, the 3 partners are:

- University of Namur: Jean-Pierre Descy, Bruno Leporcq, Marc Llirós
- ULg's Chemical Oceanography Unit : Alberto Borges and François Darchambeau
- ULB's Ecologie des Systèmes Aquatiques : Pierre Servais, Tamara Garcia-Armisen, Adriana Anzil

This project will allow to the same teams to pursue the research started during the previous FRFC-granted CAKI project. So, while the ULB's team is not involved in the EAGLES project, we will in the future invite them to our various meetings and their members will join us during the KIVU campaigns.

Sub-groups

Various sub-groups were defined (PI underlined):

- Sediments: Elie, Jean-Pierre, Steven, François and Luc
- Biogeochemistry-microbial ecology: Marc, Jean-Pierre, Bruno, François, Alberto, Pierre, Tamara, Adriana, Steven and Cédric
- Deep waters : Luc, Steven and Alberto
- Modeling: François, François Laenen (MSc student of François working on L Kivu ecological modeling), Tom, Nicole

Kivu database (WP1): UN and ULg

The Unit of Chemical Oceanography (ULg) will host the Kivu website through a http address as www.eagles.be (so, without prior reference to ULg). It will include the Kivu database.

All partners are asked to gather the existing data in their respective field of expertise during the 1st semester. Instructions will be given by the UOC reg. the formatting of the data. The KIVUdb with existing data must be finalized for the end of 2011.

Sediment cores

A 1st meeting of the sub-group will take place on **21st February**, regarding:

- presentation of the data acquired on the cores sampled in 2009 and analysed during Sebastien's MSc thesis
- dating of these cores (^{210}Pb + radiocarbon?)
- supplementary analyses on these cores: stable C and N isotopes, Si isotopes
- preparation of new sediment coring scheduled for June 2011

François will soon contact Flavio Anselmetti (EAWAG) who conducted some sediment coring in L Kivu during October 2010 and discuss with him about possible collaborations.

In situ monitoring and sediment trap deployment

A short (1 week) mission will take place in the beginning of February 2011 to:

- conclude sub-contracting with local partners (ISP-Bukavu's Dr Pascal Isumbisho, UNR's Dr Laetitia Nyinawamwiza) and define with them the organization of in situ monitoring;
- deploy sediment traps offshore Gisenyi and train the local teams for their removals and sample handling;
- collect some waters for diatom isolation (Ghent U – Elie).

François and Jean-Pierre are at the same time invited by the Rwanda Minister of Infrastructures (MININFRA) to present the EAGLES project and the potential risks of methane exploitation on the lake ecosystem during an international workshop dedicated to lake monitoring and gas exploitation. Bruno will probably join them for the training of local teams.

Kivu campaigns

Two campaigns a year were scheduled in the project. The following dates are initially proposed:

	Rainy season					Dry season				Rainy season		
	J	F	M	A	M	J	J	A	S	O	N	D
2011		**(0)**				**1**						
2012	**2**									**3**		
2013					**4**							

Two supplementary campaigns might still be defined (1 in 2011 and 1 in 2013) but we suggest maintaining their dates flexible in case of a failing campaign, etc.

Campaigns # 1, 2, 3 and 4 will involve the biogeochemical-microbial sub-group.

Deep water sampling will most probably be conducted by the MRAC team during campaigns # 3 and 4. Samples for Steven (stable isotopes of N and C in various forms) and Alberto (CO_2, CH_4 and N_2O) will also be collected during these deep water profiling.

Sediment coring by Ghent U (Elie) will take place during the 1st Kivu campaign (# 1). Water samples will also be collected for diatom cultures.

Modeling

The KUL Climate team will most probably split their tasks in two phases:

- ~10 months in 2011: for modeling of past and future climate, + period 2002-2008
- ~2 months at the end of 2013: for modeling of climate during the 2011-2013 period.

A deliverable will be proposed at the end of each phase, with data easily readable for the paleolimnology and the modelling's teams. A meeting will be scheduled at the beginning of the climate job for defining the parameters and format of the climate products.

Remote sensing

Start in 2012 (+ 1 month in 2011 for some tests on SST, etc).

Some connections between the climate modeling group and geomatics were also identified, incl. common validation of meteorological data (SST, rain, cloud, etc).

Meteorological station

The disposal of a new meteorological station is required in Rwanda, while not initially budgeted in the project. Ideally, the station should be located on an offshore floating platform. Finances might come from the BTC-CTB which helps the MININFRA to perform the monitoring of the lake. Technically, François will discuss with Marc Binard (ULg) which recently installed an autonomous meteo station in STARESO, and with Pierre-Denis Plisnier which will install some meteo stations for his starting BELSPO-CHOLTIC project around L Tanganyika.

Opportunities for extending the network

EAGLES will need more work force and the sole present BELSPO financing cannot completely meet the needs. Therefore, partners are requested to actively seek additional resources, via FNRS for collaborative research projects, FNRS/FWO - FRIA/IWT for PhD fellowships or other sources.

A possibility for post-doc fellowships is a call from BELSPO in the framework of international collaboration, targeting non-EU scientists (except those associated to the EU 7th FP). Duration : 6-18 months. The research topics are those of projects supported by BELSPO, hence it applies to EAGLES.

Deadline for application: Feb 28, 2011. More information here:
http://www.belspo.be/belspo/home/calls/postdoc_info_en.stm

Last but not least: Baby shower

All congratulations to Nathalie & Alberto for the birth of their baby Louisa on 22th December 2010. Welcome to this beautiful little girl into the EAGLES team!