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REPORT OF THE THIRD JOINT MEETING OF THE LTR'S COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

edited by

G. HANEK AND E.J. COENEN

FINNISH INTERNATIONAL DEVELOPMENT AGENCY

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

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The conclusions and recommendations given in this and other reports in the Research for the Management of the Fisheries on the Lake Tanganyika Project series are those considered appropriate at the time of preparation. They may be modified in the light of further knowledge gained at subsequent stages of the Project. The designations employed and the presentation of material in this publication do not imply the expression of any opinion on the part of FAO or FINNIDA concerning the legal status of any country, territory, city or area, or concerning the determination of its frontiers or boundaries.

PREFACE

The Research for the Management of the Fisheries on Lake Tanganyika Project (Lake Tanganyika Research) became fully operational in January 1992. It is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by the Finnish International Development Agency (FINNIDA) and the Arab Gulf Programme for United Nations Development Organizations (AGFUND).

This project aims at the determination of the biological basis for fish production on Lake Tanganyika, in order to permit the formulation of a coherent lake-wide fisheries management policy for the four riparian States (Burundi, Tanzania, Zaïre and Zambia)

Particular attention will be also given to the reinforcement of the skills and physical facilities of the fisheries research units in all four beneficiary countries as well as to the build-up of effective coordination mechanisms to ensure full collaboration between the Governments concerned.

Prof. O.V. Lindqvist
Project Scientific Coordinator

Dr. George Hanek
Project Coordinator

LAKE TANGANYIKA RESEARCH
FAO
B.P. 1250
BUJUMBURA
BURUNDI

Telex: FOODAGRI BDI 5092

Tel.: (257) 22.97.60

Fax.: (257) 22.97.61

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We wish to acknowledge the efforts of Prof. O.V. Lindqvist and Dr. H. Mölsä who edited all contributions of Finnish scientists. Similarly, we wish to record the effective assistance of Ms. Blessich and Dr. Kapetsky in drafting the adopted report. Our profound thanks go to Messrs. K.I. Katonda and P. Mannini and their staff for a very efficient preparation of the meeting's facilities, impeccable logistics and generous hospitality. Ms. Baricako's efforts in the preparation of the meeting's documentation as well as in the finalization of this document must not be neglected.

We wish to record the extremely hard work of all LTR personnel in all LTR stations around Lake Tanganyika as well as in numerous Universities and Research Institutes in Finland. Thanks to them, the technical level of all presentations was considerably higher than what we could have hoped for and consequently made us very proud.

Lastly, we wish to record the effective and constructive participation of all members of the LTR's Committees, that of numerous observers and, above all, the effective chairmanship of Mr. T.W. Maembe.

RESEARCH FOR THE MANAGEMENT OF THE FISHERIES ON LAKE TANGANYIKA

GCP/RAF/271/FIN

REPORT OF THE THIRD JOINT MEETING OF THE LTR'S COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

Kigoma (Tanzania), 28 — 30.11.1994

1. The Third Joint Meeting of the Coordination and International Scientific Committees of Project GCP/RAF/271/FIN, Research for the Management of the Fisheries on Lake Tanganyika (LTR), was held from 28 to 30 November 1994 at Kigoma, Tanzania.

ITEM 1: OPENING OF THE MEETING AND ELECTION OF THE CHAIRMAN

2. The delegate of Zambia, Chairman of the Second Joint Meeting of LTR's Coordination and International Scientific Committees, welcomed the participants and observers and called the meeting to order. The list of participants is given in Annex 1.

3. The delegate of Tanzania renewed his welcome on behalf of the host country. He drew attention to the opportunity the Committees meeting offers for the delegates from the four participating countries sharing Lake Tanganyika to exchange information and ideas. These were important contributions to the layout of a strategy for the management of the lake resources for the benefit of the riparian populations and as a source of income. He introduced and thanked Ms N.A. Sumari, the Kigoma Regional Development Director for having accepted to open the meeting.

4. The Regional Development Director for Kigoma Region stressed the importance of research on Lake Tanganyika, known world wide for its unique characteristics. She noted that past efforts of research at country level had not yielded adequate results for optimal management of the lake resources. She appreciated the concerted effort made possible through the LTR project not only for research, but also for the utilization of shared resources as an important source of food supply for the populations. The results of the ongoing studies were necessary for the determination of the lake fish production, a basis for avoiding decline in catch rates and for the continued subsistence of fisherfolks. Ms. Sumari thanked the Government of Finland for the financing of this project, and FAO for the contribution in its execution. She pleaded the donors' community to allow continuation of research through a second phase of this project, much needed for yielding more meaningful and fruitful results.

5. The Deputy FAO Representative in Tanzania thanked the Government of Tanzania for hosting the meeting. He dwelled on the many issues of importance being addressed by the project for tapping the lake resources with the ultimate goal of benefitting the fishermen and of poverty alleviation. He stressed the need for a long-term horizon in the interest of future sustainability of fisheries management. This required paying due attention to institution building at country level and to the elaboration of a subregional mechanism with adequate linkages with the fishermen. He expressed appreciation to the Project Coordinator and his whole team for their dedication and continued commitment while working under difficult conditions.

6. The delegate of Tanzania, proposed by Burundi and seconded by Zambia, was elected chairman. The delegate of Zaïre, proposed by Zambia and seconded by Burundi, was elected Vice Chairman.

ITEM 2: ADOPTION OF THE AGENDA

7. The agenda (Annex 2) was adopted with the introduction of a review of progress on recommendations put forward at the Second Coordination and International Scientific Committees meetings.

ITEM 3: REVIEW OF PROGRESS ON RECOMMENDATIONS OF THE SECOND MEETING OF THE COMMITTEES

8. The Project Coordinator noted that the rehabilitation of the research station in Zaïre was still not possible. Due to the prevailing security measures and stringent financial constraints for the execution of the very demanding research programme, Zaïre presently benefitted from the results mainly on a regional basis. It was requested that the recommendation adopted during the 2nd Joint Meeting of LTR Committees is maintained.

9. FAO was actively pursuing a search for additional funds. Despite the change in the target orientation of their assistance, AGFUND funds had been released in 1994 and used for equipment for the *R/V Tanganyika Explorer.* The equipment purchased by the project and installed on the vessel will be disposed of in the normal manner of FAO executed projects.

10. The Scientific Coordinator’s report had been structured in a more detailed manner. All documentation, including results to date from the Scientific Sampling Programme (SSP), had been made available well in advance of the meeting.

11. Participants from the four countries were involved more and more in the execution and planning of the activities, and their familiarization with the whole programme was promoted through several visits to all stations. The involvement of national scientists in reporting was emphasized.

12. FAO had provided all participating countries with a copy of the charter contract of the research vessel. Options available for the availability of such vessel had been jointly deliberated during LTR’s First Committees meeting. The contract covered a

“bare–boat” charter to FAO for a period of three years. It also provided the option of renewal to guarantee the vessel availability for extended research if the project’s extension made it possible.

13. Laboratory rearing of crustacea was postponed because of its excessive difficulty.

14. Funds should be sought and earmarked for as a priority for the continued operation of the vessel over the charter period through 1997. Should the project be forced to cease operations during the charter period, the vessel would remain available to GEF, or to member countries, if funds are made available to cover all costs.

15. Collaboration with the research project on Lake Malawi was maintained both by the University of Kuopio and by the project. Some of the staff were able to participate in the presentation of the project’s final results at a meeting in Malawi.

16. Due to a lack of a response, there was no follow–up on a possible collaboration with the International Atomic Energy Agency (IAEA) on isotopes in Lake Tanganyika.

17. Negotiations for collaboration with the GEF programme Pollution Control and Other Measures to Protect Biodiversity on Lake Tanganyika were still going on.

18. The meeting was satisfied with the progress made on its recommendations.

ITEM 4: LTR COORDINATOR’S PROGRESS REPORT

19. The Project Coordinator presented a summary of LTR activities during 1994; it is amplified in LTR/94.2. The SSP had been carried out without interruption despite the very difficult conditions.

20. The completion of the research vessel construction was a major achievement. The vessel had been built in Burundi according to project specifications and within a period of twelve months despite the intervening serious disturbances. A video was displayed to document detailed specifications and equipment on board. Trials for her commissioning were to start on 12 December 1994 to be immediately followed by selection of the crew and training in mid–water trawling. The charter period would enter into effect as of 1 January 1995. The Project Coordinator was requested to inform the Committees members about the value of the vessel at the earliest opportunity.

21. The Project Coordinator drew the attention of the meeting to the density of the programme which would be further increased with the introduction of research cruises. Additional local manpower availability was to be addressed as a matter of urgency. Six Associate Professional Officers presently engaged in activities were scheduled to end their assignments by the end of 1995.

22. Nine training courses in various subjects were completed, besides ongoing on-the-job training, including computer training of counterparts. Twenty technical documents, six field manuals, five LTR Newsletter issues had been published along with a number of travel and progress reports.

23. The meeting congratulated the Project Coordinator and all the staff for the achievements, and reemphasized the participation of national scientists in data analysis and presentation of results in ensuing technical reports. Increased involvement in data analysis and technical reporting was the logical step now building upon competence attained in sampling techniques and data inputting. Progressive increasing responsibilities at national level required an effort in assignment of additional staff.

TRIBUTE TO DR. KAFURERA

24. A moment of silence was observed for Dr. Kafurera, Scientific Director of IRAZ, who passed away recently. He was an observer at the first LTR Committee meeting. His presence will be missed.

ITEM 5: PRESENTATION OF SSP RESULTS

Hydrodynamics

25. This was presented by Dr. T. Huttula and is amplified in LTR/94/3.l.

26. The main objective is to use meteorological data to calculate horizontal and vertical water movement. This provides the possibility to study the transport the of nutrients or suspended particles (e.g., phyto- and zooplankton, fish eggs) that are crucial for fish production.

27. The main nutrient inputs are through rain, runoff, and from the anoxic depths of the lake. The model shows that upwellings are patchy and that vertical and horizontal water movements are great.

28. The 3-D model has been built and it is to be refined and verified in 1995 using data collected during April and August cruises of the *R/V Tanganyika Explorer.* The number of cruises is appropriate considering the data needs of the model and in light of the possibility of collecting additional data during the three planned cruises for hydroacoustical data and trawling. In addition, it may be possible to have a shipboard meteorological station as another data source. A PC—based version of the hydrodynamic model is to be made available in 1996.

Remote Sensing

29. This was presented by Dr. 0. Lindqvist and is amplified in LTR/94/3 .5.

30. The main objective of this component, largely financed by funds from the University of Kuopio, is to study the spatial and temporal distribution of temperature and chlorophyll and how these are related to the functions of the ecosystem.

31. Inhibition of phytoplankton production due to UV light in the near surface layers combined with the relative water clarity makes the use of satellite data for chlorophyll estimation a problem.

32. The main satellite sensor on NOAA-ll has failed and may not be replaced by NOAA-14 until mid-1995. Satellite data for temperature will be incorporated in the hydrodynamic model and in the limnology programme.

Limnology

33. This was presented by Dr. P.-D. Plisnier and set out in detail in LTR/94/3.2a.

34. The main purpose of this component is to provide environmental data to better understand the nutrient dynamics and physical processes that relate to the abundance, distribution and production of fishes.

35. The main result, for the moment, is a hypothesis on a pulsed production that links winds to the transport of nutrients from the hypolimnion upward to the productive zone. Nutrients are transported by upwelling, mainly in the south, during the windy dry season. Internal waves of short and long frequency also are set up by these wind forces. These waves, too, transport nutrients vertically, but do so throughout the lake. They prevail after upwelling events have generally ceased and they gradually decrease throughout the year until the beginning of the next windy season.

36. The programme for 1995 includes continuing the existing programme at the fixed stations and extending measurements lake wide as part of the hydroacoustic—trawling cruises.

Carbon-Energy Budget

37. This was presented by Dr. J. Sarvala and is amplified in LTR/94/3.2b.

38. The main purpose of this component is to relate primary production and dissolved organic matter to fish production.

39. An important finding is that in order to fully measure primary production, changing radiation conditions must be taken into account on a short time basis (hour, day) and measurements must reach as deep as 45 m.

40. The programme for 1995 is to begin primary production, chlorophyll—a, and light measurements in January. Measurements will be made both at fixed stations throughout the year and

during cruises. Experiments on the importance of dissolved organic matter will also be performed on the cruises.

41. On a related matter, it would be useful to know the kinds of phytoplankton; however, the workload of the project is already very heavy and the budget is limited. As a solution, the project will endeavor to identify a regular institution to contract for the identification of zooplankton by group. Therefore, the effort should remain with the latter.

<u>Zooplankton Biology</u>

42. This was presented by Ms. H. Kurki and is amplified in LTR/94/3 .3.

43. The purpose of this component is to relate the seasonal and spatial variations in abundance and distribution of zooplankton to the same parameters for fishes.

44. Crustacean zooplankters are important as the main link between primary production and pelagic fishes. No comparable studies have been completed prior to this one. Results show vertical movements that probably can be explained by predator avoidance. A problem is uncertain identification that causes noise in the data, but steps are being taken to improve this capacity.

45. The work for 1995 includes continuing the present sampling programme at fixed stations with a small reduction in data collection. Additional work is to correlate the distribution and abundance of the zooplankton with fish biological parameters and with fish stock abundance. In addition, zooplankton will be sampled in connection with the cruises for hydroacoustics and mid—water trawling. Carbon content of different development stages of copepoda will be determined and laboratory rearing experiments are to be carried out to make possible biomass and production estimates.

<u>Fish Biology</u>

46. This was presented by Mr. P. Mannini in concurrence with Mr. E. Aro. An amplified version of the report is LTR/94/3.4.

47. The purpose of this component is to understand the life cycles and demographic parameters of the pelagic species.

48. The uncritical use of fishery data can bias estimates of fish abundances as well as estimates of population parameters relating to the dynamics of stocks. Therefore, independent estimates are required from hydroacoustic surveys and from experimental fishing during the cruises. Meanwhile, length-based methods have been used to make some preliminary estimates of growth and mortality for the three most commonly occurring pelagic species.

49. Reproduction of clupeid species varies from north to south as does their food. Likewise the feeding pattern of *L. stappersii* varies from around the lake. The marked difference in length catch composition of *L. stappersii* along the longitudinal axis of the lake was pointed out.

50. Fishing mortality as exerted by the different fishing gears in use around the lake has been outlined.

51. Shrimps are very important food items for *L. stappersii,* but are little known taxonomically and ecologically.

52. The preliminary results of the daily growth increments of *L. miodon* using otoliths were briefly presented by Dr. Sarvala. This approach seems promising. A similarity between growth estimates from otolith reading and length–based methods seems to exist. If the otolith technique proves reliable, training will be given and age determination by otoliths will be incorporated in the programme of work. Still, length-based methods will have to be used as otolith reading of longer life species as *L. stappersii* can be difficult.

53. The programme for 1995 will be continued in its present form at already–established sampling locations up to June in order to have two full years of data and will be considerably expanded to accommodate the data to be collected during the hydroacoustic–mid water trawling cruises.

<u>Fish Genetics</u>

54. This was presented by Ms. P. Kuusipalo and is set out in more detail in LTR/94/3.4.

55. The purpose of this component is to estimate the level of genetic identity among local pelagic fish populations. So far the RAPD method has proved to be suitable for the study of *L. miodon.* Individual populations can be clearly identified by the presence or absence of genetical markers. The preliminary analyses indicate eight populations belonging to four geographically distinct groups.

56. In 1995, studies on *L. miodon* will be amplified and investigations of the other species will be completed using material collected synoptically from the experimental fishing during the cruises.

<u>Fishery Statistics</u>

57. This was presented by Mr. E. Coenen and is amplified in LTR/94/3.4.

58. Catch from the lake has been increasing and amounted to 170,000 t in 1992 with an estimated value of 26 million dollars. The fisheries employ about 40,000 fishermen.

59. Industrial units are on the decrease while artisanal units are increasing.

60. The 1992 catch amounts to about 51 kg/ha, ranging from 94 kg in Burundi down to 34 kg/ha in Zaïre. In comparison, earlier estimates of potential have ranged from 90 to 140 kg/ha, but the potential estimates have to be considered with caution.

61. Historical annual industrial catches show periods of equilibrium and disequilibrium in the composition of clupeids and *L. stappersii* and the same phenomenon extends to artisanal catches. Similarly, there are intra–annual changes in species composition.

62. A Deterministic Recruitment/Production model has been used to predict the evolution of *L. stappersii* bioinass in the Mpulungu area based on differing fishing efforts. These results clearly show the importance of fishery statistics to inferences on the status of stocks and for the development of the fishery management plan.

63. Regarding the upcoming year's programme, a statistical coordinator's meeting and a simultaneous frame survey are programmed for December 1994 and February, 1995, respectively. Assistance to individual countries is to be continued.

ITEM 6: LTR SCIENTIFIC COORDINATOR'S REPORT: SUMMARY OF SSP RESULTS AND PROPOSAL OF SSP PROGRAMME FOR 1995

64. This was presented by Dr. 0. Lindqvist. The report is LTR/94/4.

65. Much of the information in this report, in summary form, was presented following each of the component reports (above) in the form of supplementary comments, explanations and observations, as well as brief descriptions of the programmes of work for 1995 for each component. Therefore, these are not repeated here.

66. In summary, scientific results from each component (paragraphs 25-63 above) indicate that the existing SSP has to be continued into 1995. Moreover, an intensive period of cruises will begin early in 1995. These activities will require even greater effort by the project's field staff and increased technical inputs and coordination by Finnish scientists. Additionally, in order to maintain these activities at levels needed to ensure goods results, project funds will be expended at rate to the point that the life of the project will be shortened unless additional funds can be obtained from FINNIDA, sources such as GEF and other donors.

ITEM 7: MANAGEMENT OF LAKE TANGANYIKA FISHERIES RESOURCES

67. This was presented by Dr. G. Hanek and is amplified in LTR/94/5. The paper gave an update on the characteristics of the fisheries, the present status of former management discussions and initiatives, mainly through the regular meetings of the CIFA Subcommittee for Lake Tanganyika dealing also with other aspects

and activities regarding the fisheries on Lake Tanganyika. A proposal towards possible management actions for the resources of the lake was also presented. Possible guidelines and strategies for the elaboration of the plan by LTR with the assistance of the riparian countries were presented: the plan should be simple, should include a description of the resource, describe existing regulations, possible needs, regulation of fishing effort (to be increased or not). The plan also has to be based on sufficient knowledge of the resource and on country databases and also the involvement of the fishing community as the latter will have to accept the proposed measures. Some management actions could already be taken now. Regarding the elaboration of the plan, the role of the two joint Committees should therefore also be strengthened. Some actions, however, fall out of the scope of LTR. Other projects and organizations, the still to be created Lake Tanganyika Fisheries Commission (LTFC), etc. also are expected to contribute.

68. It was proposed that one person per country would be named to prepare a country statement involving the fishing communities’ views. A workshop on management, scheduled June 1995, should result in a draft management plan to be presented during the 4th Joint Meeting.

69. It was also noted that the elaboration of such a plan is a very complex task involving details of different areas and species, different gears, etc. The first hydroacoustical data will be very important to be available during planned workshop. The research results will contribute to a major part in the elaboration of the plan, especially the hydroacoustical estimates concerning the large pelagic area of the lake. It is important to see what is possible to do, taking into account country realities. The plan should indeed stay simple and fair for each of the 4 riparian countries and aim at the sustainability of the resource.

70. It was also observed that management touches socio—econoinics and the involvement of the fishing communities. Maybe an institution should be created to continuously involve the fishermen’ s communities.

71. It was remarked that maybe not enough data will be available to start the elaboration of such a plan. Data collection systems are not yet fully standardized. Doubts were raised about the fact that it might be too early to talk about management at this stage. Also, socio—econoinics are important as fishermen very often do not care about regulations and law enforcement. Changing the situation has often proven to be very difficult.

72. It was also noted that the process of initiating management discussions should start early as a lot of people and institutions are involved. Also the after-project realities should be considered now.

73. It was noted that harmonization of data collection and fishing gear and mesh regulations are important. Closed seasons should be considered.

74. The need for the 4 Governments to take action was stressed. Indeed, the riparian countries will, in the end, have to bear the responsibility to undertake joint management activities.

75. It was pointed out that the riparian countries should prepare a country statement on management related aspects which should be presented at the next CIFA (7th) Sub-Committee meeting for Lake Tanganyika scheduled to be held around the end of 1995.

76. It was noted that the Project should make some management recommendations which then could be considered by the Governments although it might be a bit early (due to insufficient data) to do so.

77. After a lengthy discussion, it was finally agreed that the Workshop should be held in June, 1995.

ITEM 8: 1995 CRUISE SCHEDULE FOR *R/V TANGANYIKA EXPLORER*

78. The vessel will be commissioned in December, 1994 and the charter will start as of January, 1995. Meanwhile, there will be a mission to check and rig the fishing gear, test the hydroacoustic equipment and select the skipper and the crew. About a month will be required to do the trials. Thus, the first cruise will be in February, 1995 and it will be for hydroacoustics. It will incorporate intermittent experimental fishing using the trawl. A device for zooplankton collection and larval fish sampling will be mounted on the trawl. The CTD also will be used. During the cruise there will be several vertical and horizontal samplings for limnology.

79. The trawling fishing gear has been designed, and will be tested, by FAO experts. Trawling was selected as the experimental fishing method that provides the most representative and least biased information.

80. The second cruise will take place at the end of March for hydrodynamics. It will cover both open waters and the mouths of estuaries. Meteo data will be collected simultaneously. Sampling for a second component, carbon energy and primary production, and for a third, liinnology, also will be carried out.

81. National counterparts of each country will be included in each cruise on a rotational basis. Participation in the cruises is part of the counterpart training process. Selection of crews will be made well in advance by component leaders, one of whom will be the cruise leader. Cruise schedules will be sent to all Fisheries Departments. When in port, the vessel should be opened to the authorities, whenever convenient.

82. In all, it is expected that there will be three hydroacoustic cruises and two hydrodynamics cruises in 1995 each including additional components as described above.

ITEM 9: EVALUATION MISSION OF LTR

83. The meeting endorsed the terms of reference for the joint FINNIDA/FAO Evaluation Mission. FAO will submit them for approval by FINNIDA and will make the necessary arrangements for the mission to take place at the most appropriate time in April/May 1995. The project document provides for this mission to assess the continued relevance of the project objectives and the progress and quality of scheduled activities. Conclusions and recommendations of the mission will be taken into consideration in the preparation of a proposal for a project follow-up for consideration by FINNIDA. The meeting agreed that each Government would designate their representative to act as a resource person in their own country.

ITEM 10: VENUE OF THE NEXT MEETING

84. The meeting was invited to hold its Fourth Joint Meeting in Zaïre. FAO will endeavor to arrange to have the Lake Tanganyika Sub-Committee take place in conjunction with LTR’s meetings.

ITEM 11: ANY OTHER MATTERS

85. Messages stating absence with regrets and best wishes for the meeting were received from the Ambassador from Finland to Tanzania, from the UNDP Resident Representative in Burundi and from the GEF Coordinator in New York. Other congratulatory messages were received from Messrs. Doeff and Fitzpatrick from FAO HQ.

86. The meeting was informed that Mr. E Coenen will leave the project in May, 1995. His valuable contribution, much appreciated by all, was recorded by both Committees.

87. Zambia has been involved in the Agricultural Sector Investment Programme. As of 1995, all projects will have to be related to the goals of this programme, and LTR already features therein as an important project.

88. It was suggested that a few hours are set aside for informal discussions among delegates before the formal commencement of the joint meetings.

89. A concern was raised on the training of national scientists for higher degrees. The meeting was informed that external training opportunities are not within the scope of LTR. Training of the kinds presently being offered (on the job and through workshops) was deemed to be the most efficient way to train the largest number of national counterparts within the limits of this project’s immediate objectives and budgetary constraints.

90. Nevertheless, a number of training activities is scheduled. This includes training in primary production studies, on board activities associated with multipurpose cruises and continuing computer training of all LTR personnel.

91. The possibility of having university students participate in work at LTR laboratories was brought up and this suggestion

will be studied. University students already use the LTR documentation centers.

92. LTR’s Scientific Coordinator informed the meeting that the University of Kuopio, with funds from FINNIDA, will organize an International Symposium on Lake Tanganyika research in Kuopio, Finland from 11 to 15 September 1995. Scientists from the four riparian countries will be invited to contribute through papers, abstracts and posters.

ITEM 12: ADOPTION OF THE REPORT

93. The Coordination and International Scientific Committees adopted the report on 30 November 1994.

94. The Zambian delegation thanked Tanzania for hosting the Third Joint Meeting of the LTR Committees and expressed its appreciation to the Chairman for his efficient and effective chairmanship.

95. In his closing remarks, the Chairman expressed his gratitude to the Finnish participants and especially to FINNIDA for its continuous interest and financial support and to FAO for the effective execution of the project.

RESEARCH FOR THE MANAGEMENT OF THE FISHERIES ON LAKE TANGANYIKA

GCP/RAF/2711F1N

LTR/94/2

THIRD JOINT MEETING OF THE LTR'S COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

Kigoma (Tanzania), 28—30.11.1994

LTR COORDINATOR'S REPORT: SUNMARY OF LTR'S ACTIVITIES (JULY 1993 - NOVEMBER 1994)

1. INTRODUCTION

The summary of the LTR's entire preparatory phase was presented during the 2nd Joint Meeting of LTR Committees in Lusaka in October 1993. Consequently, this report details LTR's achievements during the first 17 months of the LTR's execution phase *i.e.* from July 1993 to and including November 1994.

2. RESULTS

2.1 SSP

While the LTR's hydrological subcomponent started already in March 1993, its Scientific Sampling Programme (=SSP) started officially on 20.07.1993. Ever since, the execution of this very complex and demanding programme occupies fully or part—time a large number of persons. The results of the first full year of SSP, for each of its subcoinponents as well as its overall summary, will follow this presentation and are thus not repeated here. Instead, it is considered important to officially record and acknowledge the extremely hard work and dedication of all LTR's field staff which managed to carry out the SPP without interrupthns, under very difficult conditions.

2.2 *R/V Tanganyika Explorer*

Its construction started on 11.11.1993. LTR staff has been closely associated with this very difficult project. It helped to design both the wet and dry laboratories and ordered and supervised the installation of a large number of highly technical and sophisticated material and equipment. In addition, the construction progress was closely monitored by LTR staff. Two technical inspections took place as well; both were carried out by Mr. J. Turner, FAO’s Senior Fishery Industry Officer (Vessels), during 23–27.01.1994 and 3–10.09.1994 respectively. All electronic equipment was installed and interfaced by Mr. M. Savinainen, LTR’s consultant, during 22.10-6.11.1994. As we meet, the vessel is now completed; its commissioning will start on 12.12.1994. At the same time the selection and training of *R/V Tanganyika Explorer’s* crew will be done, thus hoping for the official charter to start on 1.1.1995.

2.3 LTR’s First Workshop on the Coordination of Fisheries Statistics for Lake Tanganyika

This workshop was held in Bujumbura, Burundi from 26 to 30.07.1994; its conclusions and recommendations were presented during the Sixth Session of the CIFA Sub-Committee for Lake Tanganyika.

2.4 Second Joint Meeting of the LTR Coordination and International Scientific Committees

Was held in Lusaka, Zambia, from 14 to 15.10.1993.

2.5 Sixth Session of the CIFA Sub-Committee for Lake Tanganyika

LTR took part in this session which was held in Lusaka, Zambia, from 18 to 19.10.1993.

2.6 Visits of LTR stations by the members of LTR International Scientific Committee

These visits were organized and took place in February 1994. Consequently, Dr. Mubainba visited LTR/Mpulungu, Prof. Bwathondi visited LTR/Kigoma, Dr. Gashagaza both LTR/Mpulungu and LTR/Kigoma and Prof S. Sarvala and Mölsä visited Mpulungu and Kigoma. In addition, immediately after this meeting, Prof. Bwathondi and Dr. Nyakageni will visit LTR/Mpulungu.

2.7 LTR Documentation Center

Thanks to the effective cooperation of FAO’s Fisheries Branch Library as well as that of many friends LTR’s Documentation Center continues to grow. Since April 1994 it is managed by Ms. S. Ndahigeze.

2.8 <u>1994 World Food Day</u>

This years WFD's theme was 'Water for Life'. It was celebrated in Burundi from 10-15.10.1994. LTR's activities were prominently featured on 14.10.1994 when a large number of prominent personalities and local media visited LTR's headquarters where a detailed briefing was provided.

2.9 <u>Training</u>

* **LTR's First Workshop on the Coordination of Fisheries Statistics for Lake Tanganyika;** Bujumbura (Burundi), 26-30.07.1993. Workshop leader: Mr. E.J. Coenen; 12 participants from Burundi, Tanzania, Zaïre, Zambia and Finland;

* **1st Assessment of** SSP; Kigoma (Tanzania), 30.08.1993. Meeting leader: Mr. E.J. Coenen, 18 participants from Burundi, Tanzania, Zaïre, Zambia and all LTR technical staff;

* **Training course in hydrodynamics;** Bujumbura (Burundi), lake and Kigoma (Tanzania), 26.02—13.03.1994. Course and cruise leaders: Dr. T. Huttula and Mr. J. Nieminen; 12 participants from Burundi, Tanzania, Zaïre, Zambia and LTR technical staff;

* **2nd Assessment of SSP; Kigoma (Tanzania),ll—12.04.1994.** Meeting leaders: Messrs. G. Hanek and E.J. Coenen; 21 participants from Burundi, Tanzania, Zaïre, Zambia, all LTR international staff and two observers from Finland;

* **Training course in carbon energy budget; Kigoma** (Tanzania), 13.04.1994. Course leaders: Drs. J. Sarvala and K. Salonen; 15 participants from Burundi, Tanzania, Zaïre, Zambia and LTR technical staff;

* **Participation at the Final Seminar of UK/SADC Pelagic Fish**
  Resource Assessment Project; Senga Bay (Malawi) , 9—11.05.1994. Messrs. Katonda, Chitamwebwa and Mannini, all from LTR/Kigoma, took part;

* **Training courses in fish biology sampling:** in Bujumbura (Burundi), 25-27.04. and 21.10.1994. Course leader: Ms.P Paffen, 2 participants from Kalemie (Zaïre); in Uvira (Zaïre), 02—04.06.1994. Course leader: Ms. P. Paffen, 2 participants from Uvira (Zaïre); in Karonda (Burundi), 15.06.1994. Course leader: Ms. P. Paffen, 1 participant from Karonda (Burundi);

* **Training courses in** operation of wind stations: in Mpulungu (Zambia), 11—12.03.1994. Course leader: Mr. P. Kotilainen, 2 participants from Mpulungu (Zambia); in Bujumbura (Burundi), 25-27.04.1994. Course leader: Mr. P.Kotilainen, 2 participants from Kaleinie (Zaïre);

* **Training courses in operation of CTD probe: in Kigoma** (Tanzania), 24–29.08.1994. Course leader: Mr. V. Langenberg, 2 participants from Kigoma; in Mpulungu (Zambia) , 10–17.09.1994. Course leader: Mr. V. Langenberg, 2 participants from Mpulungu; and

* **Ongoing computer training** of counterparts in WordPerfect, Lotus, Excel, ProCite and other software at all LTR stations.

2.10 LTR Personnel

There were numerous personnel changes during the last year. A number of national colleagues joined LTR, some replacing those transferred elsewhere or simply strengthening the existing staff in order to cope with the demanding SSP. LTR's international staff has also increased as four additional Associated Professional Officers, all Dutch nationals, joined LTR during November–December, 1993. Recently, the exceptional contract extensions for APO's Kotilainen and Kurki were secured thus ensuring the continuity of two SSP's subcomponents.The number of Finnish scientists who are associated with LTR has also increased.

The imminent task now is to select the captain and the crew for *R/V Tanganyika Explorer.* This task will be coordinated by Mr. J. Turner, FAO's Senior Fishery Technology Officer (Vessels) and LTR consultant Mr. G. Pajot, starting on 12.12.1994.

The continuous and effective cooperation of all the four participating States is now recorded and gratefully acknowledged. All of them assigned a large number of competent researchers and technicians to the LTR stations around the lake. It goes without saying that without our national colleagues it would be not be possible to execute the SSP. The dedication and hard work of LTR' s national counterpartS is hereby recorded and acknowledged.

It is also important to record the dedication and hard work of all LTR's international staff. Consequently, it is essential that the present budgetary constraints are resolved soonest so that contract extensions for all LTR's experts as well as all LTR's Associated Professional Officers are secured. It should be also noted that at least one additional APO is urgently required for LTR/Kigoma and the continuity of other APO's ensured at all costs (note: all six APO's presently with LTR are due to leave, definitely, at the end of 1995).

In view of the above and further considering the important additional work load, both in the field as well as for the reporting, once *R/V Tanganyika Explorer* cruise programme starts in January 1995, it is extremely important that the required steps, including budgetary ones, are taken without delay.

The effective operational and technical backstopping is now also recognized and recorded.

2.11 LTR Publications

The following LTR publications were produced since the Second Joint Meeting of LTR Committees:

A. Technical Documents

Coenen, E.J., Rapport sur le Premier Atelier Statistique sur
1993 la Coordination et la Standardisation des Statistiques des Pêches pour le lac Tanganyika (Bujumbura, 26-30 juillet 1993). FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika.
GCP/RAF/271/FIN-TD/11 (Fr): 11p., 5 ann.

Hanek, G. (ed.), Reports of Travel of project GCP/RAF/271/FIN.
1993 FAO/FINNIDA Research for the management of the Fisheries on Lake Tanganyika.
GCP/RAF/275/FIN—TD/12 (En): 96p.

Hanek, G. and E.J. Coenen, Report of the Second Joint Meeting
1993 of the LTR's Coordination and International Scientific Committees. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN—TD/13 (En): 35p.

Hanek, G. et E.J. Coenen, Rapport de la Deuxième Reunion
1993 Conjointe du Comité de Coordination et du Comité Scientifique International. FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika.
GCP/RAF/271/FIN-TD/13 (Fr): 39p.

Hanek, G. (ed.), 1993 Lake Tanganyika Fisheries Directory/
1993 Répertoire des pêches du lac Tanganyika 1993. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/14 (En & Fr): 69p.

Coenen, E.J. (ed.), Historical data report on the Fisheries,
1994 Fisheries Statistics, Fishing Gears and Water Quality of Lake Tanganyika (Tanzania). FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN—TD/15 (En & Fr): 115p.

Coenen, E.J. Semi-industrial fishing on Lake Tanganyika, with
1994 special reference to the fisheries statistics of the industrial fishing fleet of Kalemie (Zaïre), 10.92—11.93. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/16 (En): 39p.

Coenen, E.J. & G. Hanek, Report on LTR's Second Scientific
1994 Sampling Programme Assessment Meeting, Kigoma, 11 12.04.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/17 (En): 20p.

Coenen, E.J. Frame Survey results for Lake Tanganyika, Burundi
1994 (28—31.10.1992) and comparison with past surveys. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN—TD/18 (En): 26p.

Hanek, G. (ed.) Reports of Travel 31-45 of project
1994 GCP/RAF/271/FIN. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN—TD/19 (En): 71p.

Huttula, T. and V. Podsetchine, Hydrological modelling on Lake
1994 Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/20 (En): 19p.

Huttula, T. et V. Podsetchine, Modèle hydrologique au lac
1994 Tanganyika. FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika.
GCP/RAF/271/FIN-TD/20 (Fr): 19p.

Parkkinen J., Tuomainen V., Patomaki L., Lindqvist 0. V. and
1994 **Molsa H.** Designing Satellite Image Analysis for the Lake Tanganyika Research Project. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/21(En):28p.

Parkkinen J., V. Tuomainen, L. Patomaki, O.V. Lindqvist et
1994 **H. Molsa,** Analyses des dessins des images par satellite pour le projet de Recherche au lac Tanganyika. FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika.
GCP/RAF/271/FIN-TD/21(Fr): 29p.

Vuorinen, I. and H. Kurki, Zooplankton sampling on Lake
1994 Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN—TD/22 (En): 42p.

Vuorinen I. & H. Kurki, Résultats préliminaires sur
1994 l'échantillonnage du zooplancton au lac Tanganyika. FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika.
GCP/RAF/271/FIN-TD/22 (Fr): 43p.

Kuusipalo, L., Assessing genetic structure of pelagic fish
1994 population of Lake Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/23 (Fr): 14p.

Kuusipalo, L., Evaluation de la structure génétique des
1994 populations de poisson pélagique au lac Tanganyika. FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika.
GCP/RAF/271/FIN-TD/23 (Fr): 14p.

Coenen, E.J. & Nikomeze E., Lake Tanganyika, Burundi, results of
1994 the 1992-93 Catch Assessment Surveys. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/24 (En): 27p.

Coenen, E.J. & Nikomeze E., Résultats des Enquêtes d'Evaluation
1994 des Captures de 1992-93 au lac Tanganyika, Burundi. FAO/FINNIDA. Recherche pour l'Aménagement des Pêches au lac Tanganyika
GCP/RAF/271/FIN-TD/24 (Fr): 28p.

B. Field Guides and Manuals

Plisnier, P.—D., Field Manual for limnological sampling on
1993 Lake Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN—FM/07 (En): 37p.

Plisnier, P.-D., Manuel de terrain pour l'échantillonnage
1993 limnologique au lac Tanganyika. FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika.
GCP/RAF/271/FIN-FM/07 (Fr): 42p.

Mannini, P. Field Notes for Fish Biology. FAO/FINNIDA Research
1993 for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-FM/O8 (En): 34p.

Kurki, H. Field Notes on Zooplankton. FAO/FINNIDA Research for
1993 the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-FM/09 (En): 26p.

Kotilainen, P., Field notes for hydrodynainic studies.
1993 FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-FM/1o (En): 32p.

Heinonen, M., Regional Documentation Centre for Lake Tanganyika
1994 Fisheries Research: Acquisitions 1993/ Le Centre Régional de Documentation pour la Recherche des Pêches au Lac Tanganyika: Acquisitions 1993. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-FM/11 (En & Fr): 140p.

Langenberg, V.TH., Operation manual for STD-12 plus. FAO/FINNIDA
1994 Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-FM/12 (En): 16p.

C. Travel Reports

No.28: Bujumbura and Kigoma: P.-D. **Plisnier** (21.06 - 09.07.93), 3p.

No.29: Kalemie, Moba et Bukavu: M.W. **Bazolana** (14.04 -

23.05.1993), 13p.

No.30: Kigoma, Tanzania: M. **Heinonen** and M. **Gonçalves** (11-14.08.1993), 3p., 10 ann.

No.31: Kigoma, Tanzania: E. **Coenen** (28.08-01.09.93), 3p.

No.32: Uvira and Kigoma: G. **Hanek** (9-15.09.1993), 4p.

No.33: Rome and Bujumbura: P. **Paffen** (14-20.11.1993), 3p.

No.34: Mpulungu, Zambia: P. **Mannini** (24.11 – 01.12.1993), 2p.

No.35: Kuopio and Tampere, Finland; Horten, Norway and Rome, Italy: P. **Kotilainen** (09.09 – 10.11.1993), 6p.

No.36: Mpulungu, Zambia: E. **Bosma** and P. **Verburg** (01.11 - 07.12.1993), 5p.

No.37: Rome, Italy and Bujumbura, Burundi: V. **Langenberg** (01-11.12.1993), 3p.

No.38: Rome, Italy: G. **Hanek** (10-13.01.1994), Sp.

No.39: Kigoma, Tanzania and Mpulungu, Zambia: G. **Hanek** (16-23.02.1994), 4p.

No.40: Kigoma, Tanzania and Mpulungu, Zambia: M.M. **Gashagaza** (15–24.02.1994), 3p.

No.41: Kigoma, Tanzania and Mpulungu, Zambia: T. **Varayannis** (07-21.02.1994), 2p., 3 ann.

No.42: Kigoma, Tanzania and Mpulungu, Zambia: P. **Kotilainen** (01-17.03.1994), 6p.

No.43: Kigoma, Tanzania: G. **Hanek** and E.J. **Coenen** (10-15.04.1994), 5p.

No.44: Kigoma, Tanzania and Mpulungu, Zambia: M. **Heinonen** (10-27.04.1994), 2p.

No.45: Bujumbura, Burundi; Kigoma, Tanzania and Lake Tanganyika: T. **Huttula** and J. **Nieminen** (25.02 – 14.03.1994), 3p.

No.46: Senga Bay, Malawi: D.B.R. **Chitamwebwa**, K.I. **Katonda** and P. **Mannini** (06–17.05.1994), 9p., 1 ann.

No.47: Uvira, Zaïre and Karonda, Burundi: P. **Paffen** (02-04.06.1994 and 15.06.1994), 2p.

No.48: Irkutsk, Russia: V. **Podsetchine** (09-19.05.1994), 17p.

No.49: Mpulungu, Zambia: H. **Kurki** (23–31.07.1994), 3p

No.50: Dar es Salaam, Tanzania: E. **Coenen** and P. **Paffen** (24-31.07.1994), 5p.

No.51: Rome, Italy: G. **Hanek** (31.07 — 05.08.1994), 5p.

No.52: Kigoma, Tanzania: V. Th. **Langenberg** (23-30.08.1994), 3p.

No.53: Mpulungu, Zambia: E. **Coenen** (07-20.09.1994), 8p., 1 ann.

No.54: Kipili, Tanzania and Mpulungu, Zambia: A.D. **Kihakwi** and N.A **Challe** (06—22.08.1994), 3p.

No.55: Dar es Salaam and Kunduchi, Tanzania: G. **Hanek** (16—23.10.1994), 4p.

No.56: Rome, Italy and Bujumbura, Burundi: M. **Savinainen** (18.10 — 07.11.1994), 5p.

D. Progress Reports

No. 4: Progress Report for July - December 1993, G. **Hanek**, 8p.

No. 5: Progress Report for January — June 1994, G. **Hanek**, 9p.

No.1: APO's Progress Report by P. **Kotilainen**

No.2: APO's Progress Report by H. **Kurki**

No.3: APO's Progress Report by P. **Paffen**

No.4: APO's Progress Report by V. Th. **Langenberg**

No.5: APO's Progress Report by E. **Bosma**

No.6: APO's Progress Report by P. **Verbug**

E. Other Publications

LTR Newsletter No. 6 (September, 1993)

LTR Newsletter No. 7 (December, 1993)

LTR Newsletter No. 8 (March, 1994)

LTR Newsletter No. 9 (June, 1994)

LTR Newsletter No.10 (September, 1994)

THIRD JOINT MEETING
OF THE LTR'S
COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

Kigoma (Tanzania), 28–30.11.1994

PRESENTATION OF SSP RESULTS: HYDRODYNAMICS

by T. Huttula, P. Kotilainen, A. Peltonen and V. Podsetchine

1. INTRODUCTION

The aim of hydrological studies on Lake Tanganyika is to get detailed information on the flow and temperature regime of the lake and main factors influencing it. An intensive measurement program of meteorological parameters, flow and temperature was started in March 1993. Simultaneously, the development of a numerical circulation model of the lake begun in order to quantify the impact of different driving forces, like wind induced shear stresses, surface heat flux, and to verify the peculiarities of lake–wide circulation and occurrence of upwelling or downwelling events in the lake.

2. MATERIAL AND METHODS

Activities in hydrological SSP include the establishment of a meteorological network, consisting of four on–shore meteo and wind stations (Bujumbura, Kigoma, Kaleinie and Mpulungu), two buoy ineteo stations (off Mpulungu and off Kigoma) and two other wind stations (Kipili, Mpulungu) installed on the shore of the lake. Currents have been measured with flow cylinders from July 1993 on weekly basis at the vicinity of the three main LTR stations, i.e. Bujumbura, Kigoma and Mpulungu. At these stations, also three water level stations with automatic recorders are located. In addition, three hydrophysical cruises have been carried out. During the latest expedition in March 1994, CTD profiling was done at about 20 sites down to the depth of 300 in. During this cruise a new buoy station with a thermistor chain was installed off Kigoma. All the LTR stations and sampling areas are presented in Figure 1.

The basic data have been processed at the LTR field stations and further processing of the data for the calibration and verification of the applied numerical hydrodynamical model has taken place in Finland.

3. RESULTS

3.1 Primary observations

Although the investigations continue and the detailed analysis are still being processed, the experimental results along with the results of numerical modelling appear to be already significant. The results prove that the dynamical regime of Lake Tanganyika is dominated by the strong southerly winds particularly during the dry season.

The wind data of the north (Bujumbura) were compared to the ones from the south (Mpulungu lake meteo station), during the dry season. It was found that the momentum of wind per unit area in the south in July 1993 during a typical wind event was three fold to the one in the north.

The strong vertical mixing and upwelling at Mpulungu station can bee seen in the data collected/recorded from June—July 1993. The winds cause tilting of the thermocline. The stratification is rebuilt in October (Figure 2). The data of flow cylinder measurements show that currents at depths of 2 to 40 m near Bujuinbura mainly follow the winds but there are also occasions when the results reveal a compensational currents (Figure 3).

3.2 Model development

In the three dimensional numerical flow and lake temperature model the lake bathymetry is described using a grid system with 2700 triangular elements (Podsetchine and Huttula, 1994). At the moment, the model is able to calculate the flow field and upwelling in a totally hoinogenous water mass (barotropic model). In the near future, the thermal stratification will be included.

Short wave radiation heat flux can be calculated with an accuracy of 7 - 10 % with empirical formulae, applied earlier for lakes in temperate zones (Huttula *et al.,* 1992).

Results of simulation of the circulation patterns using the three—dimensional barotropic numerical model (Figure 4) reveal that, in the case of the steady, spatially homogeneous winds, the zones of strongest currents are located in the shallow places to the south of Cape Bangwe (near the Malagarasi estuary) and in the region of the Ifumi estuary, also on the east coast. Calculated zones of upwelling have an irregular patchy structure (Figure 5). When the model will be further developed, including the temperature stratification, the water current structure will likely differ from the one presented. The currents in the epilimnion will probably be stronger and the location of upwelling and downwelling areas will differ from the results of this report.

4. CONCLUSIONS

Analysis of hydrological data together with preliminary modelling results suggest that further stages of the hydrodynamical sub—component should concentrate on the study of baroclinic effects (vertical temperature and density stratification) and on the effects of spatial non-homogeneity of the near—surface wind field. In this respect, the need of calibration and verification data becomes evident. The lake wide expeditions will then be of great importance as the SSP data, from wind and meteo stations, are presently collected at fixed locations, and thus covering the lake insufficiently. Lake wide wind, water current and CTD measurements on the lake could provide important information, guaranteeing further development of the modelling. A major step in this respect would be a meteorological station on the *R/V TANGANYIKA EXPLORER.*

5. REFERENCES

Huttula T., Peltonen A., Bilaletdin A. and Saura M. **1992** The effect of climatic change on lake ice and water temperature. Aqua Fennica, Vol. 22(2): 129 — 142.

Huttula T., Podsetchine V. **1994** Hydrological modelling on Lake Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. GCP/RAF/271/FIN-TD/20 (En) : 19 p.

Podsetchine V. and Huttula T. **1994** Hydrological modelling on Lake Tanganyika, part II. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. In preparation.

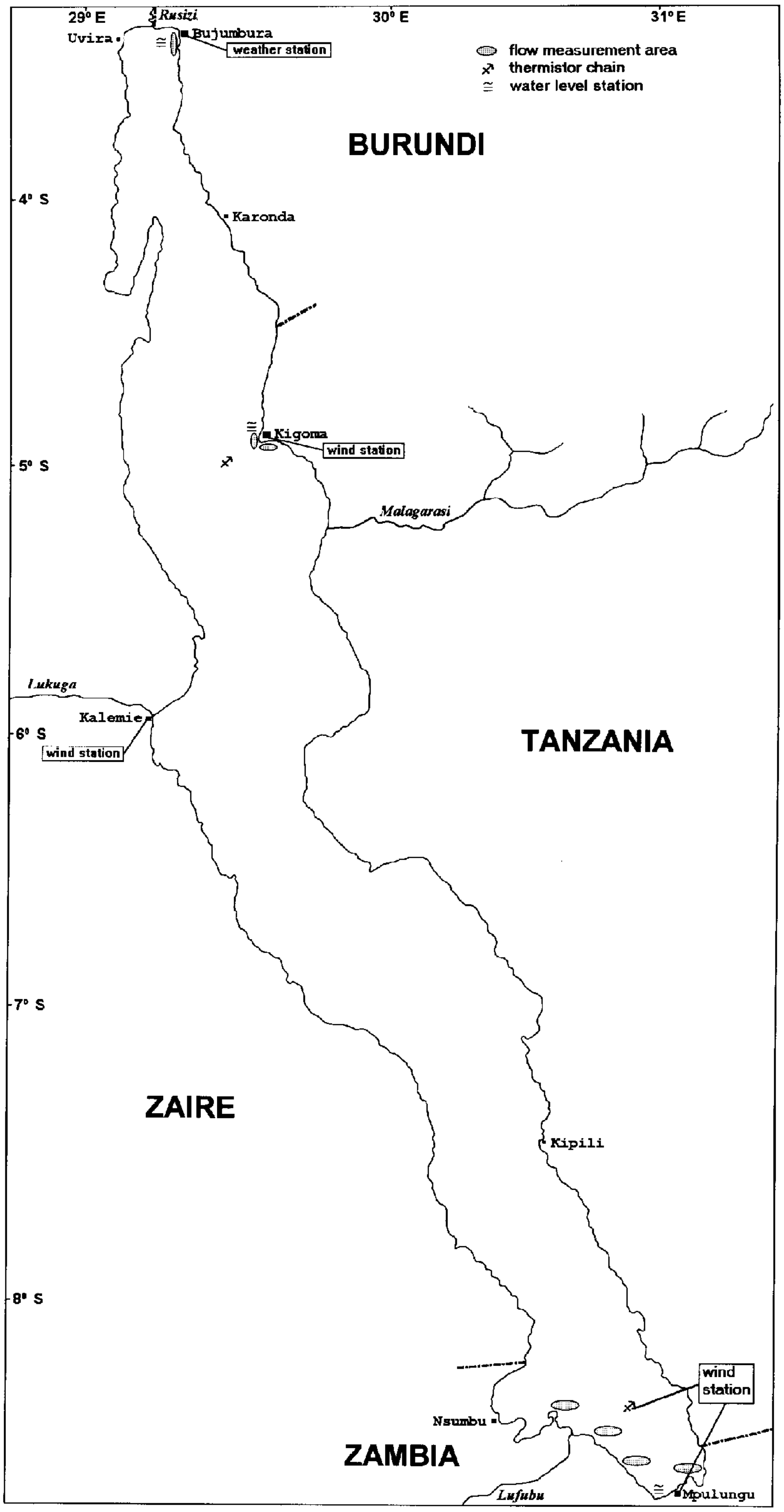

Figure 1. LTR stations and sampling areas in hydrodynamics

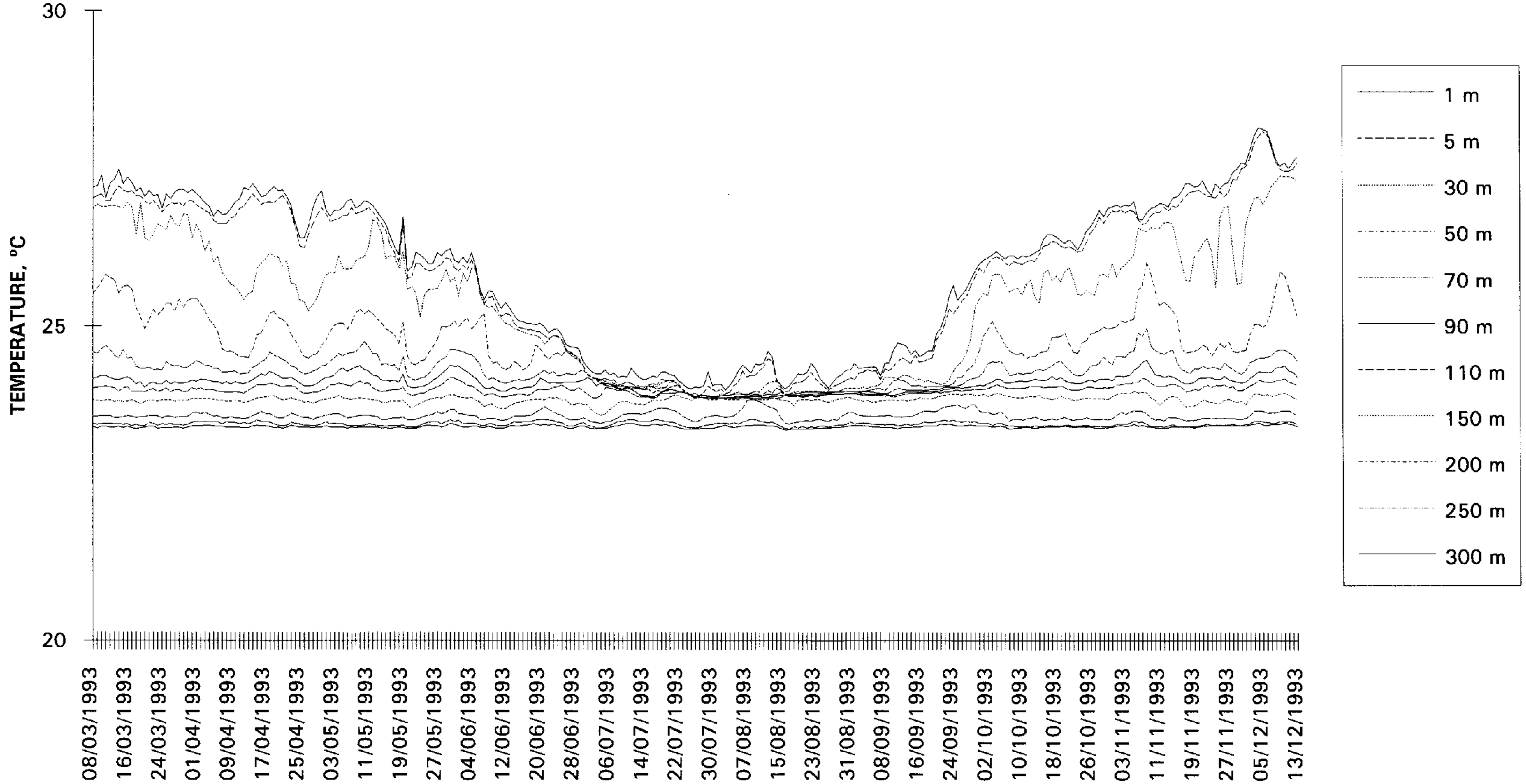

Figure 2. Water temperature stratification at different layers at Mpulungu lake meteo station.

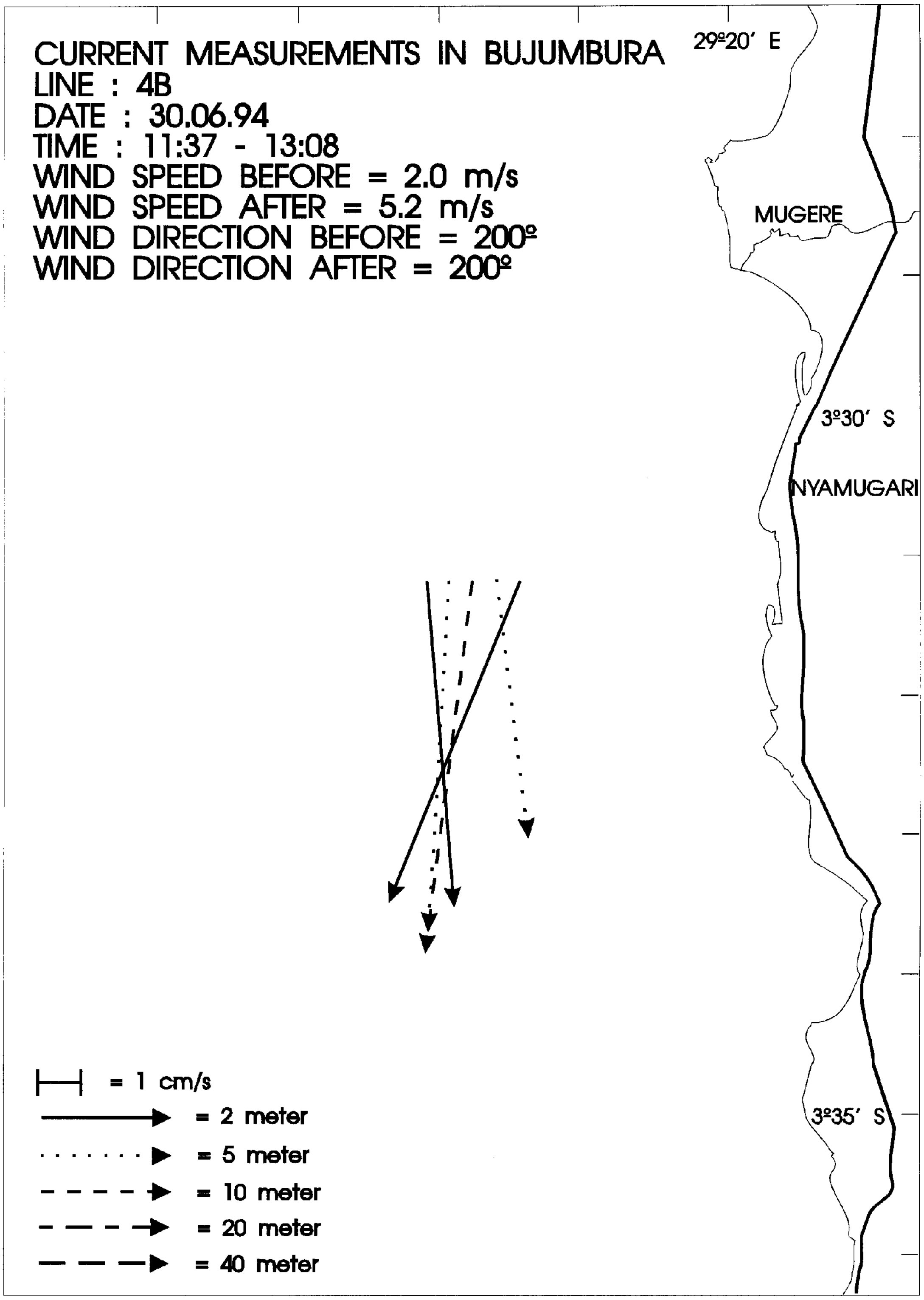

Figure 3. A current measurement off Nyamugari (south of Bujumbura) in June 1994.

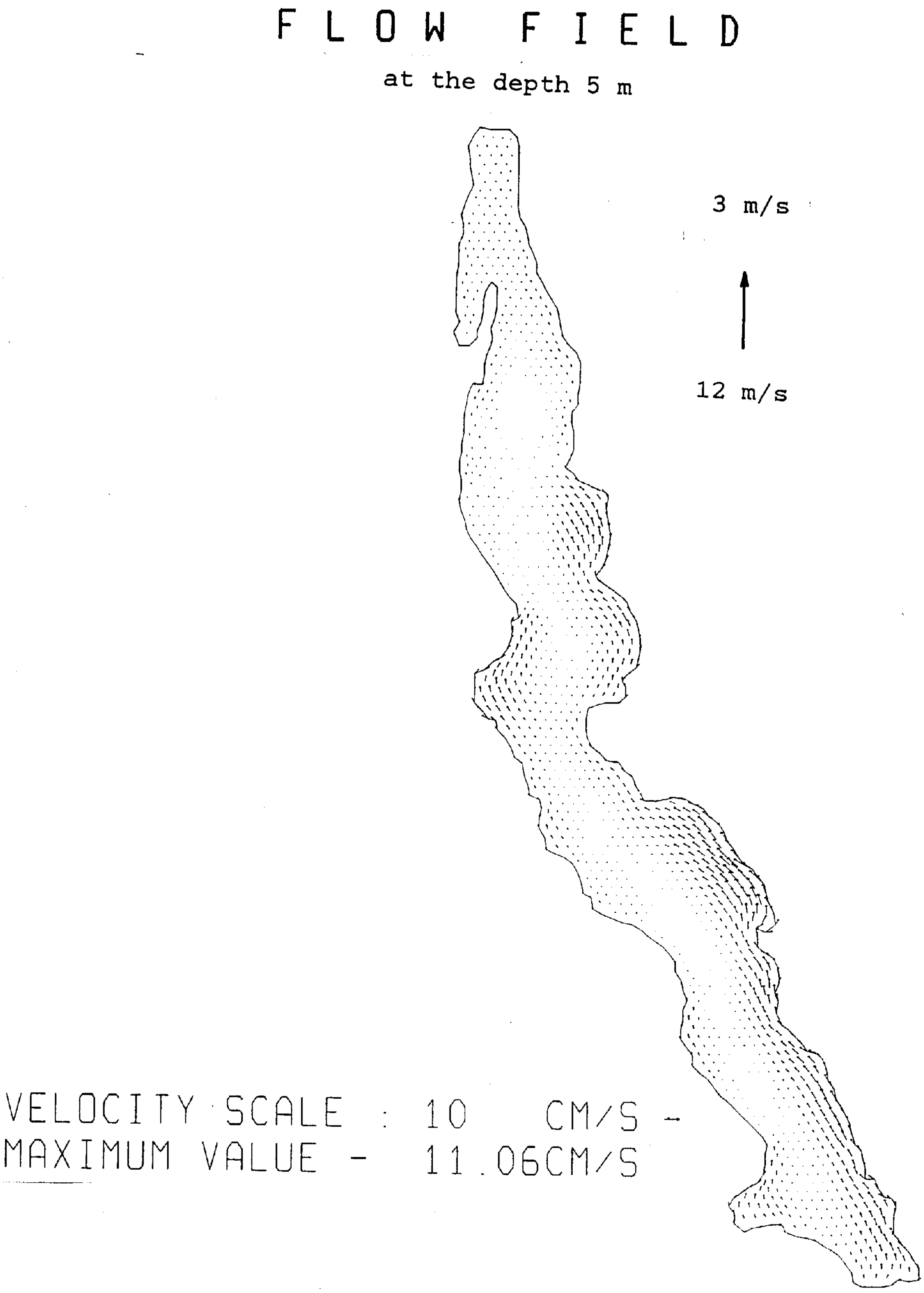

Figure 4: Simulated flow field according to three-dimensional barotropic numerical model

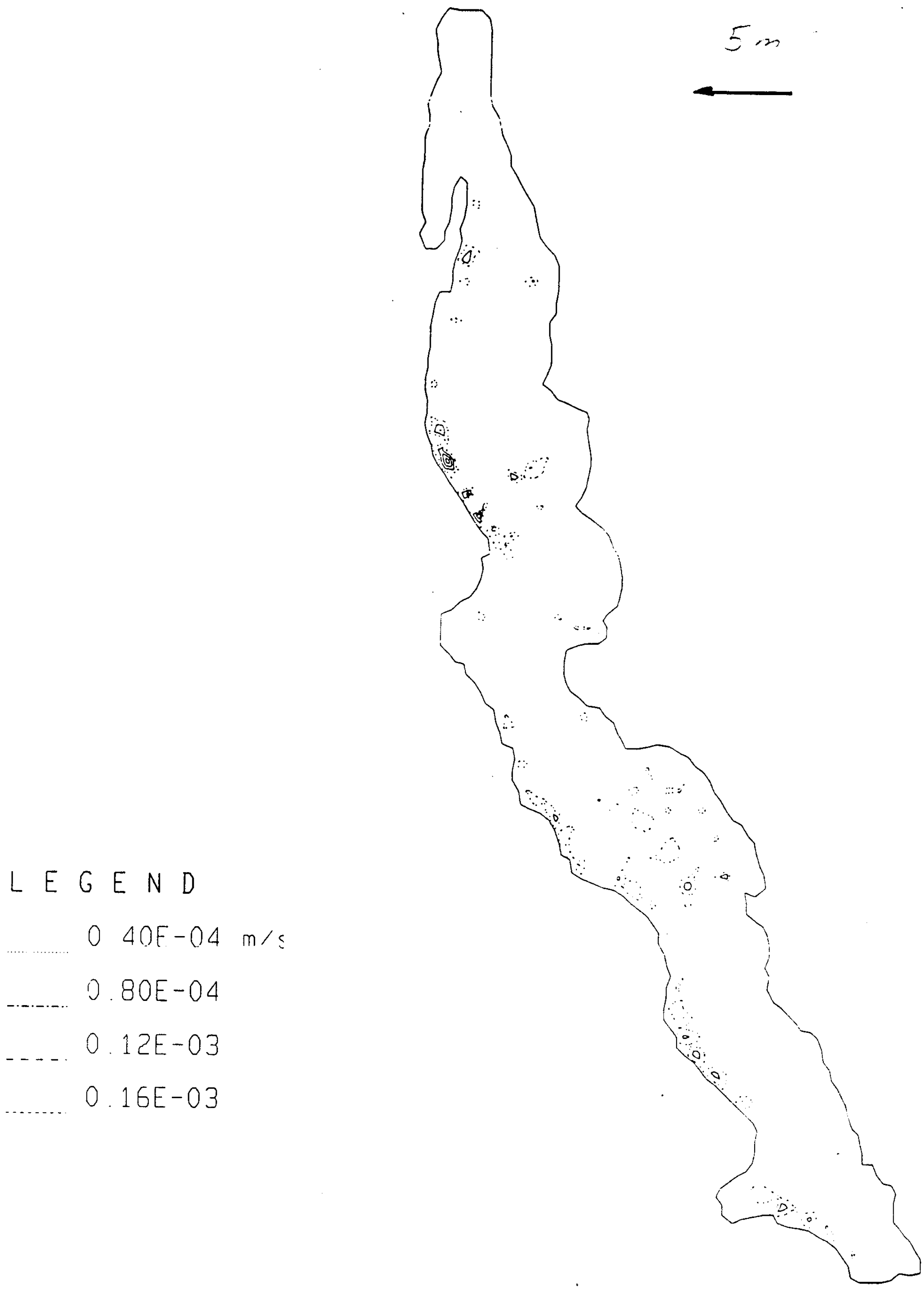

Figure 5: Vertical velocity at the surface: zones of upwelling

LTR/94/3.2a

THIRD JOINT MEETING
OF THE LTR'S
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Kigoma (Tanzania), 28–30.11.1994

PRESENTATION OF SSP RESULTS: LIMNOLOGY

by P.–D. Plisnier

1. INTRODUCTION

The objective of the limnological component is to provide information on the evolution in time and space of some of the main physical and chemical water parameters in order to provide environmental data that could help to better understand the abundance or scarcity of organisms targeted by the project: fishes and zooplankton mainly but also other potentially important organisms in the food web...

The nutrient concentrations and their fluctuations also provide important information which can be linked with hydrodynamic phenomena in order to better understand the pattern of biological production of Lake Tanganyika and its relation with the meterological environment.

2. MATERIAL AND METHODS

Three different types of sampling have been performed in each station:

- regular sampling (A) from 0 to 100 M (2 to 4 per month)
- intensive sampling (B) from 0 to 300 in during a 24 H cycle (at
  12 H, 18 H, 24 H and 06 H) every 6 weeks.
- seasonal sampling (C) at same site than B (every three months).

Each sampling was realized in the pelagic area at a distance of about 4 km from the shore (Figure 1). Exact coordinates were recorded by GPS.

The following parameters have been measured during the weekly and intensive sampling: transparency (Secchi) , temperature, dissolved oxygen, pH, conductivity, total phosphorus (TP), phosphate (TRP as PO_4^{---}) , ammonia (NH_{4-N}), nitrite ($N0_2$–N) , nitrate ($N0_3$–N) and turbidity (NTU). During seasonal sampling total hardness, calcium, alkalinity, chloride, sulphates and silicates have also been measured. The above parameters were measured with the HACH DREL 2000 methods. Most of these methods proved to be accurate and fast enough to show the important trends detected. General ranges of concentration are also in agreement with previous studies (HECKY *et al,* 1978) but adding an important dynamic value to the previous information on the lake considering the wide geographical scale of the measurements of the LTR project and their complete annual cycle realized in a standard way. Some preliminary measurements of Chlorophyll a were realized during the first year of research as well as transects with an automatic CTD recorder, mainly for conductivity and temperature profiles.

During the first year of experiments, the three stations together have accomplished a total of 91 samplings of type A, 26 samplings of type B and 14 samplings of type C. The total number of measurements was about 2230 measurements of TO, pH, conductivity and turbidity. About 1000 measurements of nutrients (P, N) have been done. During the 14 seasonal samplings, 98 measurements of the main cations and anions were realized.

Other experiments, especially to study the very dynamic evolution of transparency of water, were carried out.

3. RESULTS

While the detailed analyses still are to be finalized, the following trends were recorded:

The lake profile could be divided in 4 different layers whose depths are variable during the year (Figure 2): the epilimnion fluctuated between 0 to 20 and 0 to 105 m of depth, the upper metalimnion including the main thermocline is generally observed between 50 and 120 xn. The lower metalimnion (or intermediate zone) generally starts between 50 and 120 m to at least 350 meters. It is probably deeper and future deep sampling during lake wide cruises will investigate on this. Finally the hypolimnion might be characterized arbitrarily by a temperature below 23,5 °C. It has been observed only a few times during mixing events.

The stratification, mainly observed in the upper metalimnion is sometimes almost absent (during the dry season from June to September) in the South of the lake while the stratification is still present but weaker at the same period at the two northern station of Buj.-Uvi. and Kigoma following mainly the strong southerly winds. A stratification index (defined as the standard deviation of the average monthly temperature of each depth) shows this clearly (Figure 3)

Following the end of the wind, around September-October, the thermocline seems to show an important oscillatory movement between the two ends of the lake. This is reflected by oscillation of some parameters such as pH and conductivity at each station (Figures 4 and 5) . Important surface waves during a no wind period have been noted in Mpulungu during those months as well as a fish kill in 1993 when deep anoxic water is found at unusually high levels. A possible explanation might be that the piling up of hot water with a deep thermocline in the north is not sustained anymore when the wind stops. As the epilimnion and lower layers tend to move back to their original equilibrium position, oscillation occurs. It seems to start in Buj.-Uvi, one month later in Mpulungu (Figures 4 and 5). At the beginning the period is close to one month. Afterwards, the period is becoming shorter and the amplitude of the variation decreases as time goes on. This process takes at least 8 month. It is an important process as it might be the source of the internal waves (seiches)

Analysis of the data shows important rhythmic variations in the concentrations at different depths in each station of the Project. Two types of rhythmic movement of water corresponding apparently to internal waves have been detected.

From the preliminary analysis of weekly sampling, it seems that internal waves (seiches) are characterized by a period close to 28 days (13 per year) . An example is provided for nitrite in Buj-Uvi, ammonia in Kigoma and phosphate in Mpulungu (Figure 6). This type of rhythmic fluctuation is observed indeed for all parameters measured during A and B sampling at each LTR station during the whole year.

Nitrate seem correlated with transparency. Example for Mpulungu is shown at figure 7. Low transparency and high nitrate peaks do sometimes match but not always. Maybe this is because of other factors involved (rain, stratification,...)

During the intensive sampling B, beside the long frequency waves observed (see above) , some high frequency waves (measured in units of days or hours) transport considerable amounts of nutrients, including the very significant ones for the productivity: nitrogen (as NH_4 often oxidized as NO_2^- and NO_3^- **)** and phosphorus (PO_4^{---}) . Fluctuations of other parameters also indicate the existence of these short frequency internal waves (SFIW) at different degrees (Figures 8,9 and 10)

Median and percentiles observations of all parameters are presented in figures 11 to 14. Difference in maximal values observed are related with movement of water as explained above. Closer links are found between Mpulungu and Buj.-Uvi than with Kigoma for several parameter fluctuation. As observed previously, extremely important concentrations of NH_4^- and Phosphorus are found in the deeper layers of the lake.

4. CONCLUSIONS

Both types of observed waves match the earlier observations mentioning internal waves of 3 days and the ones showing a more or less 26-33 days period (COULTER, 1968). Those previous observations were based only on temperature and dissolved oxygen measurements. The fluctuations in the concentrations of 7 more parameters seem to show that this could be a very important process in the productivity of the lake beside the upwelling phenomena during the dry season at the South.

In general, the lake seems to be of the oligotrophic type in the surface layers while deeper layers show eutrophic characteristics. The mixing (either deep, either reaching the surface) will, at precise moments of the year, generate a very fast growth of plankton and bacteria followed by a peak of the species feeding on those directly or indirectly (via zooplankton and other food webs). This could be the cause of an extreme patchiness noted by several authors.

The program of next year will continue vertical sampling and investigate more on horizontal variations (pelagic—coast) . Rain and river analyses are also undertaken.

5. REFERENCES

EAST W., M. HOLLAND & S.0.RYDING, 1989. Eutrophication Management framework for the policy-maker. **MAB Digest,UNESCO: 83 p.**

HECKY R.E., E.J. FEE & H. KLING, 1978. Studies on the plantonic ecology of lake Tanganyika. **Fisheries and Marine Service Technical Report No 816: 51 p.**

COULTER, G.W., 1968. Hydrological processes and primary production in lake Tanganyika. **Proc. 11th Conf. Great lakes Res.Intern. Assoc. Great Lakes Res: pp. 609—626.**

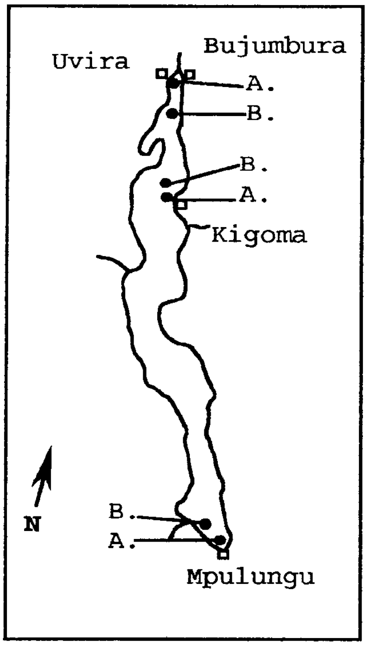


Figure 1: Position of weekly sampling A (0-100 m) and intensive sampling B (0-300m) near LTR station of Buj.-Uvi, Kigoma and Mpulungu.

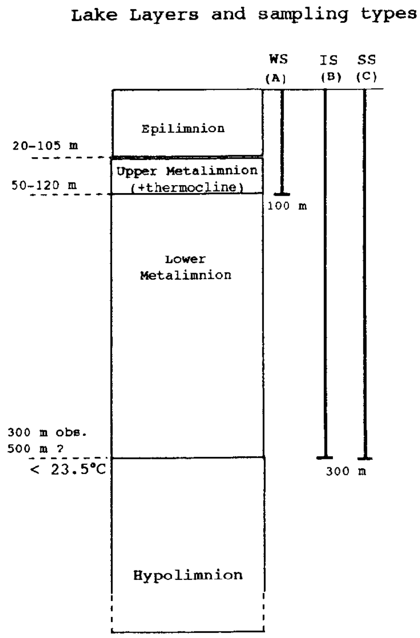


Figure 2 : Layers based on temperature stratification and known mixing. Sampling depth are shown (W.S = weekly sampling (A), I.S.= intensive sampling (B), S.S.= seasonal sampling (C)

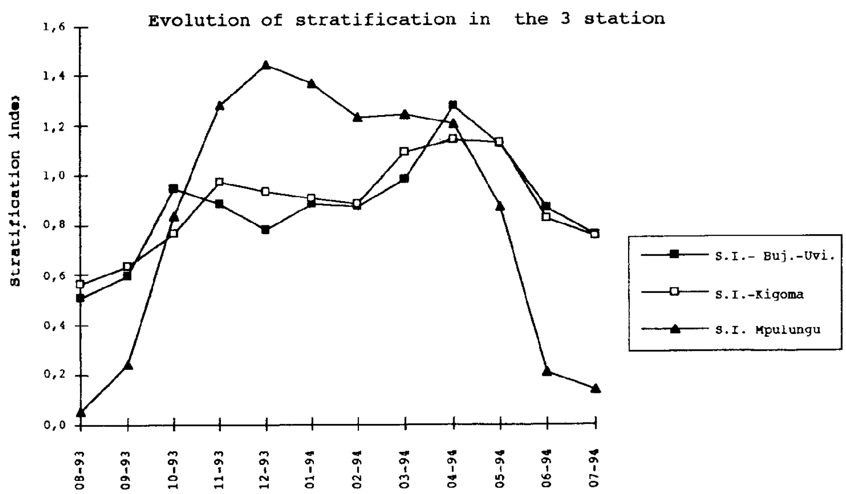


Figure 3 : Evolution of stratification index of temperature at site A of each station

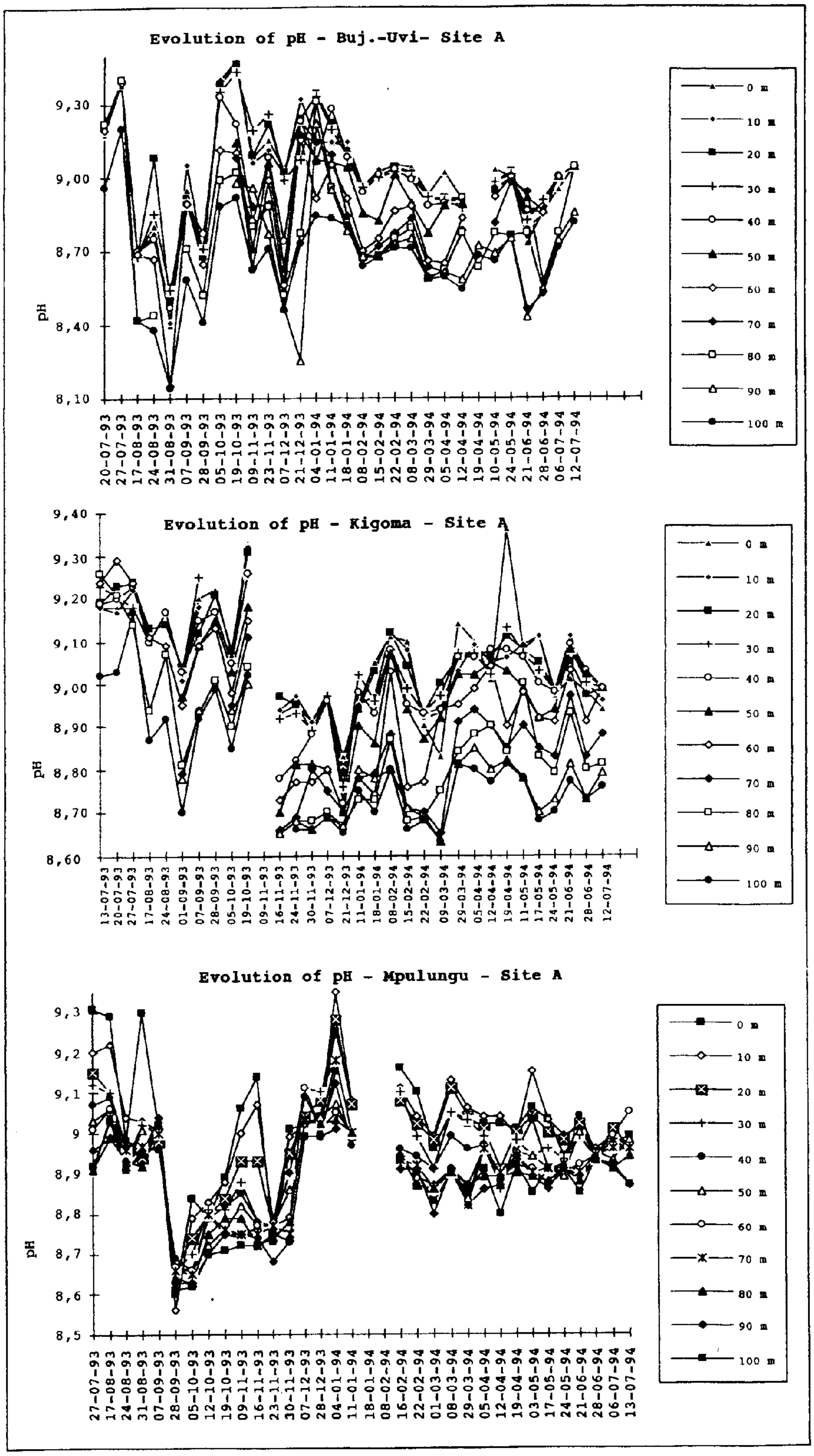


Figure 4: Evolution of pH in each station (site A) from July 1993 to July 1994.

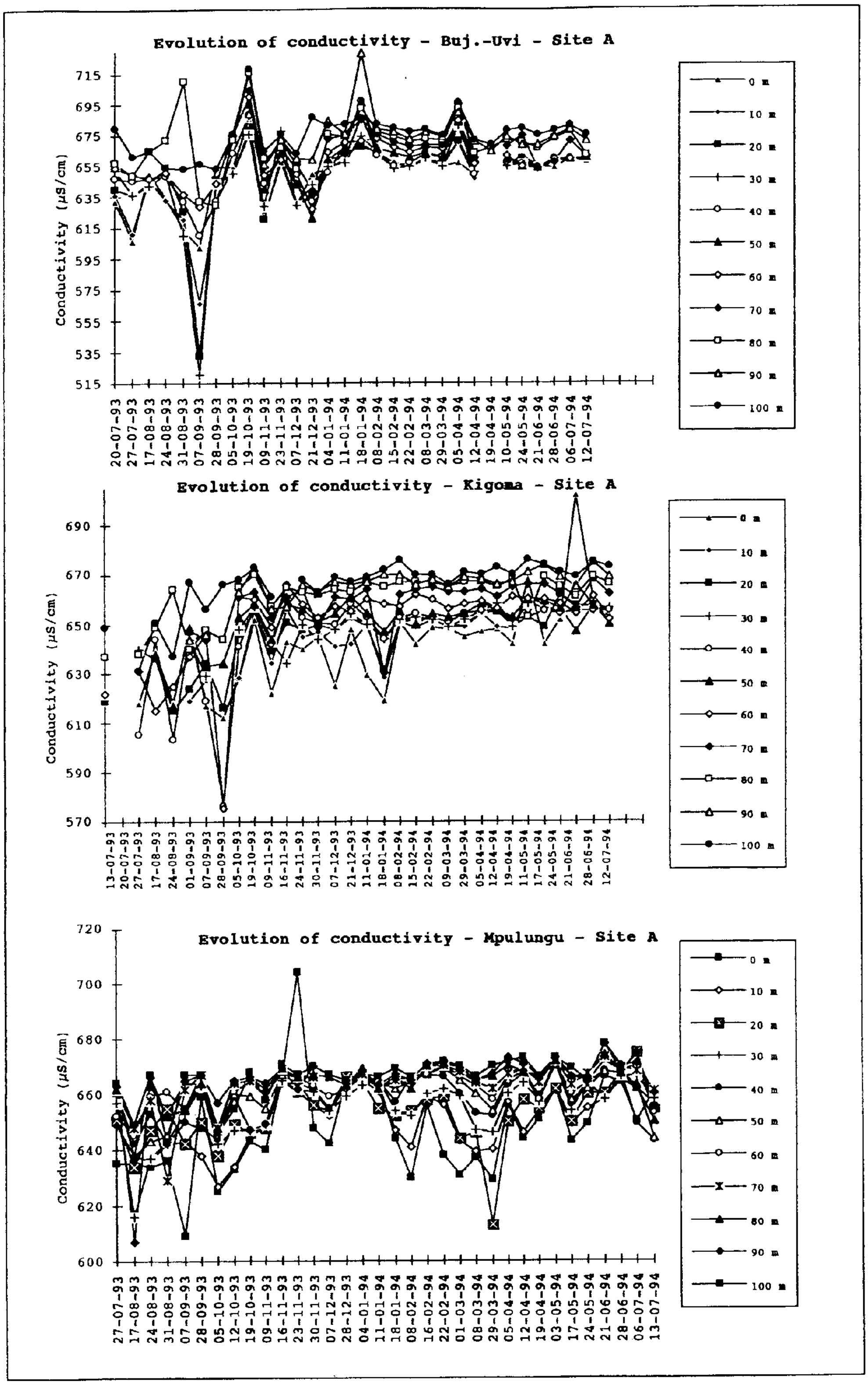


Figure 5: Evolution of conductivity (µS/cm) at each LTR station from July to August 1994

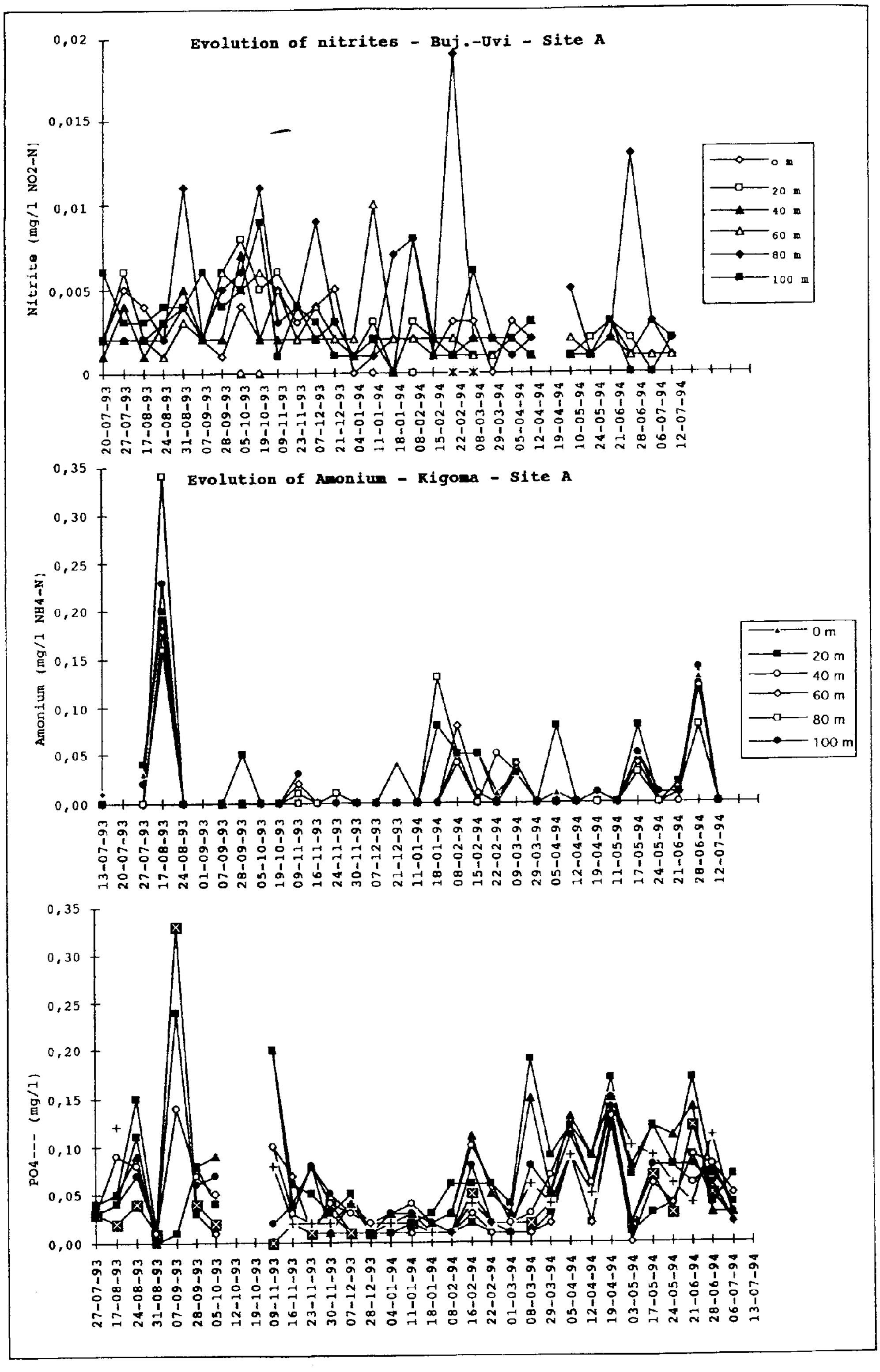


Figure 6 : Evolution of nitrite (mg/l NO2-N) at Buj.-Uvi., amonia (mg/l NH4-N) at Kigoma and phosphate (mg/l PO4---) at Mpulungu at site A of each station (0 to 100 m) between july 1993 and July 1994.

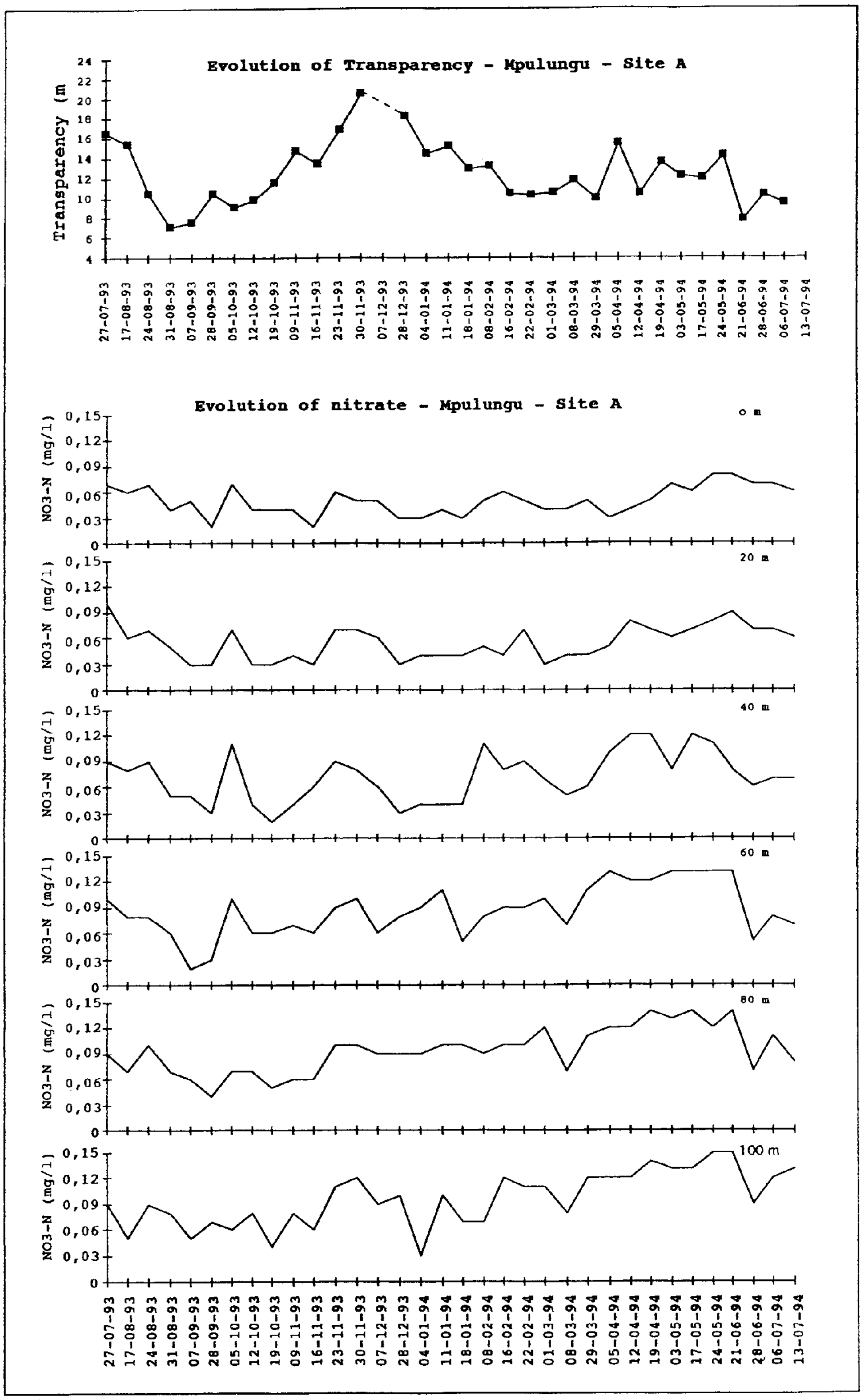


Figure 7: Evolution of nitrate (mg/l NO3-N) at each sampled depth (0 to 100 m) at site A - Mpulungu between July 1993 and july 1994. Evolution of transparency is shown.

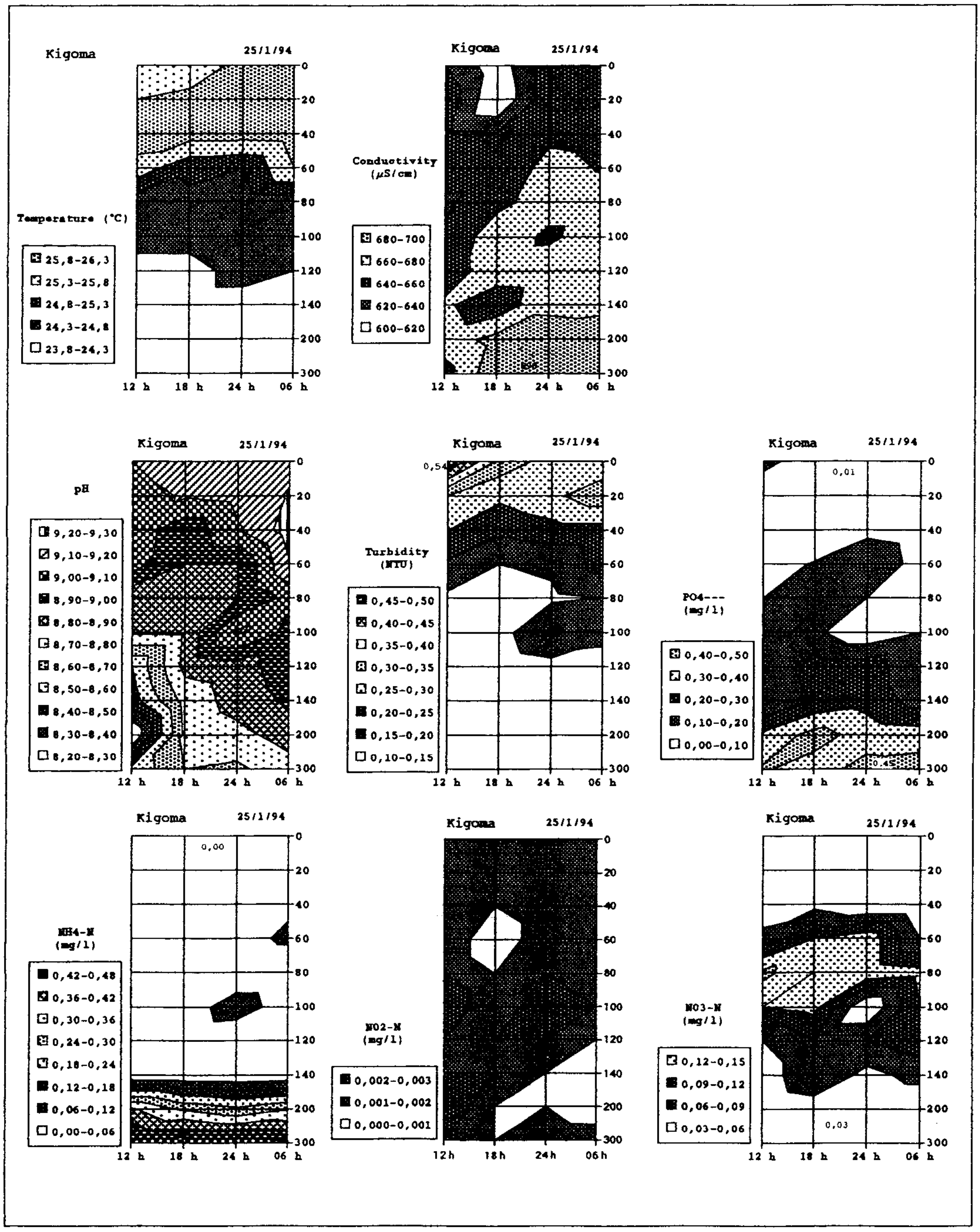


Figure 9 :Exemple of sampling B (24 H cycle) at Kigoma on 25-26/01/94 showing short time fluctuation of temperature (°C), conductivity (µS/cm),pH, turbidity (NTU), phosphates (mg/l PO4---), amonia (mg/l NH4-N), nitrite (mg/l NO2-N) and nitrate (mg/l NO3-N).

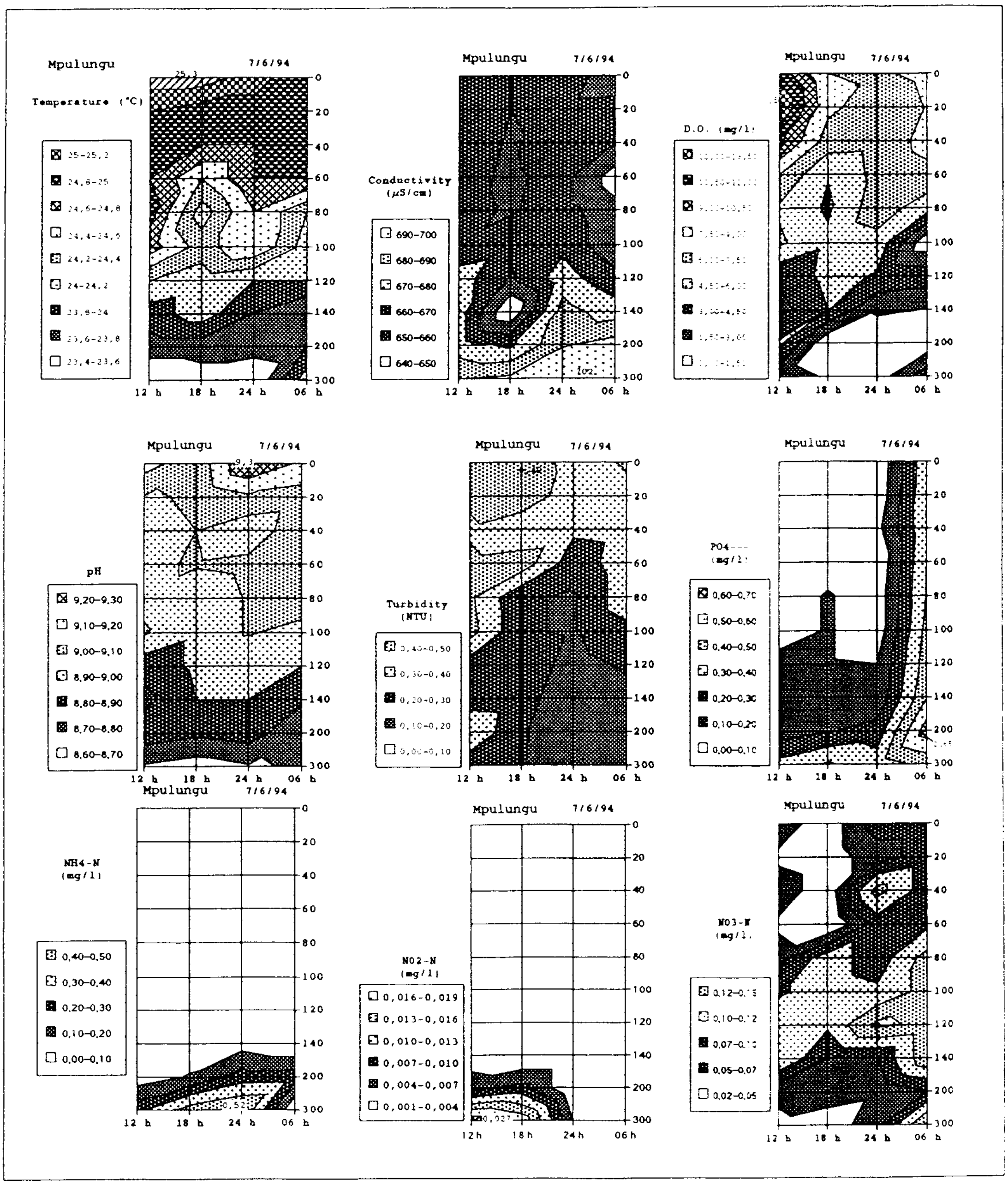
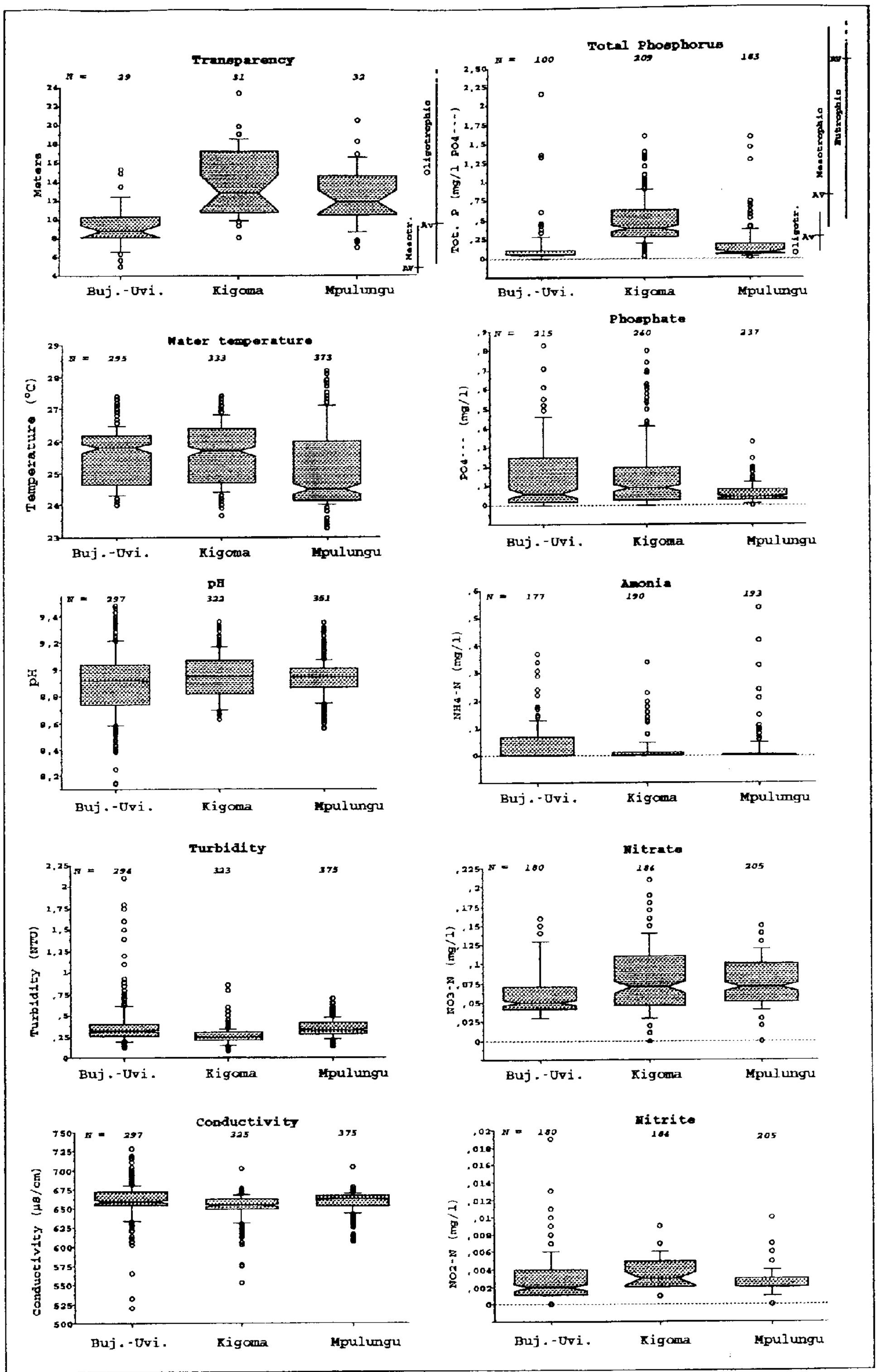


Figure 10 :Exemple of sampling B (24 H cycle) at Mpulungu on 7-8/06/94 showing short time fluctuation of temperature (°C), conductivity (µS/cm),dissolved oxygen (mg/l), pH, turbidity (NTU), phosphates (mg/l PO4---), amonia (mg/l NH4-N), nitrite (mg/l NO2-N) and nitrate (mg/l NO3-N).



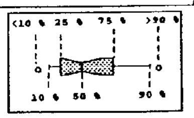


Figure 11 : Median and centiles for each parameter measured at site A (0 to 100 m) at Buj.-Uvi, Kigoma and Mpulungu between August 1993 and July 1994. Number (N) of measurements is indicated.Trophic range and average (AV) following classification of OECD (1982) in RAST & al (1989) is indicated for transparency and total phosphorus.

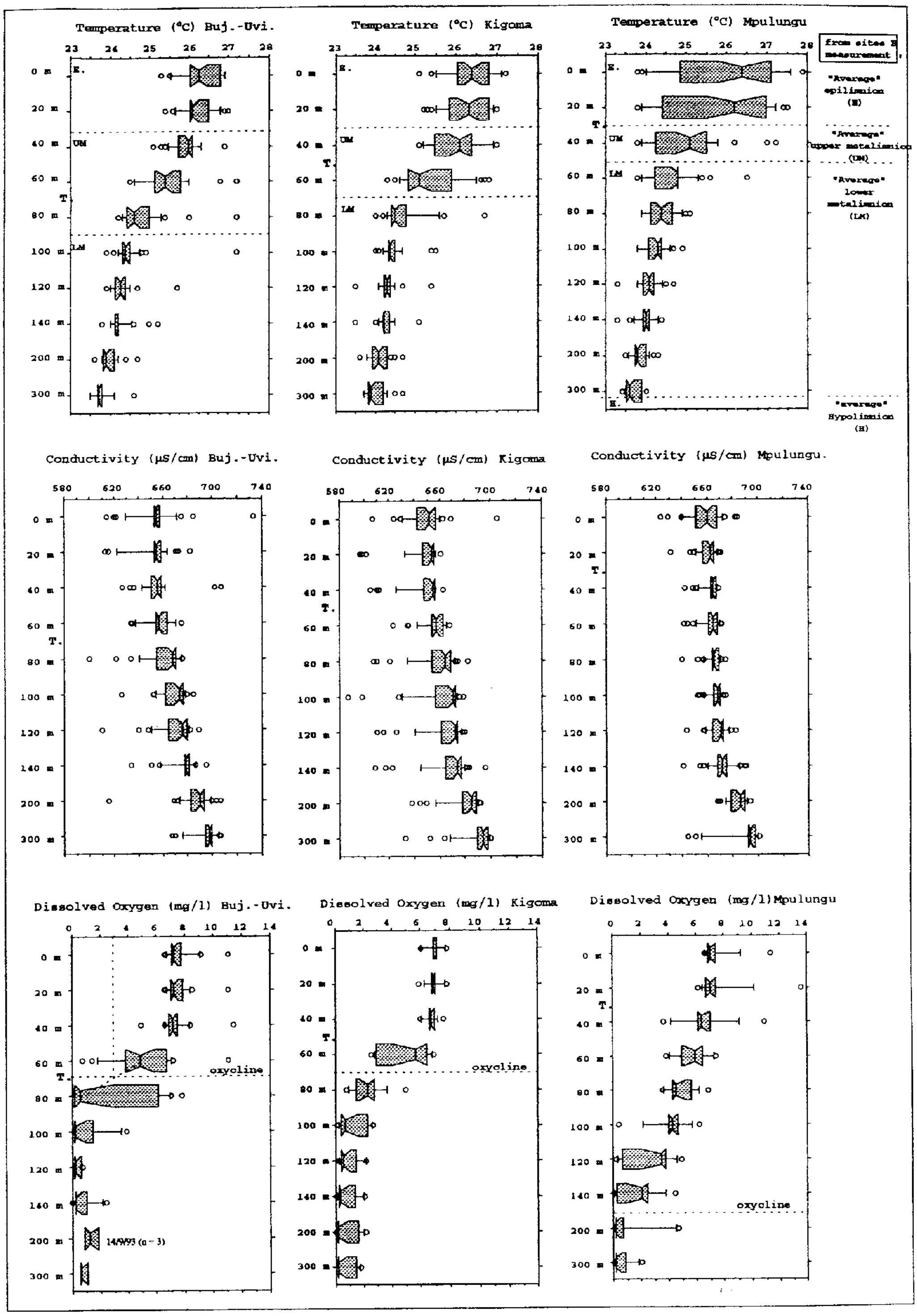
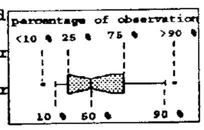


Figure 12: Medianes and percentiles of temperature (°C), conductivity (µS/cm) and dissolved oxygen (mg/l). Sampling were realised at site B (from 0 to 300 m) of each station during 24 H cycles every 6 weeks from August 1993 to July 1994 for temperature and conductivity. Note that observation for dissolved oxygen below 100 m are few and need confirmation. Identified layers are indicated. T. stands for thermocline depth.



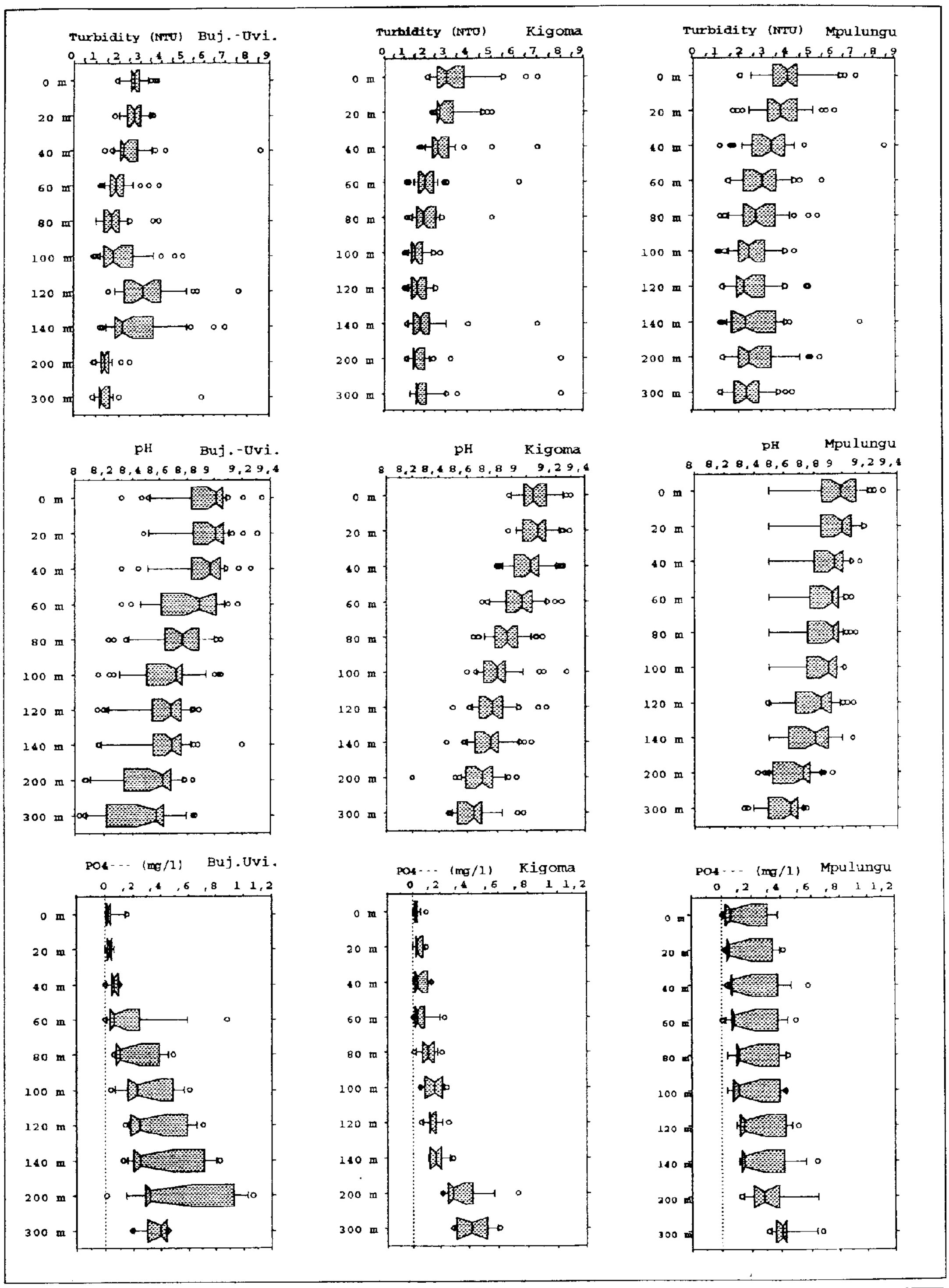
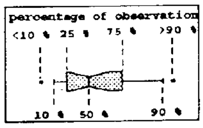
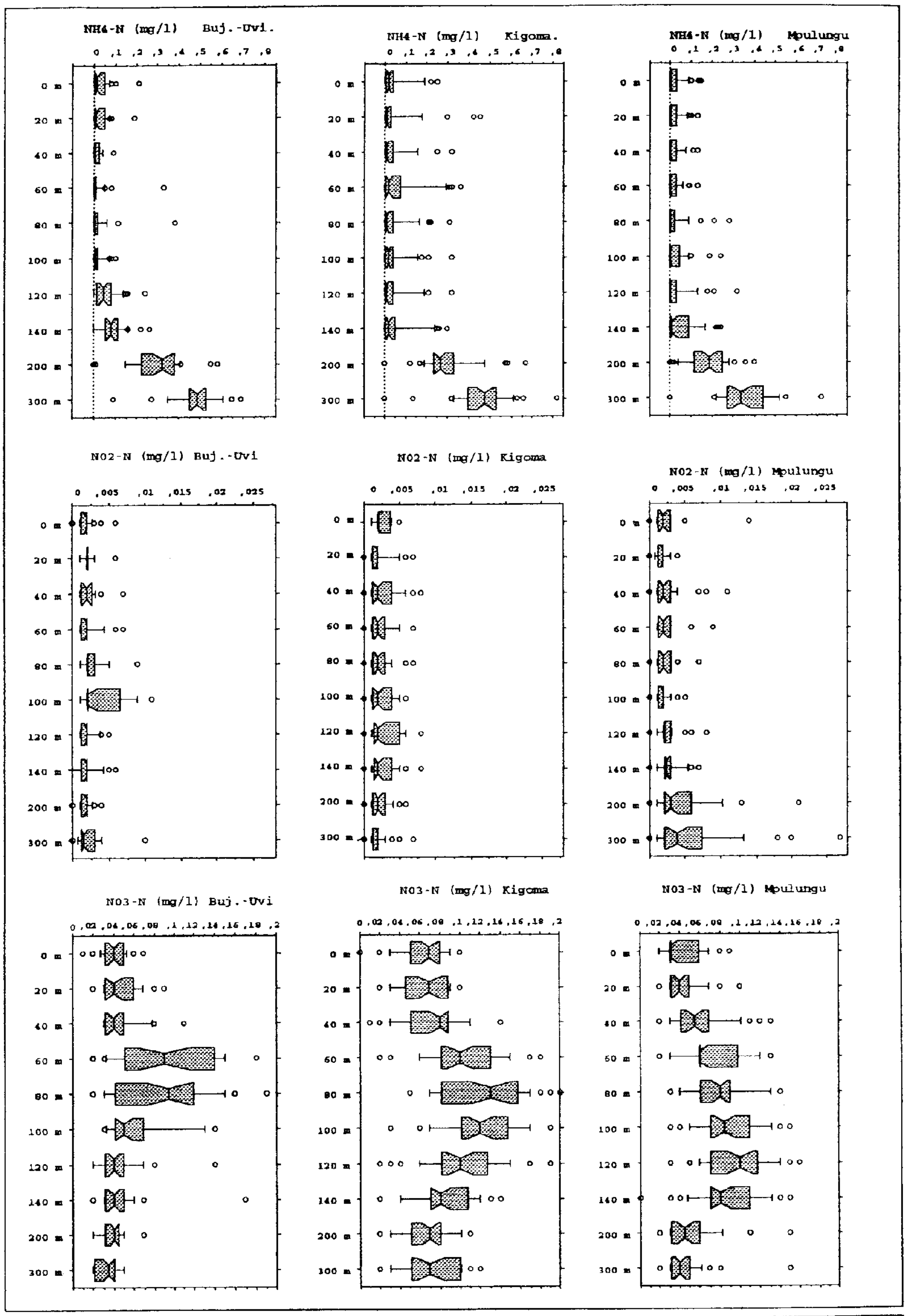


Figure 13: Medianes and percentiles measurements of turbidity (NTU), pH and phosphate (TRP, mg/l PO4---). Sampling were realised at site B (from 0 to 300 m) of each station during 24 H cycles every 6 weeks from August 1993 to July 1994.





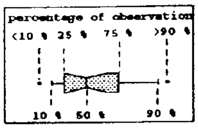


Figure 14: Medianes and percentiles measurements of amonium (mg/l NH4-N), nitrite (mg/l NO2-N) and nirate (mg/l NO3-N). Sampling were realised at site B (from 0 to 300 m) of each station during 24 H cycles every 6 weeks from August 1993 to July 1994.

**THIRD JOINT MEETING
OF THE LTR'S
COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES**

KIGOMA (TANZANIA), 28–30.11.1994

PRESENTATION OF SSP RESULTS: CARBON-ENERGY BUDGET

by K. Salonen and J. Sarvala

1. INTRODUCTION

In lakes the fisheries yield generally varies between 0.02 - 0.2 % of primary production. The higher (ca. 0.4 %) estimate for Lake Tanganyika led Hecky and Fee (1981) to hypothesize that the long geological history of the lake has allowed the evolution of highly efficient species composition. As another explanation they proposed the flux of dissolved organic matter (DOM) from the anoxic hypolimnion which may increase the production of bacteria and protozoans thus complementing phytoplankton primary production.

The earlier estimates of primary production at Tanganyika (Hecky and Fee, 1981) are limited by inadequate temporal and vertical coverage of the measurements. Thus underestimation of Tanganyika primary production might also explain the relatively high fisheries yield. Hence, along with the studies of the role of DOM, new studies of phytoplankton primary production are needed to quantify the sources of organic carbon for zooplankton maintaining the pelagic fisheries.

The estimation of phytoplankton primary production at Tanganyika is demanding. Upwelling of nutrients has been suggested as an important mechanism of nutrient transport from the anoxic hypolimnion of the southern basin. This possibility together with the large size and longitudinal form of the lake necessitate very good areal coverage of the measurements. In practice this is unrealistic. However, by using more easy complementary measurements, a limited number of primary production results could be extended to estimate primary production over larger areas. Among such measurements are satellite remote sensing and in vivo determination of the fluorescence of chlorophyll.

Photoinhibition was also reflected in the diel course of primary production. Particularly near the surface, most production was found during the early hours of the day (Fig. 3). Significant part of primary production was observed deep in the epilimnion, below 15 m.

3.3 Respiration of plankton

The results indicated that the respiration of plankton could be determined with simple 24h dark bottle technique and Winkler titration of oxygen. Spectrophotomeric determination of iodine seems to be equally precise as titration. However, the spectrophotometric method is much less susceptible to systematic errors which are extremely deteriorating as the results are calculated as a very small difference between large concentrations. Respiration may have exceeded phytoplankton primary production, but one should take into account the reservations due to shortcomings in the measurements of primary production.

4. CONCLUSIONS

The results have significant consequences for the measurement of phytoplankton primary production of Tanganyika. Due to photoinhibition, primary production in 20-60 m deep water has significant proportion in areal primary production. Therefore, primary production measured in earlier studies are likely underestimates and in future studies the vertical coverage of determinations must be extended deeper than 20 m. The large diel differences in photoinhibition result in delicate dynamics of phytoplankton primary production which makes its determination difficult. Probably only with the combination of some accessory measurements, such as light intensity and in vivo fluorescence of chlorophyll, primary production can be estimated satisfactorily. This study yielded convincing evidence that equipments for both of these measurements would be useful on the research vessel “Tanganyika Explorer”.

The results have also implications for the plans to use satellite remote sensing as a tool to estimate horizontal distribution of phytoplankton bioinass and productivity in Tanganyika. Because of the low concentration of chlorophyll and the high and rapid surface inhibition of *in vivo* fluorescence of chlorophyll, it is unlikely that remote sensing would substantially support the estimation of primary production.

Further experiments are still needed to establish best possible approaches for the determination of phytoplankton primary production at Tanganyika. Most urgently we need more information of the detailed vertical distribution and the diel course of primary production. Also the information of the size distribution of phytoplankton primary production is essential to asses its trophic importance.

2. MATERIAL AND METHODS

The experiments were made at Tanganyika in April 1994 off Bujumbura and Kigoma. In vivo fluorescence of chlorophyll a at different depths and horizontal positions were measured by a field fluorometer (Turner 10–AU). Radiocarbon method was used for the determination of phytoplankton primary production.

Radioactivity bound by organisms was assessed both on 0.2 µm filters and in water after acidification and removal of inorganic radiocarbon by exchange with air. Respiration of plankton was determined after incubation in darkness with Winkler titration of oxygen. Possibilities to measure oxygen more reliably with spectrophotometer at 260 nm were investigated.

3. RESULTS

3.1 *In vivo* fluorescence of chlorophyll *a*

The results showed that the determination of in vivo fluorescence of chlorophyll by a field fluorometer is enough sensitive even at the biomass and primary production minimum of phytoplankton of Tanganyika. At daytime, the highest *in vivo* fluorescence was always observed at 40–60 m, i.e. between the two thermoclines observed at that time. In the upper epilimnion *in vivo* fluorescence decreased dramatically during the course of day so that it often became undetectable (Fig. 1). This observation could not be caused by changing water masses, because similar decrease was also found in water taken from the epilimnion and exposed to the sunlight on the deck of the vessel. Thus the decrease of fluorescence was evidently caused by excessive solar radiation.

Horizontal series of measurements covering nearshore and offshore areas revealed sometimes remarkable patchiness which is not unexpected for large lakes. However, because of sometimes rapid decrease of fluorescence under bright sunshine, part of horizontal variation may have been due to time lag between the successive measurements.

The pronounced photoinhibition of Tanganyika phytoplankton probably results from the closeness to the equator, moderate altitude (773 m above the sea level) and high transparency of water. Similar observations have been made in a tropical high mountain Lake Titicaca (Vincent *et al*. 1984).

3.2 Phytoplankton primary production

Contrary to the observation of Hecky and Fee (1981), primary production measured by the acidification method did not seem to suffer from abiotic binding of radiocarbon. The primary production measured *in situ* was very low (Fig. 2) and showed similar inhibition by light in the uppermost water layers as was observed in the vertical distribution of *in vivo* fluorescence

In 1995 the role of dissolved organic matter through bacterial production and microbial loop will be studied. This part will be started by trying to improve the determination of dissolved inorganic carbon and by determining the growth rates of bacteria and protozoans.

5. REFERENCES

Hecky, R.E. & E.J. Fee, Primary production and rates of algal
1981 growth in Lake Tanganyika. Liinnol. Oceanogr. 26: 532–547.

Vincent, W.F., P.J. Neale, & P.J. Richerson, Photoinhibition:
1984 algal responses to bright light during diel stratification and mixing in a tropical alpine lake. J. Phycol. 20: 201–211.

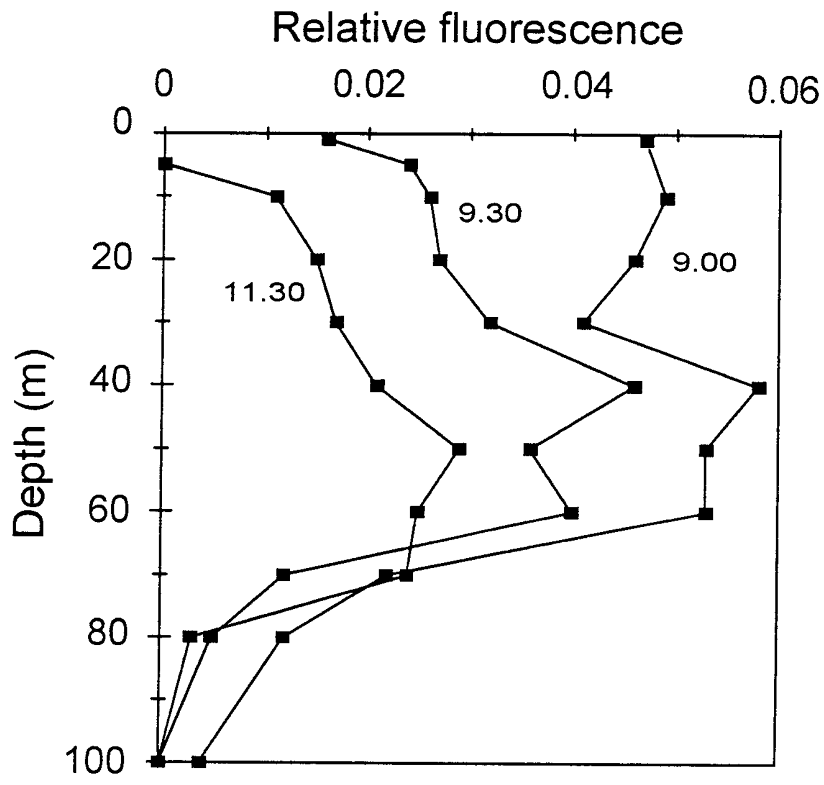


Fig. / . Vertical distribution of *in vivo* fluorescence at different times of day off Kigoma 14 April 1994.

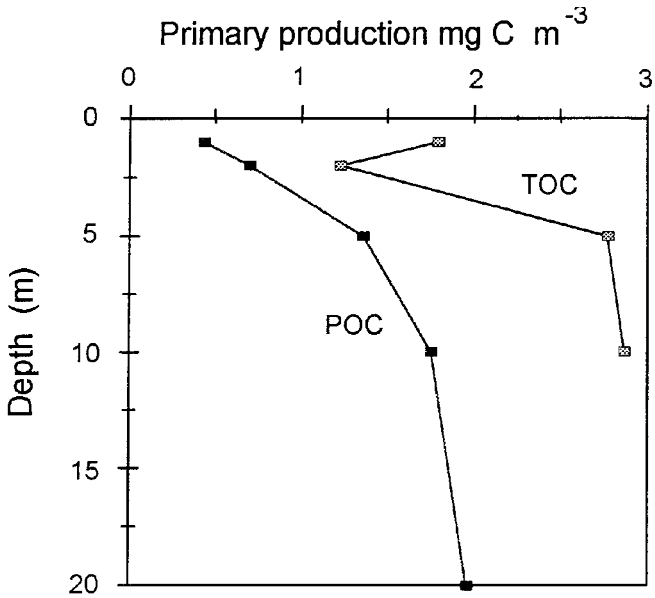


Fig. 2. Vertical distribution of primary production of phytoplankton during 3 hours (10.00 - 13.00) off Kigoma 14 April 1994. POC - particulate organic carbon production; TOC - total organic carbon production.

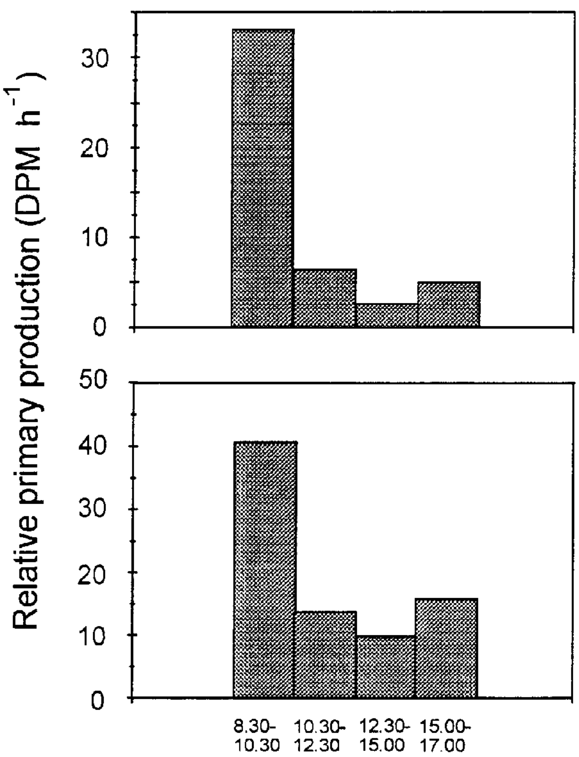


Fig. 3. Diel distribution of primary production in samples taken with ca. 2 h intervals on 14 April 1994 from two depths off Kigoma.

THIRD JOINT MEETING
OF THE LTRS
COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

Kigoma (Tanzania), 28—30.11.1994

PRESENTATION OF SSP RESULTS: ZOOPLANKTON BIOLOGY

by H.Kurki and I. Vuorinen

1. INTRODUCTION

Lake Tanganyika has always been described as an oligotrophic lake due to its high transparency, which can sometimes be up to 23.5m (measured off Kigoma on 28.6.1994). The standing crop of algae is low (Hecky and Kling, 1981) but algal growth rates and levels of primary production are extremely high (Hecky and Fee, 1981). Furthermore, the transfer efficiency from primary producers to zooplankton is efficient at approximately 17% (Hecky and Fee, 1981 and Burgis, 1984) and crustacean zooplankton is the only link between primary production and fish. Thus, pelagic zooplankton forms a central role in the lake ecosystem transferring the energy from primary producers to the pelagic clupeids and juveniles of *Lates stappersii.* It is also important to know the relative significance of Diaptomid vs. Cyclopoid crustaceans as these groups are differently utilized by their predators.

The current sampling scheme aims at studying the seasonal and spatial variations in the abundance and diversity of the pelagic zooplankton community. The objective is to determine predator—prey relationships, seasonal and spatial dynamics and ecological interactions between trophic stages together with the information from other subcomponents of the Scientific Sampling Programme (hereafter SSP). The ultimate aim is to quantitatively describe the biological basis of fish production in the lake and, on that basis, to prepare a lake—wide fisheries management plan.

In this report, the differences in zooplankton composition and seasonal changes in zooplankton in the northern part (Bujumbura and Kigoma) and in southern part (Kipili and Mpulungu) of the lake are presented and discussed. Diel vertical distribution and migration patterns at the sampling localities are also described. A brief summary of annual abundance changes of macrozooplankton is presented.

2. MATERIAL AND METHODS

The sampling schedule consisted of two parts:

1) Regular weekly sampling in the pelagic zone including a vertical tow from 100 meters depth to the surface in daytime using a plankton net of 100 mm mesh size and 25 cm opening.

2) Six-weekly intensive sampling including four series of samples during a 24-hour cycle starting at 12 hrs and ending the next morning at 6 hrs. Samples were taken from certain depths, brought to the surface and sieved with a plankton net.

The methods used are described in detail in Kurki (1993), Vuorinen (1993), and Vuorinen and Kurki (1994).

The sampling sites were selected to represent the pelagic area where the depth for regular weekly sampling was at least 120 m and for 24-hour sampling at least 320 m. In Table 1, the distances from the shore and the maximum depth at each sampling point are given.

Table 1 : Distance from the Shore and the maximum depth at the sampling site on lake Tanganyika

	regular sampling		24 hours sampling	
Station	**km**	**depth/m**	**km**	**depth/m**
Bujumbura	**5.5**	**120**	**9.0**	**>300**
Kigoma	**2.5**	**250—500**	**4.0**	**250—500**
Mpulungu	**6.5**	**120**	**4.0**	**320**
Kipili	**5.0**	**>100**	**—**	**-**

Weekly sampling was carried out in Bujumbura 28 times, in Kigoma 40 times, in Kipili 37 times (started in November 1993) and in Mpulungu 38 times.

24—hour intensive sampling was done in Bujumbura 8 times and in Kigoma and Mpulungu 9 times. Each 24-hour sampling consisted of four vertical sampling series from a minimum of eight depths. Therefore, in each sampling cycle a minimum of 32 zooplankton samples were collected.

The overall number of zooplankton samples collected at each station is presented in Table 2.

Table 2: The number of zooplankton samples collected at each station during the first year of SSP

Station	regular sampling	24 hours cycle
Bujumbura	**28**	**260**
Kigoma	**40**	**288**
Kipili	**37**	**-**
Mpulungu	**38**	**312**

In Figure 1, the sampling sites in Bujumbura, Kigoma, Kipili and Mpulungu are presented. The letter A stands for regular sampling and letter B for 24-hour cycle.

3. RESULTS

3.1 Pelagic zooplankton composition

The pelagic zooplankton was dominated by crustacean copepoda *Tropodiaptomus simplex* (Diaptomidae) and Cyclopidae. Minor constituents of the pelagic zooplankton were medusae *(Limnocnida tanganyicae)* , Atyidae shrimps, fish larvae and in Bujumbura waters protozoan *Vorticella* sp. In Kipili waters Ergasilidae were found occasionally.

A non–parametric Mann–Whitney U–test was run to test the differences in numbers of *Tropodiaptomus simplex* and Cyclopoida at different sampling localities using the data of the first year of SSP.

3.1.1 Bujumbura

Cyclopidae Copepoda dominated the zooplankton in Bujumbura waters when expressed as number per m^3 (at the risk level of O.0004)(Table 3). During the observation period, Cyclopidae formed 61% (nauplii 12%, copepodids and adults 49%) of the total pelagic zooplankton and 32% of the zooplankton consisted of *Tropodiaptomus simplex* (nauplii 13%, copepodids and adults 19%). *Limnocnida tanganyicae,* protozoan *Vorticella* sp. and other unspecified and unidentified plankters were minor constituents of the pelagic zooplankton. Once during the observation period, *Vorticella* sp. represented 34 % of the total number of zooplankton (17.8.1993).

3.1.2 Kigoma

Similarly to Bujumbura, Cyclopidae formed the major part of the pelagic zooplankton in Kigoma accounting for 69% (nauplii 12%, copepodids and adults 57%) of the total zooplankton. *Tropodiaptomus simplex* had a share of 31% (nauplii 19%, copepodids and adults 12%) of the total number of individuals. The number of *Limnocnida tanganyicae* never exceeded 120 individuals per m^3 and the number of shrimps was less than 25 individuals per m^3 throughout the observation period. Fish larvae were counted occasionally in the samples but never exceeded one individual per m^2.

3.1.3 Kipili

The zooplankton sampling programme started only in November 1993 in Kipili substation, thus the data do not cover the whole year.

The number of Cyclopidae and *Tropodiaptomus simplex* was different at the risk level of p=0.022 (Table 3). Cyclopidae contributed 57% (nauplii 3%, copepodids and adults 54%) of the total number of the pelagic zooplankton during the observation period. *Tropodiaptomus simplex* formed 41% (nauplii 21%, copepodids and adults 20%) and shrimps accounted for 2% of the pelagic zooplankton. Once during the observation period shrimps accounted for 17% (9.11.1993) of the total number of individuals. *Limnocnida* tanganyicae was found in each sample, the maximum being 100 individuals per m^3 (17.5.1994). Ergasilidae copepods were found occasionally in samples together with fish larvae.

3.1.4 Mpulungu

Tropodiaptomus simplex and Cyclopidae were found in equal numbers (p=0.1586) (Table 3). When expressed as percentage values, Cyclopidae contributed 54% (nauplii 15%, copepodids and adults 39%) and *Tropodiaptomus simplex* 45% (nauplii 12%, copepodids and adults 33%) to the total number of pelagic zooplankton during the observation period. *Limnocnida tanganyicae* was undetectable several times but once accounted for 4% (23.5.1994) of the total number. The number of shrimps went once above 50 specimens per m^3 (19.10.1994). Throughout the study period, shrimps were observed in the samples though in low numbers. Fish larvae were counted occasionally.

<u>Table 3</u>: Mann-Whitney U-test of equal means of *Tropodiaptomus simplex* and Cyclopidae. Observation period July 1993–July 1994 (Kipili: November 1993–July 1994).

U = test value
μ = mean
SD =standard deviation
z = normalized test value
p = risk level

Bujumbura		Kigoma		Kipili		Mpulungu	
Tropo	Cyclo	Tropo	Cyclo	Tropo	Cyclo	Tropo	Cyclo
n28	n=28	n=40	n=40	n=37	n=37	n=38	n=38
R_1=546	R_2=994	R_1=994	R_2=2171	R_1=1176	R_2=1599	R_1=1327	R_2=1599
U=644		U=1426		U=896		U=858	
μ=392		μ=800		μ=684.5		μ=722	
SD=61.0		SD=103.9		SD=92.5		SD=96.3	
z=4.12		z=6.024		z=2.29		z=1.413	
p=0.0004		p=O.OOOO		p=0.022		p=0.159	

3.2. Seasonal changes

The year was divided into three seasons according to Coulter and Spigel (1991):

Dry season:	June, July, August
Wet warming season:	September, October, November
Season of maximum stability:	December, January, February, March April, May

The density differences between seasons were tested with the Mann–Whitney U-test of equal means.

Off Bujumbura, no difference in number of *Tropodiaptomus simplex* could be observed at the risk level of 0.05 between dry and wet warming season. Instead, the density of *Tropodiaptomus simplex* was higher during the wet warming season and the dry season compared to the season of maximum stability at the risk level of 0.05. The number of Cyclopidae did not change between the seasons but remained at the same abundance level.

In Kigoma waters, *Tropodiaptomus simplex* was more abundant during the wet warming period and during the season of maximum stability than during the dry season (at the risk level of 0.05) but remained at the same level during the months of September - May. Cyclopidae showed similar seasonal changes in abundance as the Diaptomidae.

In Kipili the overall number of both *Tropodiaptomus simplex* and Cyclopidae did not change between the seasons but remained at the same abundance level. Off Mpulungu, the same was observed: neither *Tropodiaptomus simplex* nor Cyclopidae showed any seasonal changes in abundance.

3.3 Population dynamics

Both *Tropodiaptomus simplex* and Cyclopidae showed periodicity in their abundance pattern but the timing was slightly different among the stations and between the two zooplankton groups. In the extreme northern end (Bujumbura), Copepoda (including both Diaptomidae and Cyclopidae) had abundance maxima in July 1993 (Figure 2) and in the southern end (Mpulungu) in August 1993 (Figure 5) whilst in Kigoma low numbers were counted (Figure 3) . In Kigoma, first clear abundance peaks were observed in October 1993 for the Diaptomidae and in November 1993 for the Cyclopidae (Figure 3). In Bujumbura, Cyclopidae showed a slight increase in density in November 1993. In the south, off Mpulungu, no abundance maxima could be observed in October and November 1993.

In Kipili, which is situated in the southern basin, a regular zooplankton sampling started in November 1993. First clear abundance maxima were observed in February 1994 for both Diaptomidae and Cyclopidae (Figure 4). In Mpulungu, in the extreme southern end of the lake a slight increase in the number of Cyclopidae was detected one month earlier, in January 1994 (Figure 5).

In Kigoma waters, the overall number of Copepoda showed a decreasing trend in December 1993 and January 1994. While numbers of *Tropodiaptomus* decreased through February and March 1994, Cyclopoida reached minimum density in January 1994. Cyclopoida had a second clear abundance peak in May 1994 and *Tropodiaptomus simplex* in April 1994. In Bujumbura, a similar change in numbers of Copepoda could be observed though not as clear as in Kigoma. The overall number of Copepoda decreased in Bujumbura but higher densities of Cyclopoida were observed in April 1994 and of *Tropodiaptomus* in June 1994 (Figure 2). In Mpulungu waters, the number of Copepoda decreased and a third clear abundance peak after August 1993 and January 1994 was observed in July 1994 (Figure 5). In Kipili waters, following February 1994 abundance maxima, both *Tropodiaptomus* and Cyclopoida decreased in number and second high abundance’s were counted in May and June 1994 (Figure 4).

Kigoma and Bujumbura data showed similar periodicity apart from July 1993. In the south, in Kipili and in Mpulungu, the timing of abundance changes were similar to each other.

More detailed analysis of the population dynamics of *Tropodiaptomus simplex* and Cyclopidae will be presented in the technical document on the zooplankton subcomponent of SSP.

3.4 Zooplankton abundance at the sampling localities: some comparison

All the data collected during the first year of SSP was used for testing (Mann-Whitney U-test) the differences in abundance’s of the pelagic Copepoda among the four stations. The overall Copepoda density (including both *Tropodiaptomus simplex* and Cyclopidae) was at its lowest level for all stations in Mpulungu waters. The highest abundance level was maintained in

Bujumbura waters. The zooplankton density was at the same level between Kigoma and Kipili but slightly less off Kigoma than off Bujumbura.

The number of *Tropodiaptomus simplex* was at its highest level in the most northern part of the lake (in Bujumbura). In Kigoma waters and in the most southern part (in Mpulungu) *Tropodiaptomus simplex* was found in equal numbers. In Kipili, *Tropodiaptomus simplex* was found in greater numbers than in Mpulungu but in equal numbers with Bujumbura and Kigoma.

The number of Cyclopidae was clearly highest in the northern basin; Bujumbura and Kigoma data showed the same density level. Similarly, Kigoma and Kipili showed the same abundance numbers. In Mpulungu waters, the number of Cyclopidae was lowest.

3.5 Vertical distribution and migration of the pelagic Copepoda during 24-hour cycle

In this report only a brief summary of the vertical distribution and migration of the pelagic Copepoda during 24-hour cycles at the sampling localities is presented. More detailed analysis (moon effect, distribution pattern and migration during different seasons) will be presented in the technical document on the zooplankton subcomponent results.

3.5.1 Bujumbura

In Bujumbura waters, Copepoda were found in low numbers below 100 meters. Zooplankton tended to concentrate in the water layers 0-80 m, maximum density being at 20 and 40 m (Figure 10).

Vertical migration could be observed in *Tropodiaptomus simplex* copepodids and adults: density maximum was at 0 and 20 meters during sunset and at the sunrise at 100 meters (FIGURES 10a-d). Naupliar stages of *T. simplex* did not show diel vertical migration; vertical distribution pattern was the same throughout the day and night (Figures 10e-h). Cyclopoida copepods did not show diel vertical migration but remained at the same depths during day and night (Figures lOm-p).

At midday, zooplankton samples contained more individuals than at other hours (18 hrs, 24 hrs, 06 hrs). At midday, the mean number of zooplankton collected was 382312 individuals per m^3 (mean of 8 24-hour cycles) and at dawn 2400040 specimens per m^3. The majority of the plankters were Cyclopoida copepods accounting for 58-63% of the total Copepoda.

3.5.2 Kigoma

Copepodid and adult stages of *Tropodiaptomus simplex* showed diel vertical migration (Figures lla-d). At midday, the abundance maximum was at 120 in and the surface was devoid of animals, by sunset plankters had ascended mostly to 20-40 m. At

7 hrs in the morning, zooplankton were found mostly below 60 m (Figures lla-d). Naupliar stages had diel vertical migration as well: in day samples, the surface layer (0 m) had only few animals and abundance maximum was at 20 in (Figure lle) . In the evening highest abundance's were counted at 0 m (Figure llf). The following morning, water layers from 0 to 120 m were occupied by nauplii with density maxima being at 0 and 20 m (Figure llh).

Cyclopoid copepodids and adults ascended to the surface at the sunset but descending to deeper layers at dawn was not pronounced (Figures lli-l). At 13 hrs, the surface was lacking animals and density maxima were at 20-60 m (Figure lli) . Some individuals were found at 140 m. By 1 hr, zooplankton had concentrated above 40 m and the following morning there was no change in the distribution pattern (Figures 11k and 1). Cyclopoid nauplii did not show different distribution pattern between day and evening: abundance maxima were at 20 and 40 meters (Figure llm and n). At midnight, the surface layer (0 m) was occupied by nauplii abundance maxima being at 0, 20 and 40 m (Figure 110). 80 m was virtually devoid of nauplii but at 100 m some animals could be found. No migration downwards had taken place by next morning but nauplii remained at 0, 20 and 40 m (Figure llp).

The zooplankton collected during the 24–hour cycle was dominated by Cyclopoid nauplii: at midday 76%, at sunset 75%, at midnight and at dawn 78% of the Copepoda collected were Cyclopidae nauplii (mean values of 9 24-hour cycles). *Tropodiaptomus simplex* was a minor constituent comprising 6–8% of the zooplankton collected. The total number of zooplankton collected during different hours remained at the same level: 292000–330000 individuals per m^3.

3.5.3 Mpulungu

In Mpulungu, zooplankters were found up to 220 m: Cyclopidae copepodids and adults were occupying the water layers 200-220m in the morning (Figure 121), few Cyclopoid nauplii were at 200 m (Figure 12p) and few Diaptomidae copepodids and adults at 200- 220 m layers (Figure 12d)

Zooplankton tended to avoid surface at midday, both *Tropodiaptomus* and Cyclopidae were found in low numbers at 0 m (Figures 12a, e, and m). Copepodids and adults of both Copepoda groups had ascended closer to the surface by sunset (Figures 12b and j). Two abundance peaks could be observed, namely at 20 m and at 120 m. By midnight copepodids and adults had distributed from 0 to 140 m and 140 m showed higher density than 100 and 120 m (mean values of 8 24-hour cycles) (Figures 12c and 1). At dawn, descending had taken place and plankters were found mostly at 40-140 m (Figures 12 e and m). Cyclopoid copepodids and adults showed clear abundance peaks at 140 m.

Nauplii were widely distributed but some tendency to migrate upwards at the sunset could be observed (Figures 12f and n). At midnight, few animals were found at 100 and 120 m but concentration to 140 m could be observed (Figures 12g and o).

Slightly fewer animals were collected in the evening and during the night than in daytime. The number of individuals caught varied between 183000 and 225000 animals per m^3. Cyclopidae formed 52-58% and *Tropodiaptomus simplex* 38-44% of the total Copepoda sampled.

3.5.4 Comparison among the stations

In Mpulungu area, zooplankton distributed deeper than in the northern part of the lake (Kigoma and Bujumbura area). In Bujumbura zooplankton was mostly found in 0–80 m and in Mpulungu the water layers up to 220 m were occupied by zooplankton.

In Kigoma area diel vertical migration was most pronounced. Diaptomidae copepodids and adults shifted from as deep as 120 m to the surface in the night and again ascended to 60-100 m at dawn. In Bujumbura waters, only *Tropodiaptomus simplex* copepodids and adults showed diel vertical migration and in Mpulungu area the migration pattern was not clear.

3.6 Macrozooplankton

Medusae *(Limnocnida tanganyicae),* shrimps (Atyidae sp.) and fish larvae were found in the pelagic zooplankton at all the sampling localities.

In Bujumbura, medusae were counted throughout the observation period showing peak abundance’s in October 1993, January and June 1994 (Figure 6a). Shrimps were counted in low numbers, mostly the monthly mean was below 5 individuals per m^3. In November 1993, the monthly mean reached 15 individuals per m^3 (Figure 6b).

In Kigoma waters, medusae were found regularly. The highest abundance was reached in November 1993 (Figure 7a). Atyidae shrimps were constant components of the pelagic zooplankton. Abundance maxima in October 1993, February and June 1994 were preceded by increasing numbers and followed by decreasing density (Figure 7b).

In the south basin, in Kipili, the medusae increased in number and eventually reached a peak abundance in May 1994. In June and July 1994, a decreasing trend in density was observed (Figure 8a). Shrimps had a peak abundance in February 1994, when mean abundance of 700 individuals in m^3 was counted (Figure 8b).

In the south point (Mpulungu) , medusae were almost absent in the samples from August 1993 to November 1993. Highest densities were reached in April 1994 followed by a decrease (Figure 9a). Atyidae were found to be constant constituents of the pelagic zooplankton though the density changed. Highest abundance’s were counted in August, October 1993, April and July 1994 (Figure 9b)

4. CONCLUSIONS

The zooplankton densities were highest in the northern part of the lake (Bujumbura and Kigoma) and lowest in Mpulungu waters when all the data was pooled together. The difference found in abundance between southern and northern ends of the lake might suggest that the sampling locations are not placed in comparable manner in relation to pelagic and littoral ecosystems. Another explanation for this variance could be a real difference between planktonic ecosystems, with considerably more Cyclopoida in the northern end of the lake and lower zooplankton production in the southern end of the lake.

In the northern part of the lake Cyclopidae dominated the pelagic zooplankton and in the south end of the lake *Tropodiaptomus simplex* were in equal numbers with Cyclopidae. Rufli (1981) reported *Tropodiaptomus simplex* to contribute 45 % to the total number of pelagic zooplankton (August 1975-July 1976) and Cyclopoida copepods 49-60% in Kigoma waters. During the current study the percentage shares in Kigoma waters were 31% for *Tropodiaptomus* and Cyclopoida 69%

Seasonal changes in number of *Tropodiaptomus simplex* could be observed both in Bujumbura and in Kigoma waters but not in the southern part of the lake (Kipili and Mpulungu). In Bujumbura, during the second part of the wet season (season of maximum stability) the numbers were low compared to the dry season and first part of the wet season (wet warming period) . The same was reported by Rufli (1976): during the lakewide survey in May 1976, zooplankton density was 41% of the density of the October 1975 survey. During the dry season, upwelling takes place and nutrients are mixed with the epilimnion. Consequently, primary production boosts up and causes zooplankton abundance to increase. During the phase of maximum stability, thermal stratification is strong and no nutrient mixing between epilimnion and hypolimnion takes place and therefore zooplankton abundance remains low.

In Kigoma waters, the number of zooplankton fluctuated during the stratification period. From November 1993, the density decreased and high numbers were reached again in April *(Tropodiaptomus simplex)* and May 1994 (Cyclopidae). *Stolothrissa tanganyicae* catches were high in November and December 1993 and in April and May 1994 (data from fish biology subcomponent) in Kigoma waters with a decreasing catch in between those months. Possibly, zooplankton were preyed upon by clupeids which caused the number of zooplankton to decrease. Low predation pressure by clupeids allowed zooplankton to build up the population which resulted in April and May 1994 abundance maxima.

In Mpulungu, in the lake’s extreme south, a CPUE of clupeids were high in August, September 1993 and in July 1994 compared to other months (data from fish biology subcomponent). The pelagic Copepoda had abundance peaks in August 1993 and in July 1994. The number of Copepoda decreased in September 1993 which can be an indication of predation pressure by clupeids as in Kigoma area.

Narita *et al.,* (1986) reported increased numbers of egg carrying *Tropodiaptomus simplex* in September and October and suspected high reproduction rate to be a product of the high primary production. During the current study, high numbers of egg carrying females were counted in September and October 1993 off Bujumbura and off Mpulungu. In Kigoma, a clear reproduction peak was observed only in April 1994.

In Kipili waters, the average yearly number of shrimps was 15 times greater than in Mpulungu and 40 times greater than in Kigoma. In Bujumbura, the number of shrimps was lowest, the yearly mean being half that of Kigoma. Shrimps are important diet constituents of *L. stappersii* in Kigoma area and in the south in Mpulungu (information from fish biology subcomponent). The zooplankton net does not catch effectively shrimps but data gives us some indication of spatial and seasonal variations of shrimp abundance's.

In Kigoma area, diel vertical migration of *Tropodiaptomus simplex* copepodids and adults was clear. It can be probably explained by the predator-avoidance hypothesis (e.g. Gliwics, 1986): due to their considerably large size *Tropodiaptomus simplex* have to seek for refuge in deeper water layers in order to hide from planktivorous predators (clupeids) which are visual predators and prey mostly upon copepods *(Stolothrissa* stomachs opened in LTR Kigoma in October 1994 consisted mostly of Copepoda). At dusk, when light intensity decreases, ascending to the surface and grazing on phytoplankton takes place. Vertical distribution pattern can also be related to photoinhibition of primary production (Salonen and Sarvala, 1994).

Plotting together vertical distribution of Copepoda nauplii and temperature data collected in Kigoma revealed that nauplii mostly concentrated above the thermocline and very few specimens were found below 25°C.

Abundance's of clupeids and zooplankton seem to be strongly connected (according to the results of the first year of SSP). Studying the feeding of clupeids would give us more insight in this relationship. Currently fish biology and zooplankton field leaders are preparing a sampling scheme for clupeid stomach content analysis which would be implemented at all LTR stations.

Data collected up to now revealed the vital importance of regular sampling. Since August 1994, sampling has been done strictly on weekly basis and taking three replicate zooplankton samples. This should clarify the nature of short term variations in numbers.

The uncertainties in identification of the Copepoda bring noise in the data. Stations are still lacking proper identification keys. The zooplankton subcomponent leader together with the field leader should contact qualified taxonomists in order to solve this problem. Good quality photographs could be produced to facilitate the identification.

In Bujumbura, the zooplankton study has suffered from lack of manpower and that has caused delays in counting and data processing. Sampling has been done less often in Bujumbura than in Kigoma and Mpulungu (regular sampling was done in Bujumbura 28 times, Kigoma 40 times and in Mpulungu 38 times during the first year of SSP). In Bujumbura emphasis should be given to have enough researchers to work on the zooplankton subcomponent.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Burgis, M.J., An estimate of zooplankton biomass for Lake 1984 Tanganyika. Verh. Internat. Limnol. 22:1199–1203.

Coulter, G.W. and R.H. Spigel, Hydrodynamics. *In* (Coulter, G.W. 1991 ed.): Lake Tanganyika and its life (Chapter 3). British Museum (Natural History) and Oxford University Press. pp:49–75.

Gliwics, Z.M., Predation and the evolution of vertical migration 1986 behaviour in zooplankton. Nature. 320:746-748.

Hecky, R.E. and F.J. Fee, Primary production and rates of algal 1981 growth in Lake Tanganyika. Limnol.Oceanogr. 26:532–547.

Hecky, R.E. and H.J. Kling, The phytoplankton and 1981 protozooplankton of the euphotic zone of Lake Tanganyika: Species composition, biomass, chlorophyll content, and spatiotemporal distribution. Limnol.Oceanogr. 26(3) :548–564.

Kurki, H., Field notes on Zooplankton. FAO/FINNIDA Research for 1993 the Management of the Fisheries on Lake Tanganyika. GCP/RAF/271/FIN–FM/09 (En) : 26p.

Narita, T., N. Mulimbwa and T. Mizuno, Vertical distribution and 1986 seasonal abundance of zooplankters in Lake Tanganyika. African Study Monographs. 6:1–16.

Rufli, H., Preliminary analysis of zooplankton sampling in Lake 1976 Tanganyika in May 1976. Lake Tanganyika Fishery Research and Development Project. FI:DP/URT/71/0l2/44: 10-p.

Rufli, H., Seasonal abundance and composition of zooplankton in 1981 Lake Tanganyika, off Kigoma, and relation to the planktivorous fish *Stolothrissa.* Unpubl.

Salonen, K. and J. Sarvala, Sources of energy for secondary 1994 production in Lake Tanganyika. Objectives, basic approaches and first results ("Carbon–energy budget of Lake Tanganyika"). FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. GCP/RAF/271/FIN–TD/## (En) : ##-p.

Vuorinen, I., Sampling and counting zooplankton of Lake 1993 Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. GCP/RAF/271/FIN-FM/06 (En) : 19p.

Vuorinen, I. and H. Kurki, Preliminary results of zooplankton 1994 sampling in Lake Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. GCP/RAF/271/FIN-TD/22 (En): 37p.

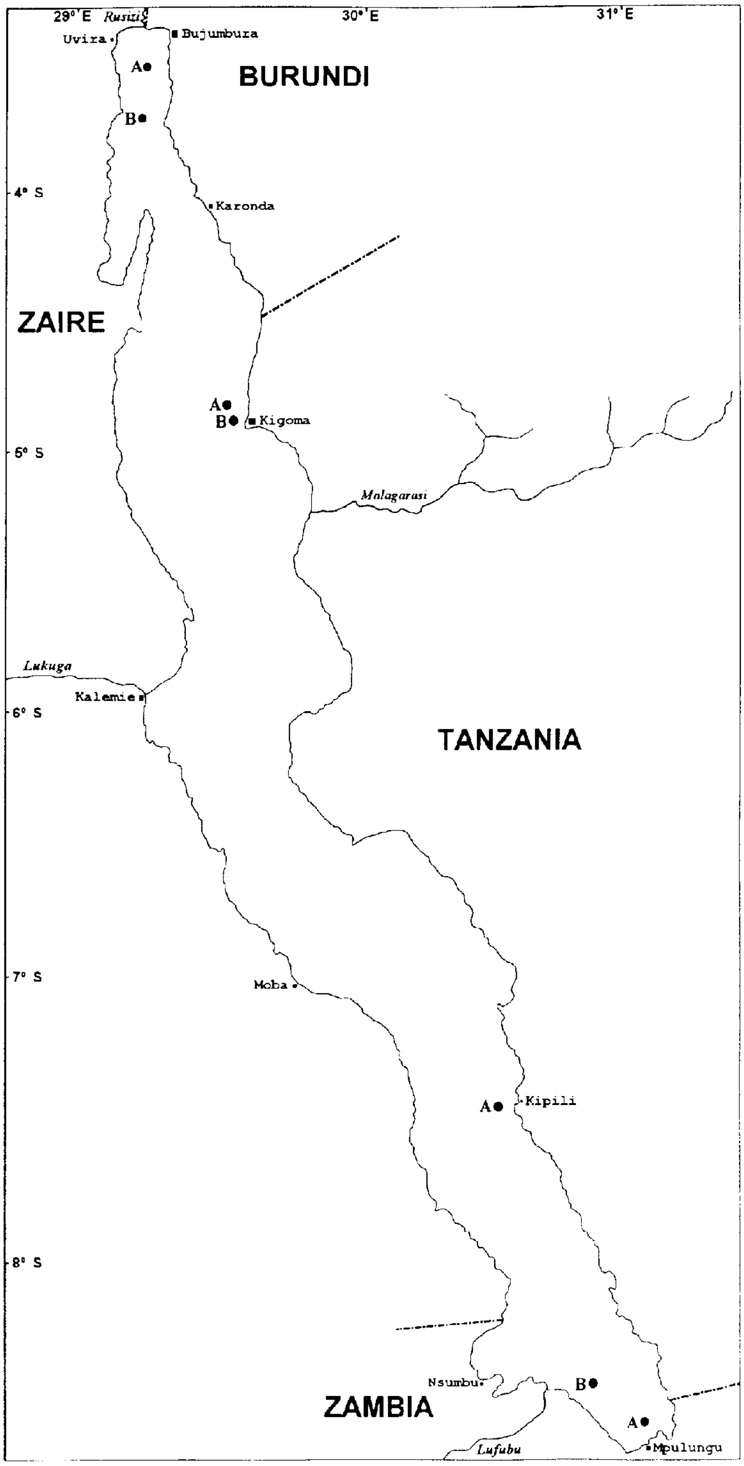


Fig. 1: LTR sampling localities (A:weekly sampling; B:24-hours cycle)

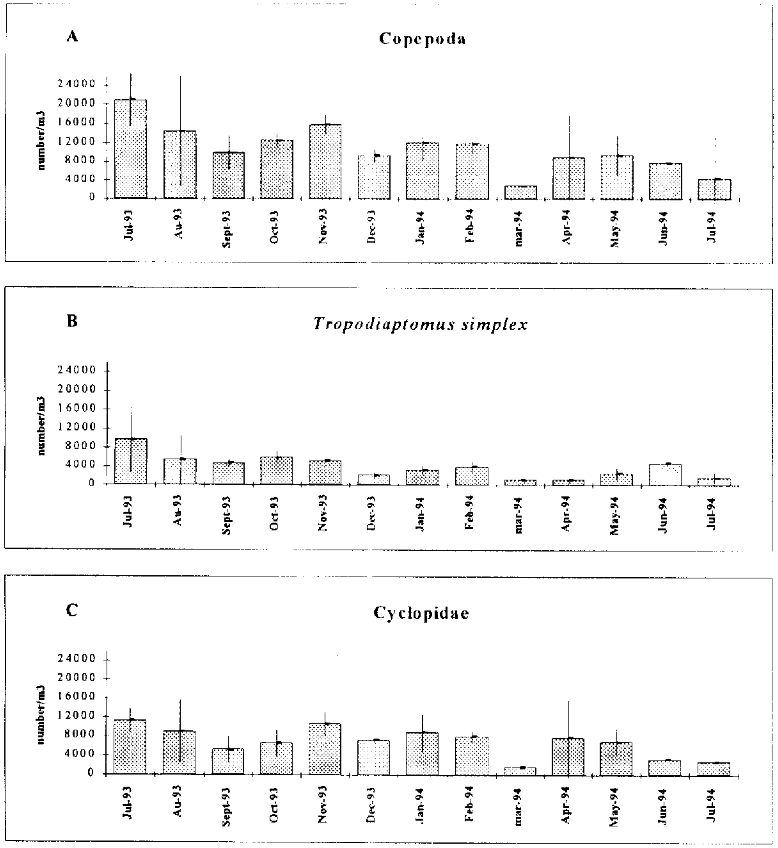


Fig 2 : Abundance of Copepoda in Bujumbura, Burundi

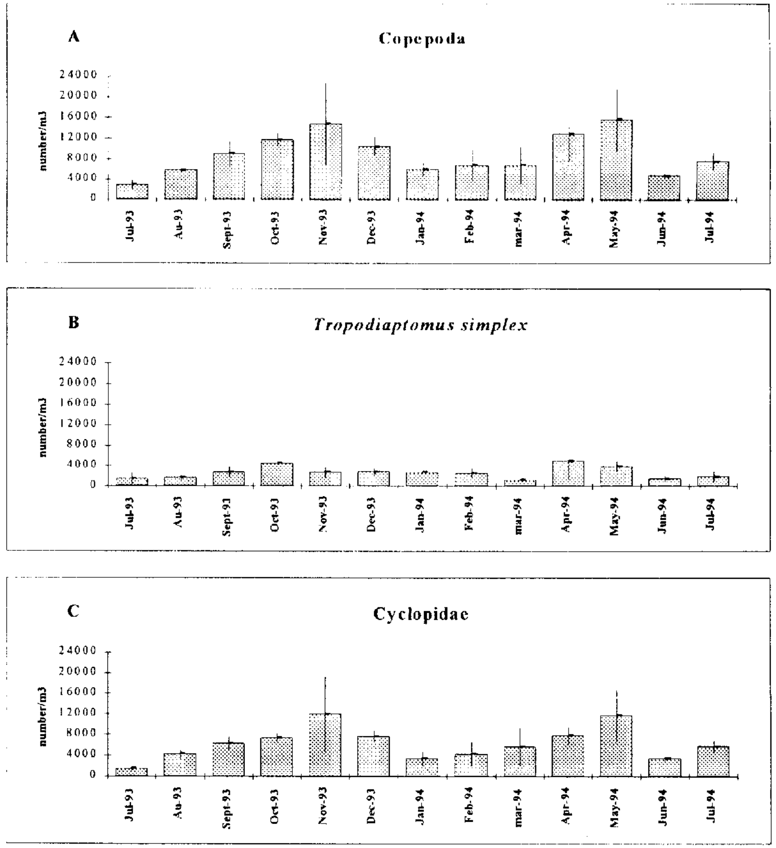


Fig 3 : Abundance of the pelagic Copepoda in Kigoma, Tanzania

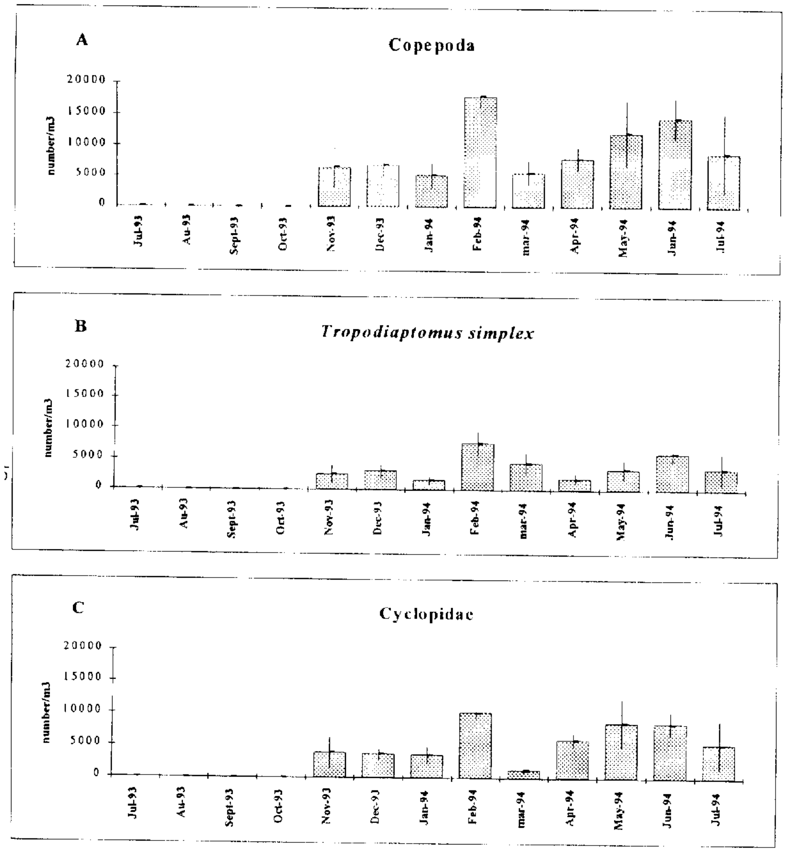


Fig 4 : Abundance of the pelagic Copepoda in Kipili, Tanzania

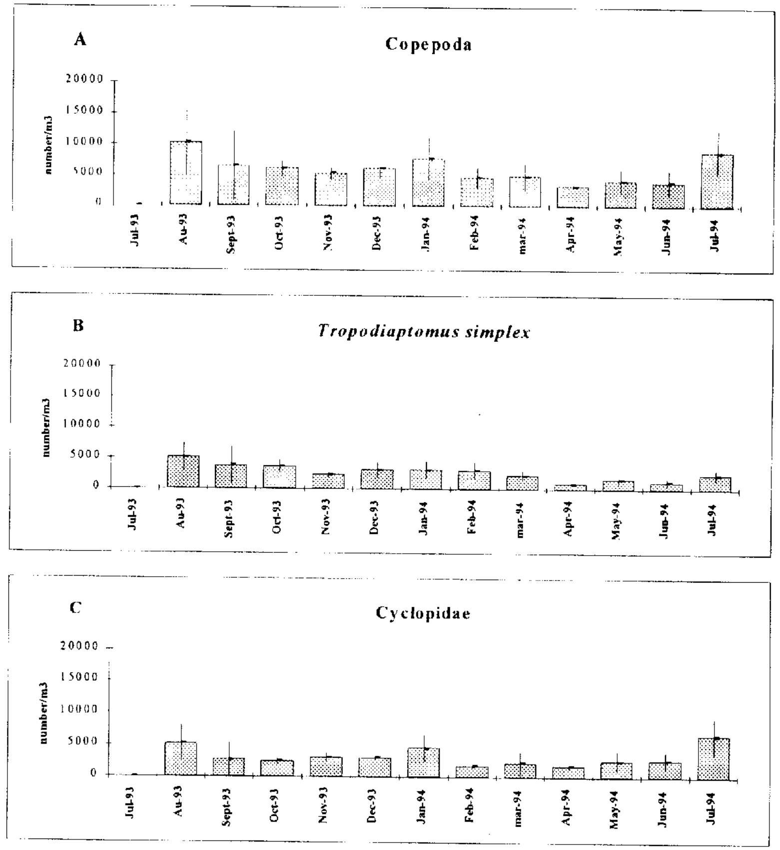


Fig 5 : Abundance of the pelagic Copepoda in Mpulungu, Zambia

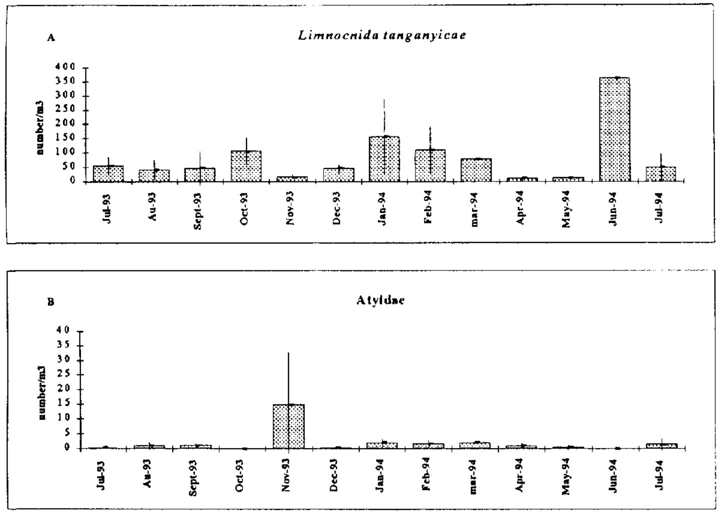


Fig 6: Abundance of macrozooplankton in Bujumbura, Burundi

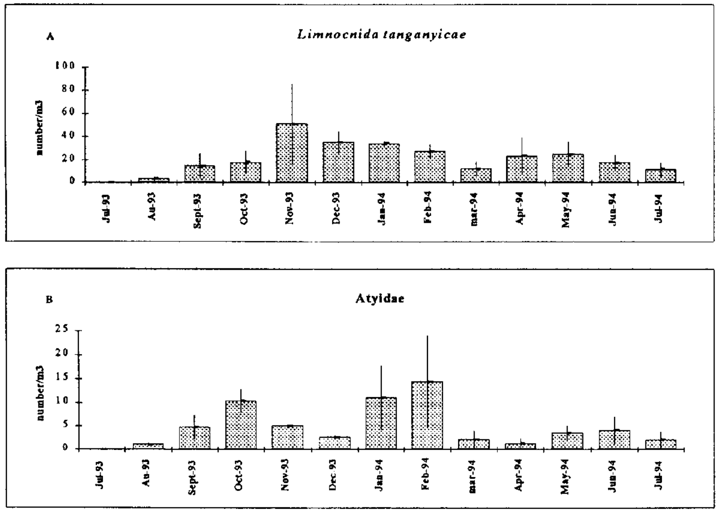


Fig 7: Abundance of macrozooplankton in Kigoma, Tanzania

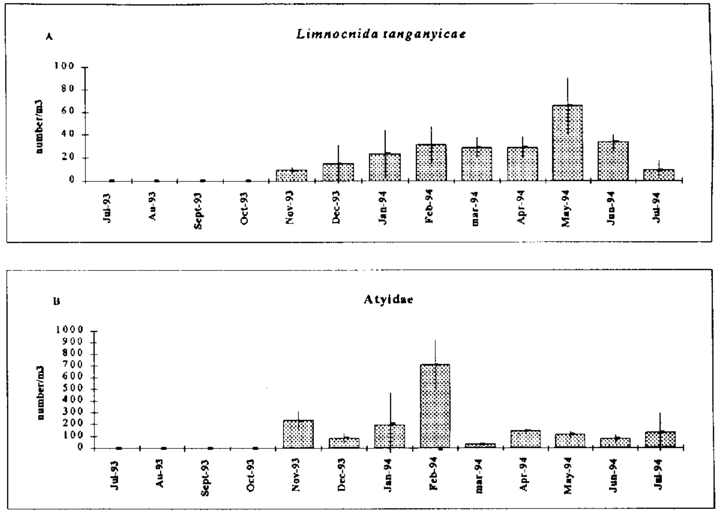


Fig 8: Abundance of macrozooplankton in Kipili, Tanzania

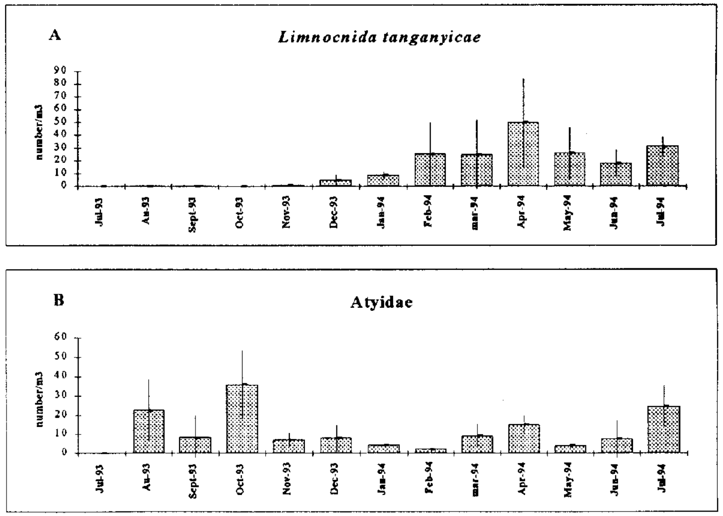


Fig 9: Abundance of macrozooplankton in Mpulungu, Zambia

Tropodiaptomus simplex copepodids and adults

Tropodiaptomus simplex nauplii

Cyclopidae copepodids and adults

Cyclopidae nauplii

Fig 10: Vertical distribution of the pelagic Copepoda in Bujumbura, Burundi. Mean values and standard deviations of eight 24-hours cycles.

Tropodiaptomus simplex copepodids and adults | Tropodiaptomus simplex nauplii | Cyclopidae copepodids and adults | Cyclopidae nauplii

Fig 11: Vertical distribution of the pelagic Copepoda in Kigoma, Tanzania. Mean values and standard deviations of nine 24-hour cycles.

Tropodiaptomus simplex copepodids and adults

Tropodiaptomus simplex nauplii

Cyclopidae copepodids and adults

Cyclopidae nauplii

Fig 12: Vertical distribution of the pelagic Copepoda Mpulungu, Zambia. Mean values and standard deviations of eight 24-hour cycles.

THIRD JOINT MEETING
OF THE LTR'S
COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

Kigoma (Tanzania), 28—30.11.1994

PRESENTATION OF SSP RESULTS: FISH BIOLOGY

by P. Mannini

1. INTRODUCTION

Within the LTR framework, the fish and fishery biology subcomponent aims at understanding the life cycle and at estimating relevant demographical parameters of the major pelagic stocks. It is hoped that information on distribution, production and exploitation patterns of *Lates stappersii, Stolothrissa tanganicae* and *Limnothrissa miodon* will provide a significant input for the management of the lake's fisheries.

Preliminary results are presented here, as a result of partial processing of the large database which has been built during the first twelve months of lakewide data collection. Data analysis is still at the early stages and much more work has to be carried out. No final statement can yet be drawn but only observations which are in need of further validation. Finally, the utilization of commercial fish catch, which do not necessarily provide data representative of the true populations (Pope, 1988), calls for a note of caution.

2. MATERIALS AND METHODS

Fish data collection work around the lake (Fig. 1) has been carried out following standardized procedures (Aro, 1993, Mannini, 1993). Commercial catches have been sampled from fishing gears which target the lake's pelagic fish stocks. Thus, in the northern sector of the lake samples are from artisanal lift net fishery, from both industrial (purse seine) and artisanal fishery in Kigoma area. At the southern end (Kipili and Mpulungu) beach seine fishery was included as this gear efficiently catches small pelagics during certain phases of their life cycle.

Sampling was done weekly during each lunar fishing season; monthly deck sampling on board of purse seiner units was performed in Tanzania and Zambia. Overall, more than one thousand and two hundred samples of the three target species were collected from July 1993 to July 1994. Individual total length (TL) for length frequency (L/F) analysis was recorded from about three hundred thousand specimens. Sexual analysis was performed according to length stratified sub-sampling. Since March 1994 this procedure was further expanded to collect data on individual body wet weight (W), gonadal weight and, in case of *L. stappersii,* on stomach contents (Mannini, 1994). The entire amount of collected data (currently of more than ten megabytes) is stored in computer files which are updated as the sampling work proceeds.

3. RESULTS

3.1 Reproduction patterns

S. tanganicae females are more abundant than the males in the different areas of the lake. Overall lakewide sex ratio (SR) expressed as females to males is 1.8. Longevity can be different between the two sexes as females reach a slightly larger size than males. Highest occurrence of reproducing specimens in the northern end of the lake takes place from October to December (Fig. 2) . During the rest of the year, *S. tanganicae* specimens are found in early stages of gonadal development. Mean annual length at maturity (the length at which 50% of population is mature, $L_{m50\%}$) is 80 and 75 mm for females and males respectively. $L_{m50\%}$ decreases to 75 mm during the breeding peak.

In Kigoma waters, not more than 20% of the sampled population is always sexually mature or close to full maturity. Percentages are higher during January and February and from May to July. $L_{m50\%}$ is 90 mm for females and 85 mm for males. However, as earlier observed (Ellis, 1971), $L_{m50\%}$ may vary during the year and decrease when breeding activity is greatest. In July 1993 and January 1994 $L_{m50\%}$ was observed at 75 and 80 mm for females and males respectively.

At the south end of the lake, the percentage distribution of sexually active *S. tanganicae* seems to indicate that reproduction occurs throughout the year. An increasing trend starts in January and shows a peak in February. The apparent percentage rise in May is not supported by a satisfactory number of specimens. Both sexes reach $L_{m50\%}$ at 75 mm.

Limnothrissa miodon females reach larger size than males, just as for *S. tanganicae*. Sex ratio, from Mpulungu, Kigoma and Uvira data, is similar, varying from 1.1 to 1.4, while it is strongly shifted towards females in Burundi with a value of 4.1 which strongly contributes to elevating the overall SR to 2.1. At this stage it is hazardous to attempt to explain such high local value which needs to be checked by further data and analysis.

At the northern end of the lake, a major breeding peak occurs during October and November followed by a decline which is temporarily reverted in February-April when a second pulse of minor intensity originates (Fig. 2). Males reach $L_{m50\%}$ at 85 mm and females at 100 mm which, indeed, seems an excessively large size.

The sexual activity pattern appears to be less regular in Kigoma waters. Females show marked variations from month to month in the percentage of ready or close to spawning individuals. Apparent January and February peaks for both sexes cannot be considered as they are from a small number of fish. Higher percentages seem to occur from May to September; still, a clear pattern cannot be identified. The determination of $L_{m50\%}$, is also difficult, massive maturity would result to be reached by females at the length of 140 mm and never by males. Probably this inconclusive result is due to the fact that the sampled *Limnothrissa* population, in Kigoma area, is composed of larger individuals (smallest recorded TL was 80 mm) which have already attained $L_{m50\%}$.

Part of *the L. miodon* population in the south of the lake has mature gonads during the whole year, but a six months lasting increase of the percentage of reproducing fish takes place from January till May-June. Length at maturity is attained in both sexes at 80 mm TL.

No reproduction pattern can be outlined from *L. stappersii* in the north of the lake. Adult specimens are rare in commercial catches of artisanal and industrial fisheries, and almost non existent in the available samples.

L. stappersii females grow more than males reaching larger size and SR is in favour of females by a factor of 1.2. Females reproductive phase is quite similar between Kigoma and Mpulungu areas (Fig.3). Higher frequency of mature females extends over several months (from November to March in Kigoma and to April in Mpulungu). In the south of the lake the occurrence of mature males well confirms this pattern, while in Kigoma it is unclear as breeding males show a declining trend from the maximum in

August till June-July of the following year when it starts reverting. Annual $L_{m50\%}$ is reached by *L. stappersii* females at 255 mm and by males at 285 mm, while in Mpulungu it is at 265 mm and 255 mm respectively.

3.2 Growth

Von Bertalanffy growth function (VBGF) parameters have been estimated for all target species from the main study areas. Not all data sets have been used, some were discarded because unsuitable for length-based analysis *(i.e.* lack of evidence of modal class progression). ELEFAN I method (Pauly and David, 1980, 1981; Pauly, 1987), SLCA (Shepherd, 1987) and projection matrix method (Basson *et al.,* 1988) were used. The last two methods could not be applied to clupeids' L/F data. They were useful to provide estimates, alternative to those obtained through ELEFAN I, when applied to *L. stappersii* length distributions. Results are reported in Table 1. To facilitate the comparison of growth performances phi prime values (Pauly and Munro, 1984) are also included in the same table.

All species show relatively fast growth patterns which appear quite similar all around the lake. *S. tanganicae* has the shortest life-span which is of about 1.5 year and very few individuals can live up to 2 years. Growth curve indicates an average growth rite of 12 mm mo^{-1} during the first six months of life.

Growth performances of *L. miodon* at the two ends of the lake appear almost identical showing an increase in length of about 11 mm mo' during the first six months of life. A quicker growth would result from Kipili samples. Average longevity of this species is estimated at 2.5 years.

L. stappersii growth could not be inferred in the northern sector of the lake because the available commercial catch samples contain almost exclusively individuals whose annual mean TL is about 95 mm. Hence only a part of the population is represented, adult individuals are definitely rare in artisanal and industrial fishery catches. Growth in the south of the lake (Mpulungu and Kipili) and in Kigoma waters is quite similar although a slightly quicker performance results from the Kigoma data. Growth increment in length is about 15 mm mo^{-1} during the first year of life. Longevity can be estimated as being between 5 to 6.5 years depending on differences in VBGF parameters and in the observed maximum length (L_{max}).

3.3 Mortality rates

Preliminary estimates of total mortality (Z) and natural mortality (M) were attempted by using different methods. Results are reported in Table 2. Total mortality estimates obtained by length-converted catch curve (Pauly, 1983, 1984) are considered as reference values.

S. tanganicae has high Z values ranging from 4.2 to 7.8 yr^{-1}, the latter might be affected by overestimation. Highest values are from the north of the lake while the average value is lower in the south. Total mortality rates of *Limnothrissa* are very similar in the north and south end of the lake (growth is similar too). Higher Z value is from Kipili area where a relatively faster growth performance was observed. *L. stappersii* displays Z which decreases from south to north. Estimates range from 2.5 (Mpulungu) to 1.5 yr^{-1} (Kigoma) and they appear to be correlated with differences in growth rates.

Difficulties in estimating natural mortality are well known. Several methods have been used to approximate this parameter, they are empirical equations whose parameters are concerned, for example, with species longevity, growth performance, mean environmental temperature, age of massive sexual maturation. Therefore all of them are somehow related to the species growth. Results from Pauly's method (1980) are considered as reference values as this is a frequently used approach employed in temperate as well as tropical waters.

Stolothrissa exhibits, as expected, the highest natural mortality, average value is 3.6 yr^{-1}. *Limnothrissa* displays natural mortality which can be averaged from Pauly's equation as 77 2 yr^{-1}. It falls between 1.8 and 2.3 yr^{-1} when considering other available estimates. *L. stappersii* natural mortality assumes a mean value for the whole lake of 0.8 yr^{-1}, as temperature input was kept constant (T = 25°C) differences in M are explained by differences in growth parameters. Other methods estimate M values which are, although quite close, slightly superior to the above mean value.

3.4 Fishing mortality and catch composition

Fishing mortality can be approximated subtracting N from Z and the exploitation rate (E) is given by F/Z ration. Some caution is required when considering F and E values as Z and M coefficients are quite rough estimates, either because obtained from commercial catch samples and because they are based on the assumption of a "constant parameter system" which is rarely, if ever, met in real life (Sparre and Venema, 1992). Length composition of the annual catch by fishing gear is presented in Figures 4, 5, 6.

S. tanganicae would appear to experience higher F in the northern end of the lake compared to the other areas investigated. Exploitation rate varies accordingly and it does not shown any clear indication of overexploitation. The minimum TL at which *Stolothrissa* enter beach seine and purse fishery is 21 and 31 mm respectively corresponding to a relative recruitment age (Tr, i.e. the youngest age at which the fish may be vulnerable to fishing gears) of about one and half-two months. Fishing mortality exerted by artisanal fishery affects *Stolothrissa* juveniles up to the length of 50 mm (about four months relative age) when they appear to temporarily leave inshore waters and are recruited to the industrial fishery. At the length of 70 mm a more ubiquitous behaviour is shown appearing in both artisanal and industrial catches. In Kipili area, minimum length is observed at 35 (beach seine) and 41 mm (lift net) and in Kigoma waters *Stolothrissa* starts to be exploited at the length of 31 mm (three months relative age) . It recruits at the minimum length of 31 mm (about two months relative age) in Karonda and Uvira and 21 mm (one and half month of age) in Bujumbura area.

L. miodon shows quite high F values which are similar at the northern and southern ends of the lake and higher in Kipili area. Exploitation rates, which follows the same trend, indicate an intense exploitation which still cannot be referred to as overexploitation. This species experiences in the south early fishing mortality due to the local use of unselective fishing gears (both beach seine and lift net are equipped with mosquito net or tissue cloth codend) . Recruitment into such fisheries can take place at 13 mm (beach seine) and 21 mm (lift net) TL corresponding to a relative age of less than two months. Consequently, a tentative estimate of the length at which 50% of the fish are retained in the gear ($L_{50\%}$) results in 18 mm TL. The annual mean length in the catch is 50 mm. Large individuals occur almost exclusively in purse seine fishery. In Kipili the same gears but with a more selective mesh size determine the recruitment to start at the minimum length of 27 mm, and the mean length from the catch is 80 mm. Further north, in Kigoma area, only large sized *Limnothrissa* is affected by fishing mortality from open water gears (lift net and purse seine) . *Limnothrissa* appears in the lift net catch at the length of 80 mm and a size-related shift takes place as larger specimens appear mainly in purse seine catch. However, this is not indicative of size— related migration because, in this area, lift net and purse seine, whose net mesh sizes are similar, share the same fishing grounds. In the northern end of the lake

Limnothrissa occurs in artisanal catch from the minimum length of 22 mm and mean length caught is 66 mm. Largest specimens occur in inshore beach seine catches.

L. stappersii undergoes a gradually increasing F proceeding from north to south and E rates suggest that heavy exploitation is taking place in the southern area. The allocation of industrial fishery effort in the lake would support such hypothesis. Fishing mortality acting on *L. stappersii* in Mpulungu area is entirely due to industrial fishery while further north artisanal lift net fishery replaces it. *L. stappersii* recruits into purse seine fishery at the length of 80 mm (about 8 months of relative age), the bulk of the catch is composed of adult specimens (mean TL is 264 mm). Young *L. stappersii* occur in Kipili lift net catch at the minimum length of 55 mm. Similar to industrial fishery the catch is sustained by adult fish (mean TL is 234 mm) . In Kigoma area both industrial and artisanal fisheries target on *L. stappersii* and catch composition does not seem to reflect any-age specific pattern. Juveniles enter massively into the fishery from the length of 50 mm, which leads to an annual mean length in the catch of 174 mm. Proceeding northwards *L. stappersii* is still exploited by both artisanal and industrial fishery. Mean length in the catch maintains the progressive decreasing trend being 126 mm TL in Karonda area to drop at less than 100 mm at the extreme end of the lake. Almost virtually adult specimens do not occur in the catch further north than Karonda.

3.5 Feeding regime of *L. stappersii*

A total of 1096 stomachs (318 at Mpulungu and 778 at Kigoma) were investigated, during each month of study empty stomachs were never more than 3% of the total (Kigoma data). Fullness condition was mainly (77%) “nearly empty” or “half full” which could mean that feeding takes place at around dusk and during the first dark hours. Stomach contents are reported as frequency of occurrence, percentage number and weight of different food categories (Fig. 7). A note of caution is required as how much the prey concentration (e.g. shrimps) is affected by artificial fish gathering during fishing operations has not yet been satisfactorily assessed. However, with regard to this matter, Pearce (1981) stated, on the basis of his findings, that it is unlikely that occurrence of shrimps in the stomachs of *L. stappersii* is an artifact due to light attraction.

The diet of *L. stappersii* in the south is mostly based on clupeids and shrimps. In some periods of the year (June-July) shrimps may replace almost entirely clupeid preys. In Kigoma waters, *L. stappersii* displays a more heterogeneous food spectrum including copepods (March), and fish larvae (most likely clupeid larvae) . As far as identification of fish remains allows, *S. tanganicae* is the most common clupeid prey in Kigoma area.

Ontogenetic changes in feeding can be observed from the length of 100 mm in the south (Fig. 8). The simple dual diet composition (clupeids and shrimps) is almost constant throughout the length (than age) range investigated. In Kigoma sector, between 50 and 100 mm length *L. stappersii* feed on meso- and macroplankton (copepods and shrimps) and begins to prey upon fish larvae and *Stolothrissa* from 100 mm length onwards. During the adult phase of life, larvae appear sporadically in the diet which is based on shrimps and clupeids. Largest specimens are nearly piscivorous.

4. CONCLUSIONS

Catch per unit of effort (CPUE) as index of stock relative abundance can be an erroneous assumption in the case of small shoaling pelagic fish (Csirke, 1988) , even more when fish are gathered by artificial light attraction. Keeping this in mind, it can be observed that, within the period of investigation, clupeid abundance in artisanal fishery catches has two major pulses whose timing is quite uniform around the lake. The first abundance increase takes place between the end of the rainy season and can last till well into the dry season. Eventually a second pulse occurs during the wet season from November to February at the northern end, October—November in Kigoma area while in the south there is no evidence of it from industrial catch (artisanal fishery statistics are not available) . This pattern of clupeid abundance could indicate that clupeids do not undertake extensive migration along the longitudinal axis of the lake. Similar to clupeids, *L. stappersii* displays a bimodal abundance pattern over the year and an evident negative correlation, as earlier reported (Roest, 1988), exists with clupeid abundance.

Clupeids’ reproduction never entirely stops during the year as ready to spawn and close to maturity specimens always occur. Over this continued reproduction pattern there are maxima lasting for a few months when occurrence of reproducing specimens is higher. Following the chronological progression it would appear that timing in reproduction maxima, at least at the two ends of the lake, is different. Also it would seem common to both *Limnothrissa* and *Stolothrissa* to have more extended breeding periods at the south of the lake than at the north. Probably the reproductive phases of clupeids vary between the years as previous observations are not uniform and only partially correspond with present findings.

L. stappersii reproductive cycle has a similar pattern in Mpulungu and Kigoma waters lasting from November to March (Kigoma) and April (Mpulungu). Such apparent spawning homogeneity, if substantiated, could suggest that extensive longitudinal spawning migration are unlikely to happen as reproduction takes place simultaneously in different areas of the lake. However, the possible age-related distribution of *L. stappersii* needs to be investigated. The size composition at the utmost northern part of the lake bears this out. In this area, in 1993-94, *L. stappersii* stock was composed of juveniles only. Definitely this does not look like a breeding area for the species; whether it is a preferred nursery area (i.e. area of high concentration of juveniles) has to be carefully evaluated.

Growth parameters and mortality rates can be compared with those obtained earlier by different authors (Table 3). It is worth recalling that length-based methods allow to estimate the parameters which provide the best fit to the available data which, in turn, can be far from being representative of the true population in the lake. Clupeids aging by otolith daily growth increments reading is underway and further and, possibly, “robust” insight on *Limnothrissa* and *Stolothrissa* growth will be soon available.

Preliminary mortality estimates are quite high for all the three species. This is what is generally expected from fast-growth short-life tropical species. A first tentative indication on production (P) and mean annual biomass (Bm) ratio, P/Bm, could be hazarded considering Z as equivalent to P/Bm (Allen, 1971). This would mean that annual production can have the magnitude of approximately five times the mean biomass of *Stolothrissa,* four times in case of *Limnothrissa* and between one and a half and two times for *L. stappersii.*

Analysis of feeding regime of *L. stappersii* is providing more complete information on its food spectrum. Definitely, shrimp preys play an important role, especially at the south of the lake, to sustain *L. stappersii* adult population. Shrimps appear to have a relevant collocation within the food web being preys of either clupeids (Coulter, 1991) as well as of *L. stappersii.* Further research on shrimp population, together with a satisfactory taxonomic identification, is needed. Implementation of research work on stomach contents of both clupeid species is currently being finalized.

Finally, length data, and preliminary experimental fishing data from Kigoma, evidence that almost all LTR target fish species show size–related inshore and offshore distributions either due to feeding or to spawning behaviour. In order to have a more complete and valid information on life cycles, effort should be put to implement a simple monthly programme of experimental fishing. It can be realized by temporarily hiring, for a few days each month, a common fishing unit *(i.e.* catamaran) whose commercial gear selectivity could be reduced by a small meshed cover.

5. ACKNOWLEDGMENTS

I wish to acknowledge the continuous data collection work of fish biology teams around the lake. I am also grateful for the data processing work carried out at each LTR station by G. Milindi and P. Verburg (LTR Mpulungu), K. Katonda, A. Kihakwi and M. Kissaka (LTR Kigoma). Special thanks are due to Ms. P. Paffen (LTR Bujumbura) who processed and discussed the large amount of data from the north of the lake. Finally, I want to thank Ms. H. Kurki, my colleague at Kigoma, for many informal and fruitful discussions.

Kigoma, 04.11.1994

First draft, still missing Table 3 and references.

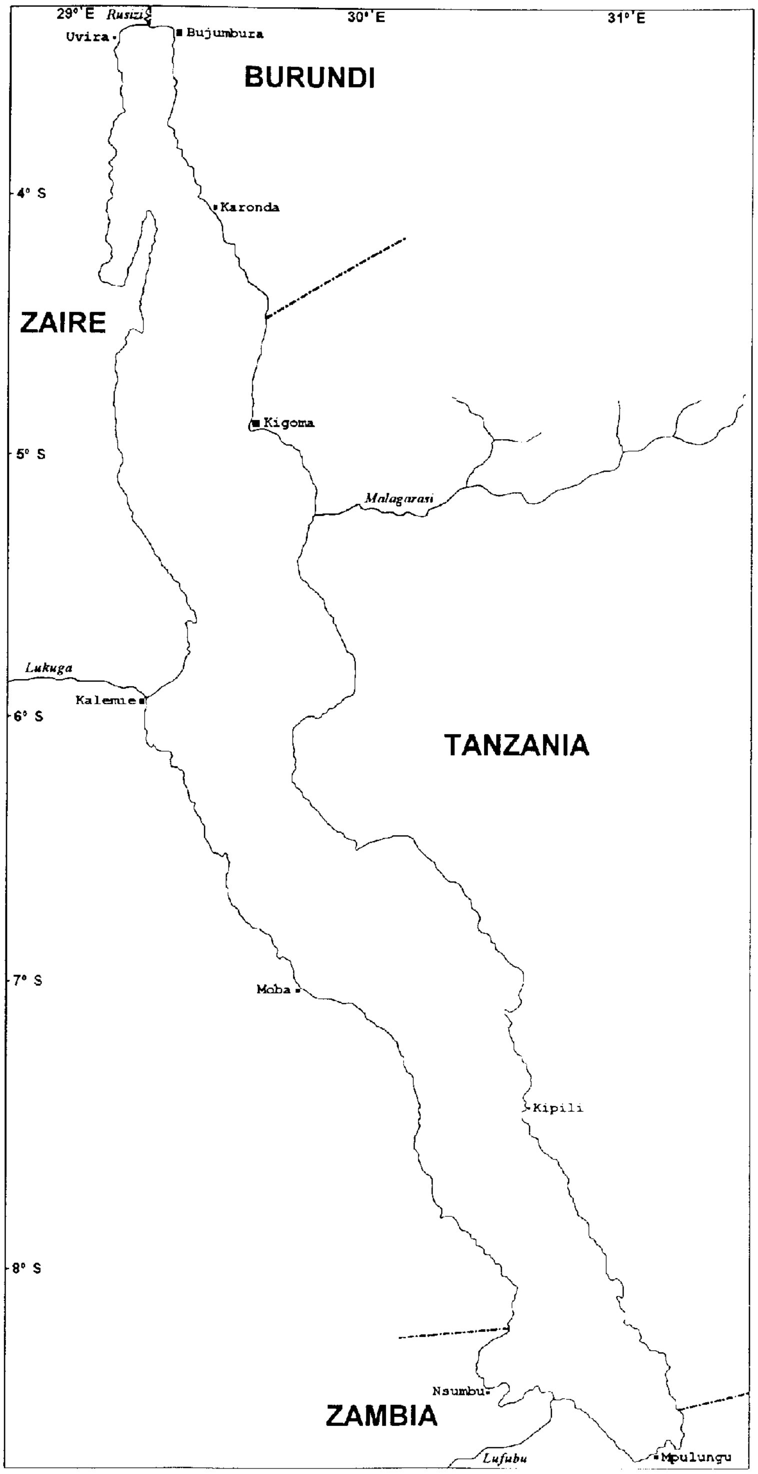


Fig. 1: Lake Tanganyika, LTR stations and substations

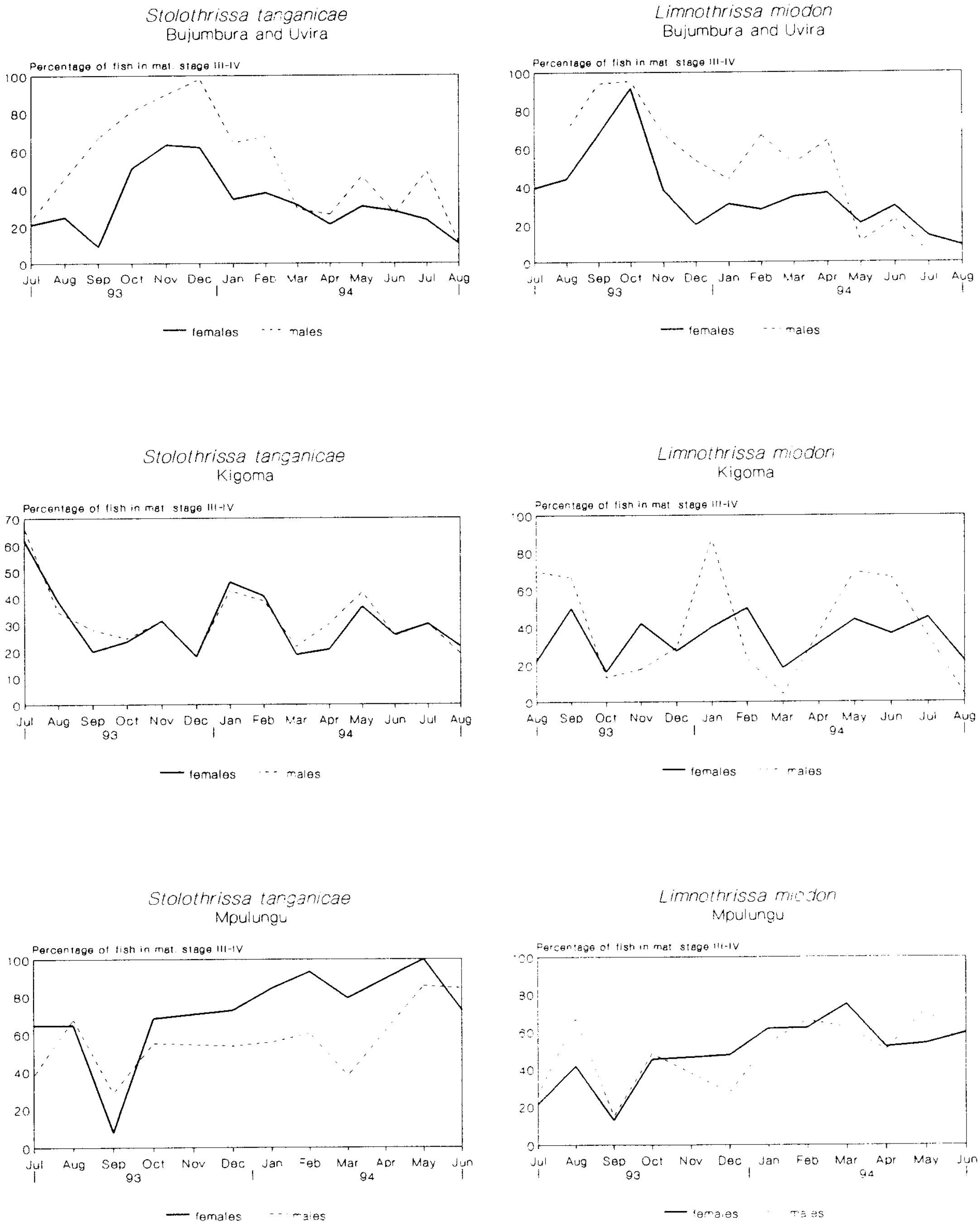
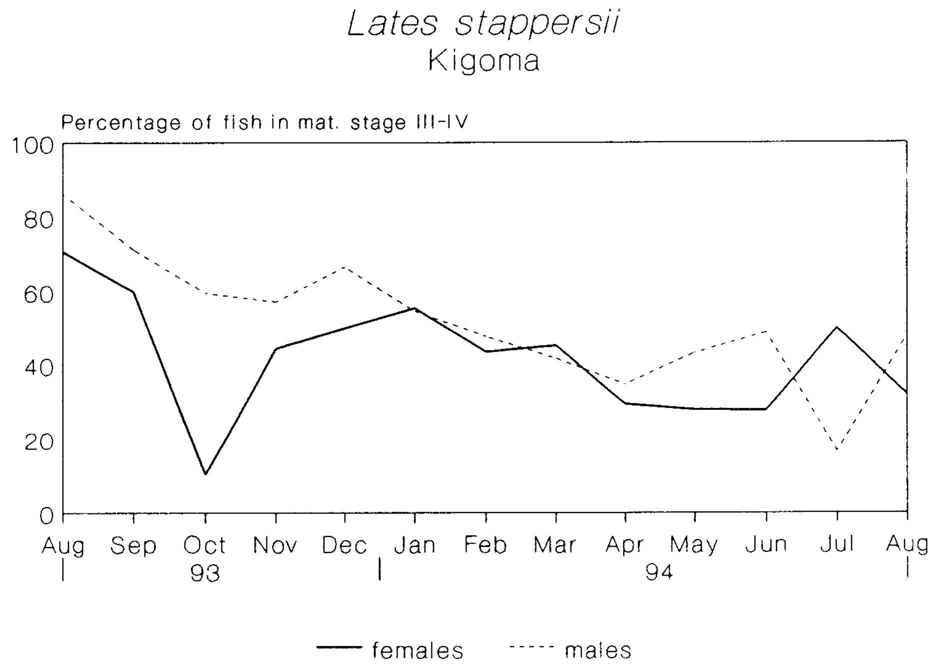
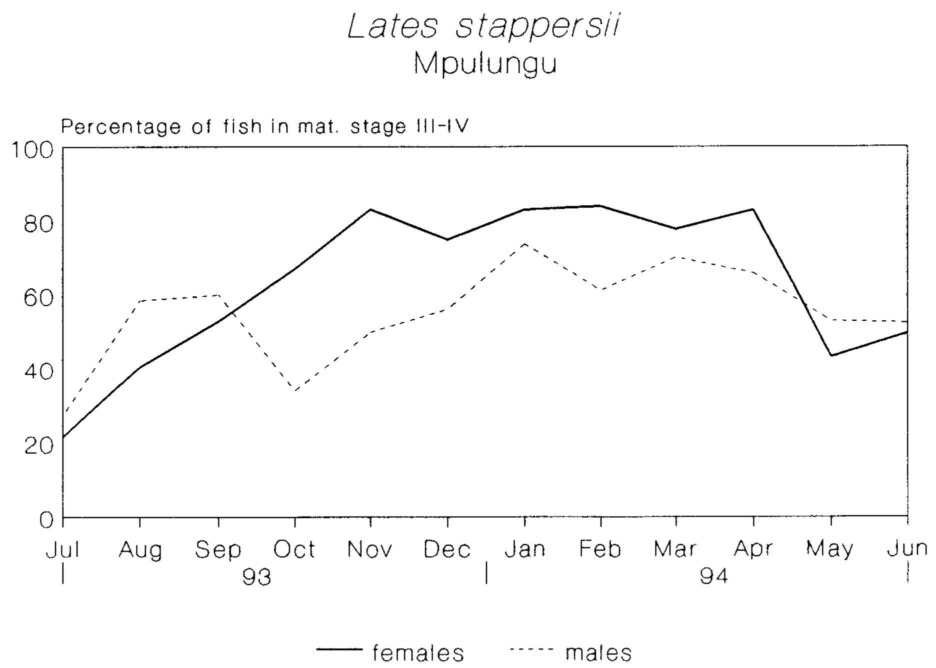

Stolothrissa tanganicae
Bujumbura and Uvira
Percentage of fish in mat. stage III-IV
100
80
60
40
20
0
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
93
94
females
males
Limnothrissa miodon
Bujumbura and Uvira
Percentage of fish in mat. stage III-IV
100
80
60
40
20
0
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
93
94
females
males
Stolothrissa tanganicae
Kigoma
Percentage of fish in mat. stage III-IV
70
60
50
40
30
20
10
0
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
93
94
females
males
Limnothrissa miodon
Kigoma
Percentage of fish in mat. stage III-IV
100
80
60
40
20
0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
93
94
females
males
Stolothrissa tanganicae
Mpulungu
Percentage of fish in mat. stage III-IV
100
80
60
40
20
0
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun
93
94
females
males
Limnothrissa miodon
Mpulungu
Percentage of fish in mat. stage III-IV
100
80
60
40
20
0
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun
93
94
females
males

Figure 2



Lates stappersii
Kigoma
Percentage of fish in mat. stage III-IV
100
80
60
40
20
0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
93
94
females
males



Lates stappersii
Mpulungu
Percentage of fish in mat. stage III-IV
100
80
60
40
20
0
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun
93
94
females
males

Figure 3

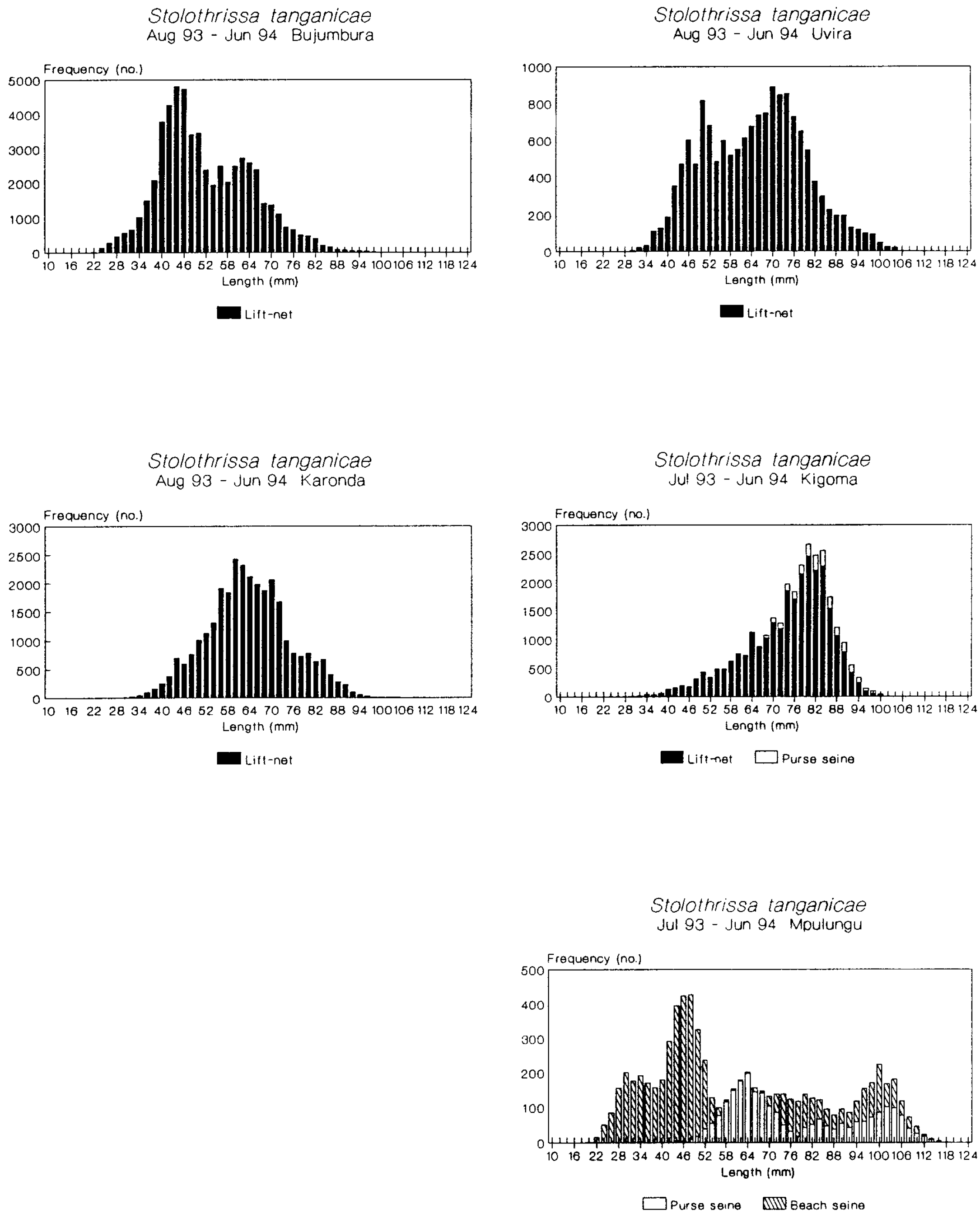
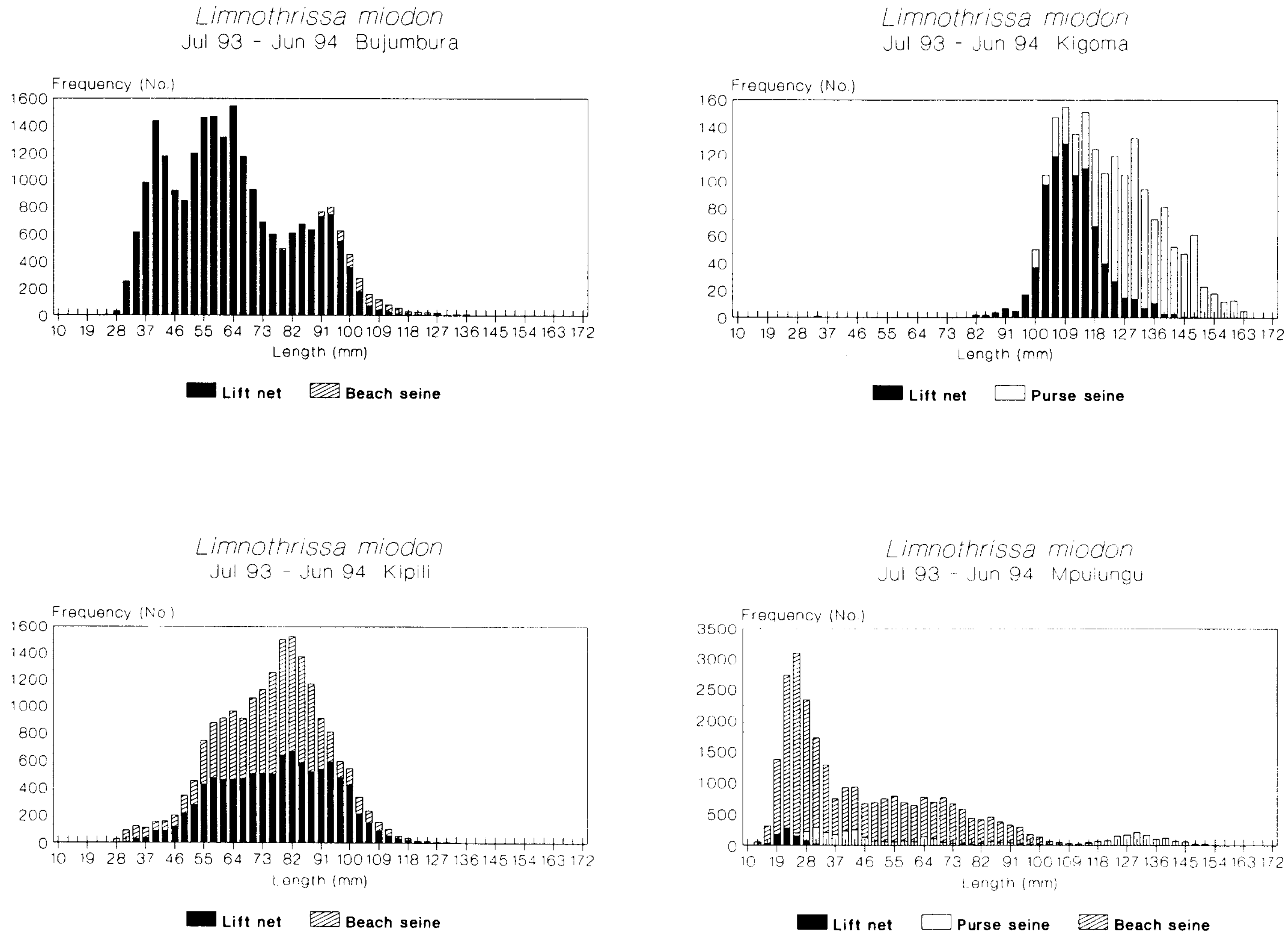

Stolothrissa tanganicae
Aug 93 - Jun 94 Bujumbura
Frequency (no.)
Length (mm)
Lift-net
Stolothrissa tanganicae
Aug 93 - Jun 94 Uvira
Length (mm)
Lift-net
Stolothrissa tanganicae
Aug 93 - Jun 94 Karonda
Frequency (no.)
Length (mm)
Lift-net
Stolothrissa tanganicae
Jul 93 - Jun 94 Kigoma
Frequency (no.)
Length (mm)
Lift-net
Purse seine
Stolothrissa tanganicae
Jul 93 - Jun 94 Mpulungu
Frequency (no.)
Length (mm)
Purse seine
Beach seine

Figure 4



Limnothrissa miodon
Jul 93 - Jun 94 Bujumbura
Frequency (No.)
1600
1400
1200
1000
800
600
400
200
0
10 19 28 37 46 55 64 73 82 91 100 109 118 127 136 145 154 163 172
Length (mm)
Lift net
Beach seine
Limnothrissa miodon
Jul 93 - Jun 94 Kigoma
Frequency (No.)
160
140
120
100
80
60
40
20
0
10 19 28 37 46 55 64 73 82 91 100 109 118 127 136 145 154 163 172
Length (mm)
Lift net
Purse seine
Limnothrissa miodon
Jul 93 - Jun 94 Kipili
Frequency (No.)
1600
1400
1200
1000
800
600
400
200
0
10 19 28 37 46 55 64 73 82 91 100 109 118 127 136 145 154 163 172
Length (mm)
Lift net
Beach seine
Limnothrissa miodon
Jul 93 - Jun 94 Mpulungu
Frequency (No.)
3500
3000
2500
2000
1500
1000
500
0
10 19 28 37 46 55 64 73 82 91 100 109 118 127 136 145 154 163 172
Length (mm)
Lift net
Purse seine
Beach seine

Figure 5

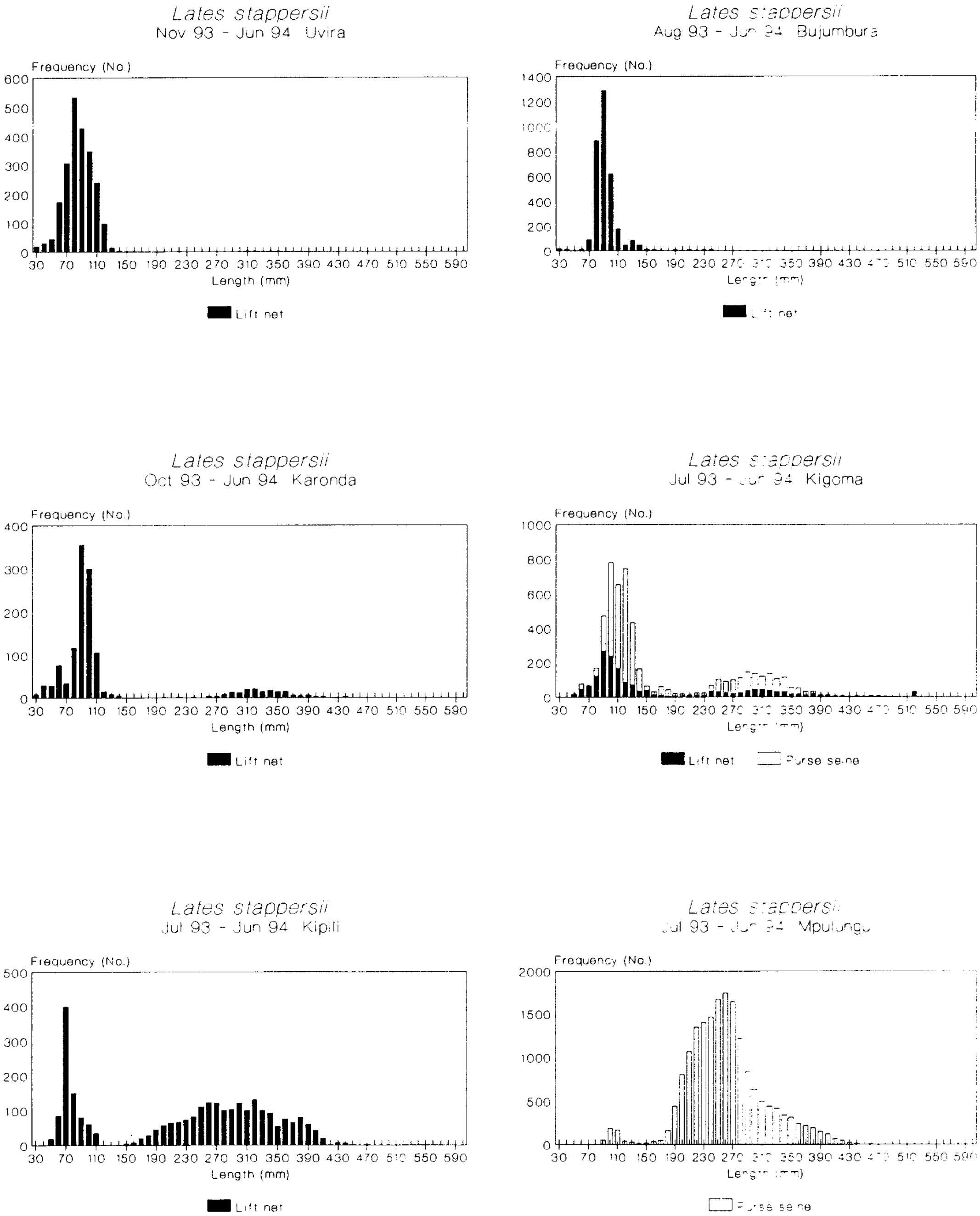

Lates stappersii
Nov 93 - Jun 94 Uvira
Frequency (No.)
Length (mm)
Lift net
Lates stappersii
Aug 93 - Jun 94 Bujumbura
Frequency (No.)
Lates stappersii
Oct 93 - Jun 94 Karonda
Frequency (No.)
Length (mm)
Lift net
Lates stappersii
Jul 93 - Jun 94 Kigoma
Frequency (No.)
Lift net
Purse seine
Lates stappersii
Jul 93 - Jun 94 Kipili
Frequency (No.)
Length (mm)
Lift net
Lates stappersii
Jul 93 - Jun 94 Mpulungu
Frequency (No.)
Purse seine

Figure 6

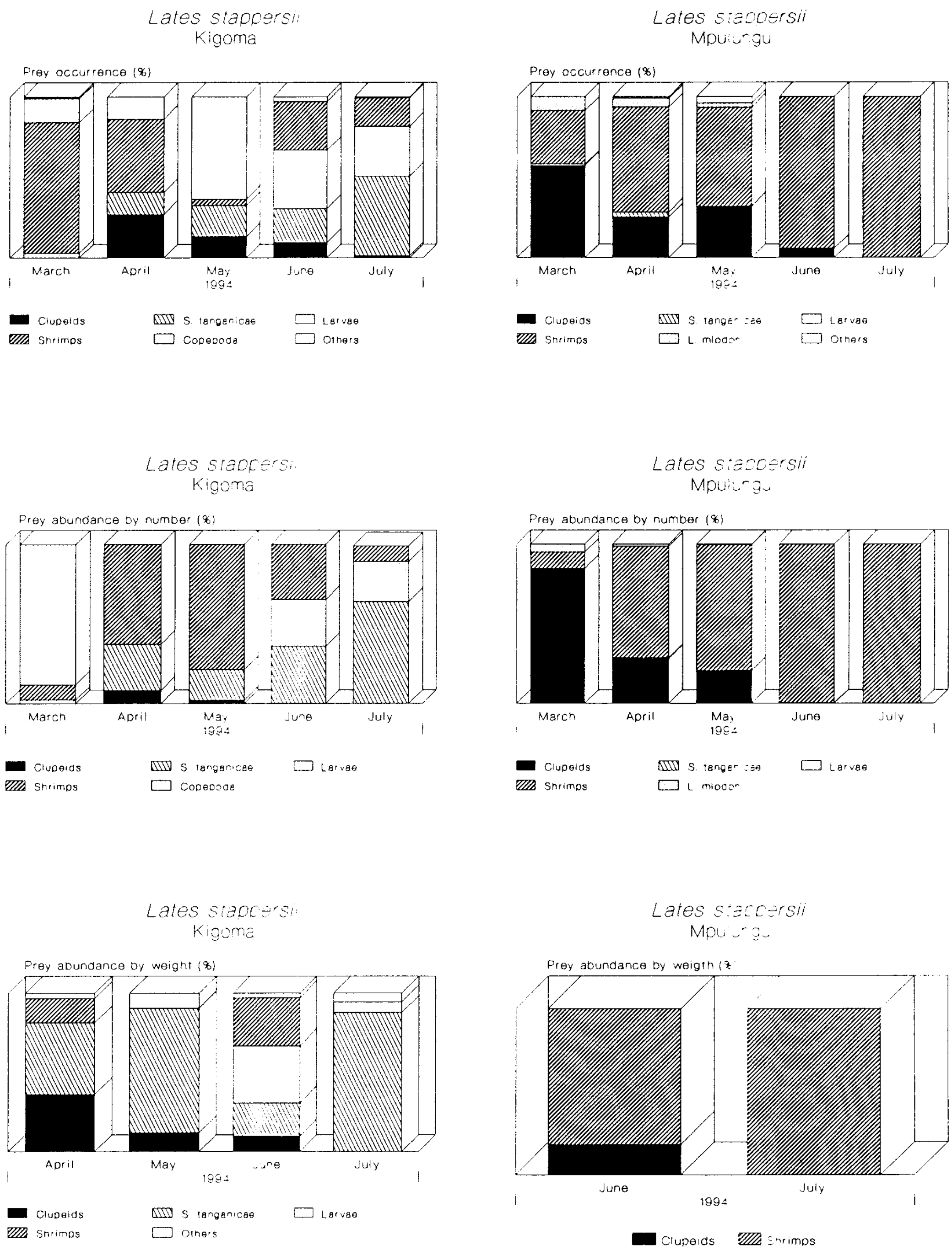
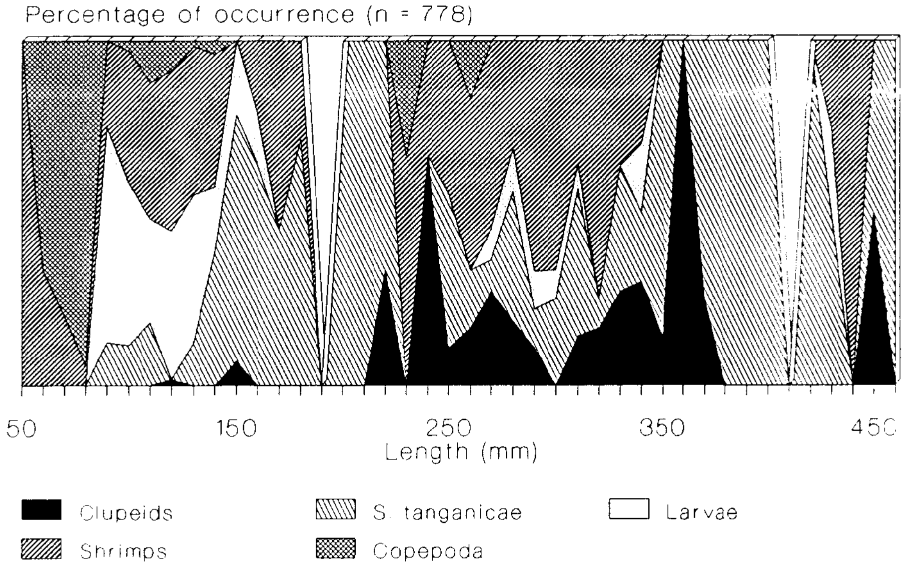

Lates stappersii
Kigoma
Prey occurrence (%)
March
April
May
June
July
1994
Clupeids
Shrimps
S. tanganicae
Copepoda
Larvae
Others
Lates stappersii
Mpulungu
Prey occurrence (%)
L. miodon
Prey abundance by number (%)
Prey abundance by weight (%)
Prey abundance by weigth (%)

Figure 7

Lates stappersii
Kigoma



Lates stappersii
Mpulungu

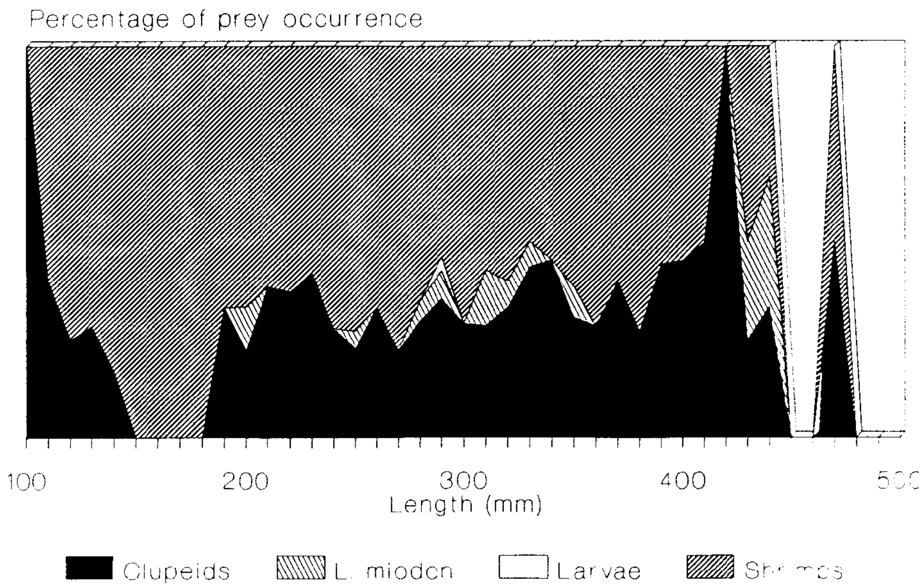


Figure 8

Stolothrissa tanganicae					
Area	**Observed TLmax**	**Method**	**Asymptotic TL (Loo, mm)**	**Growth constant (K , annual)**	**Phi prime**
Zaire (Uvira)	115	ELEFAN I	110	2.47	4.48
Burundi (Bujumbura)	108	ELEFAN I	114	2.08	4.44
Burundi (Karonda)	115	ELEFAN I	111	1.90	4.37
Tanzania (Kigoma)	106	ELEFAN I	100	1.85	4.27
Zambia (Mpulungu)	115	ELEFAN I	110	2.00	4.38
Limnothrissa miodon					
Area	**Observed TLmax**	**Method**	**Asymptotic TL (Loo, mm)**	**Growth constant (K , annual)**	**Phi prime**
Burundi (Bujumbura)	152	ELEFAN I	176	0.86	4.43
Tanzania (Kipili)	157	ELEFAN I	175	1.16	4.55
Zambia (Mpulungu)	161	ELEFAN I	178	0.84	4.42
Lates stappersii					
Area	**Observed TLmax**	**Method**	**Asymptotic TL (Loo, mm)**	**Growth constant (K , annual)**	**Phi prime**
Tanzania (Kigoma)	545	ELEFAN I	582	0.43	5.17
" "	"	SLCA	604	0.41	5.17
" "	"	Proj. Matrix	586	0.54	5.27
Tanzania (Kipili)	475	ELEFAN I	595	0.30	5.03
" "	"	SLCA	578	0.32	5.03
Zambia (Mpulungu)	488	ELEFAN I	589	0.37	5.10
" "	"	SLCA	545	0.40	5.08

Table 1. Estimates of growth parameters by species from different L/F data sets

Area	Total mortality (Z, annual)			Natural mortality (M, annual)				
	I	II	III	IV	V	VI	VII	VIII
Stolothrissa tanganicae								
Zaire (Uvira)	6.32	7.41	6.24	4.05	2.18	2.69	3.07	4.61
Burundi (Bujumbura)	7.83	10.5	6.35	3.58	2.1	2.27	3.29	4.93
Burundi (Karonda)	4.23	6.28	3.74	3.4	2.1	2.08	2.09	3.14
Tanzania (Kigoma)	4.7	4.32	5.84	3.44	1.49	2.03	2.3	3.45
Zambia (Mpulungu)				3.53	2.1	2.19	3.07	4.61
Limnothrissa miodon								
Burundi (Bujumbura)	4.27	3.89	3.51	1.78	1.79	0.98	1.84	2.76
Tanzania (Kipili)	6.16	6	4.74	2.17	1.81	1.30	2.3	3.45
Zambia (Mpulungu)	4.12	3.29	3.74	1.75	1.81	0.96	2.21	3.32
Lates stappersii								
Tanzania (Kigoma)	1.56	1.93	1.29	0.81	1.04	0.53	0.77	1.15
SLCA VBGF parameters	1.61	1.94	1.54	0.78	1.04	0.50	0.77	1.15
Projmat VBGF paramet.	1.98	2.44	2.03	0.94	1.2	0.64	0.92	1.38
Tanzania (Kipili)	1.89	1.3	2.03	0.64	0.8	0.39	0.84	1.26
SLCA VBGF parameters	1.87	1.3	2.03	0.67	0.8	0.41	0.84	1.26
Zambia (Mpulungu)	2.58	2.7	2.03	0.73	0.94	0.46	0.92	1.38
SLCA VBGF parameters	2.43	2.47	1.71	0.79	0.91	0.49	0.81	1.22

Table 2. Estimates of mortality parameters. Latin numbers refers to methods used in computation. I) Pauly (1983), II) Beverton and Holt (1956), III) Hoenig in Gayanilo et al. (in press) (in press), IV) Pauly (1980), V) Rikhter and Efanov (1976), VI) Gunderson and Dygert (1988), VII) and VIII) Alagaraya (1984).

THIRD JOINT MEETING
OF THE LTR'S
COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

KIGOMA (TANZANIA), 28–30.11.1994

PRESENTATION OF SSP RESULTS: REMOTE SENSING

by J. Parkkinen, V. Tuomainen, L. Patomaki,
O.V. Lindqvist and H. Mölsä

1. INTRODUCTION

Remote sensing works as an important tool for the Lake Tanganyika Research Project (LTR-Project) to provide information on the spatial and temporal variations of surface water conditions of the lake. In favourable conditions, this method enables lake temperature data to be obtained and it also gives an indication of the relative vegetation index at the same moment all over the lake, which is not possible by any reasonable field sampling programme. The image analysis, which need to be calibrated with actual ground–truth measurements, can be used in estimating the relative physical and biological differences in and between the surface areas of the lake. Remote sensing gives complementary results directly to the other components of the LTR programme, such as limnology and hydrodynamics, and hopefully, indirectly also to fish biology and plankton ecology.

We hope to use remote sensing in observing the occurrence and extent of the expected upwelling events in the lake, but especially at the southern end. These observations will be related first to the hydrological model of the lake. We also hope to use the images for areal comparisons between different parts of the lake and relate them to possible differences in its limnology and biological production at large. The two parameters we are employing now are surface temperature and the so–called vegetation index.

Satellite based remote sensing has been used in environmental research since the early 1970's. During the past few years, however, its use has greatly expanded, partly due to the easier accessibility of satellite images than before and to the degrease in their price. The imaging characteristics have also been developed greatly during the past two decades.

One of the first tasks of this study was to find out the feasibility of different satellite sensors and their channels for the project's use. The other aims were to set up routines for analyses of satellite images and, accordingly, to process some sample images of Lake Tanganyika for preliminary investigation of the lake water dynamics.

In this report, some basics of satellite imagery are described. Then the criteria for selection of NOAA AVHRR images, as well as the first image analyses of Lake Tanganyika, are given. At the end, the results and future plans will be discussed.

2. BASICS OF REMOTE SENSING

2.1. Basic aspects

In satellite-borne remote sensing, the image channels describe the distribution of light reflected from the earth's surface or the heat radiated by the earth. Each channel sees the earth through a narrow window in the electromagnetic spectrum. On the visible region of the spectrum, the satellite image corresponds to the situation where the globe was observed through a coloured filter. In the longest wavelength's channels, the images give the distribution of surface temperature. In Figure 1, the absorption spectrum of chlorophyll *a* is given. Furthermore, channel 1 and the beginning of channel 2 of the NOAA AVHRR imager are shown.

By designing the wavelength range for the satellite image channels properly, the desired information can be achieved. For example, in order to obtain an estimate of chlorophyll a concentration, one channel should be around the top of the chlorophyll absorption peak and another (reference) channel on the wavelength region where chlorophyll a has no effect. From Figure 1, one can see that the band at 650 - 680 nm could be the first channel and the other band could be located anywhere from 450 nm to 600 nm. In the case of the NOAA satellites, the spectral bands can not be chosen by will. Instead, they are fixed with only one band being within the visible region of electromagnetic region as shown in Figure 1. This band covers a much larger band than necessary and thus includes information from diverse other vegetation as well. Therefore, all measurements from these images are referred to as indicating vegetation" instead of chlorophyll a.

2.2. Satellite alternatives

Three of the present earth-orbiting satellites could be considered for the Lake Tanganyika Research Project, namely Landsat, NOAA, and SPOT. The sensors of Landsat and SPOT satellites would provide much better spatial and a little better spectral resolution, but they pass the lake less frequently than NOAA 11, which passes the lake once around noon (at 3:00 p.m., GMT) and once at midnight (at 3:00 a.m., GMT). Another drawback is that the images of Landsat and SPOT are much too expensive for the current budget of LTR-project. Therefore, the NOAA AVHRR images were chosen. Some general characteristics of the AVHRR images of NOAA are shown in Table 1.

Table 1

The characteristics of the NOAA AVHRR images

Channel	Wavelength (nm)	
1	580 – 680	(green – red)
2	720 – 1 100	(near IR)
3	3 550 – 3 930	(middle IR)
4	10 500 – 11 500	(thermal IR)
5	11 500 – 12 500	(thermal IR)

(1 000 nm = 1 micrometer)

Spatial resolution on the ground: 1.1 km x 1.1 km, at nadir

Passes over Lake Tanganyika: NOAA-ll, NOAA-12

For further reference on the basis of remote sensing as well as the characteristics of the satellite imagers, one should consult, e.g., Lillesand & Kiefer (1987), and Meaden & Kapetsky (1991)

The spatial resolution of NOAA AVHRR (1.1 km x 1.1 km) is not very good when compared to that of the Landsat TM (30 x 30 m). Lake Tanganyika is, however, so large in its area and lacks complicated shore lines and small islands, that the AVHRR resolution might be good enough for the task. In Figure 2, an enlargement of one AVHRR–image is shown to give an idea of its spatial resolution. In Figure 3 a NOAA AVHRR-image over the whole lake is shown.

2.3. Image sources

The NOAA AVHRR images may be obtained from at least two commercial sources. One is Eurimage in Frascati (Rome) , Italy, cooperating with the European Space Agency (ESA), and the other one is the Satellite Applications Centre in Pretoria, South Africa. The UK/SADC Lake Fisheries Project on Lake Malawi is receiving the NOAA images with its own receiver. It is also possible to obtain some images for comparison from that project.

All images for the LTR Project have been bought from Eurimage. A set of images was ordered from the Satellite Applications Centre, Pretoria. However, we have not been able to receive accurate enough information about their preprocessing. We have not used these images. Furthermore, Lake Tanganyika is included in only 16% of images received by the South–African receiving station. In the images from Eurimage, country borders as well as every fifth latitudinal and every tenth longitudinal line has been included in the auxiliary data that can be overlaid on the image (Fig. 3).

There are now so called “quick look” satellite images of the lake available through the international computer network, Internet. In these images, the near–intrared channel in the daytime and the thermal channel at night of the NOAA imager are shown. These images make it possible to obtain a general view over lake and the lake’s position in the image. These “quick looks” can mainly be used for selecting a noncloudy day for more careful analysis.

3. SATELLITE IMAGE ANALYSIS

To study the capability of the AVHRR-imager in estimation of the vegetation on the lake surface, in the current study, we have used the well known formula

$$NDV_1 = \frac{CH_2 - CH_1}{CH_2 + CH_1} \qquad (\backslash 2)$$

where NDVI is the so called “normalized difference vegetation index”, and CH_i is the intensity of the channel i in the satellite image (Los, 1993). Here, channel 1 includes one absorption peak of chlorophyll *a* and channel 2 is a reference channel.

In the image calibration, we have tested two different methods. According to the first one, the NDVI values are scaled to positive values by taking the darkest point (lowest value) of the image in both channels as a scaling (offset value) pixel. This is effectively one kind of atmospheric correction and is based on the idea that the radiance, at least in one pixel in every image, is equal to zero and thus the value in the lowest point is due to reflectance from the atmosphere. This method is not always reliable, since it is sometimes difficult to be sure that the lowest value is not an erroneous one, artefact, or otherwise corrupted. Furthermore, this method only gives relative values of the NDVI.

In the second method, the same formula for $NDVI_2$ is used, but for the channel values, the calibration tables from NOAA are used (Los, 1993) to determine the real pixel reflectances of the images.

The lake surface temperature is another important attribute computed from the images. As stated before, it can be determined directly from the thermal channels of the satellite image. In the AVHRR imager, there are two thermal channels (channels 4 and 5) The computing of the actual temperature on the lake surface is based on the physical models of the imaging.

4. RESULTS

4.1. vegetation index and surface temperature

Nine NOAA AVHRR images were obtained from Eurimage. The acquisition dates, times, and the scene Ids (Eurimage reference code) are shown in Table 2. The complete data, in digital form, is available from the Department of Applied Physics of the University of Kuopio, Finland.

Table 2

The data information of images obtained from Eurimage and the list of images were ordered from the Satellite Applications Centre. The list includes acquisitions dates, times and the reference number of each organization.

ESA/ESRIN, Frascati, Italy

Satellite	Date & Time		Scene id.
NOAA–ll AVHRR	29.06.1991	12:50	NB119106291250
NOAA–ll AVHRR	26.05.1992	13:18	NB119205261318
NOAA–ll AVHRR	03.06.1992	13:24	NB119206031324
NOAA–ll AVHRR	04.06.1992	13:12	NB119206041312
NOAA–ll AVHRR	23.07.1992	13:28	NB119207231328
NOAA–ll AVHRR	31.07.1992	13:33	NB119207311333
NOAA–ll AVHRR	11.09.1992	13:30	NB119209111330
NOAA–ll AVHRR	12.09.1992	13:19	NB119209121319
NOAA–ll AVHRR	19.09.1992	13:35	NB119209191335

SAC MIKOMTEK/CSIR, Pretoria, South Africa

Satellite	Date & Time	SAC Refer.
NOAA–ll AVHRR	29.07.1993	1:21 1DD93363–004
NOAA–12 AVHRR	12.08.1993	17:14 1DD93363–006
NOAA–ll AVHRR	19.08.1993	2:07 1DD93363–002

For data acquisition, the hardware, that includes a Silicon Graphics UNIX workstation, was set up at the University of Kuopio, Finland. The image processing software used was Khoros from the University of New Mexico. A personal computer has been used for graphics crafting and word processing.

C–programs were written to pre–process the images. The necessary information was extracted from the files. The lake area was clipped out of the original images, which also covered large land areas around the lake. The computation of the NDVI and the temperature from the images, as described above, were executed with the aid of the Khoros program.

The vegetation index, $NDVI_2$ and the surface temperature, using channel 4, were computed from all the images received. The spatial distributions of the results calculated from the first entry in the Table 2 are shown in Figures 4 and 5.

The images also indicate that the central parts of the lake are rather poor in “chlorophyll~, with a ‘green’ belt extending in the littoral zone. It should be possible for nutrients to enter the lake with airborne dust.

4.2. Upwelling

Upwelling of waters has been an interesting phenomenon which we have also been looking for in the satellite images. The only apparent upwelling image at the southern end of the lake is from June 29, 1991, with some secondary upwellings elsewhere in the littoral zone. In this case, the apparent upwelling event can be seen in the vegetation index but not in the temperature pattern. In the pictures obtained in 1992, no such events were clearly observed. This may indicate that the upwelling event is a rare one, or its surface effects are modest at best, or disappear quickly. Preliminary limnological and hydrological data indicates that the lake water may mix deeply even after a short high wind, but the stratification is quickly restored, in a matter of hours or days.

4.3. Cloudiness over Lake Tanganyika

Along with the study of the NOAA AVHRR images mentioned above, cloud cover over the lake during Jan.–June 1991 was followed through the so called quick-look images of AVHRR at the European Space Agency (ESA), Frascati, Italy. The 1991 survey was based on images taken weekly between the dates 1.1.1991 and 14.4.1991 and again between 5.6.1991 and 29.6.1991.

For the year 1993, the images were obtained in Kuopio from the University of Edinburgh through the Internet computer network. This source is based on the geostationary Meteosat satellite, which is located above the equator and which covers half of the globe including Africa. These “quick-looks” roughly show the target area and its cloud cover. The 1993 survey was based on the images taken every tenth day between 4.1.1993 and 7.6.1993. A subjective categorisation for both studies is given in Table 3.

4.4. Geometrical correction

When the satellite flies over the lake, it may see the lake at different angles at different times. This causes some problems in pointing the pixel on the image corresponding to a particular position on the lake. To be able to find corresponding points from separate satellite images and to find their position on the ground, we have set up software to geometricaly transform the image.

Another need for geometrical correction is due to the spherical shape of the earth’s surface and the wide viewing angle of the imager. A picture element of the satellite image corresponds to a wider region on the lake by the vertical border of the image, than it does in the middle of the image. The effect of geometric correction can be seen in Figure 6 (compare Fig. 3)

Table 3.

A subjective categorisation of cloudiness over Lake Tanganyika in the spring 1991 and spring 1993.sisteks " 3. A subjective categorisation of cloudiness over Lake Tanganyika in the spring 1991 and spring 1993." \f taulu

	cloudy or very cloudy	moderate	clear
1991	14.1.— 8.3.	15.3.—14.4.	5.6.—29.6.
1993	4.l.—29.3.	19.4.—17.5.	28.5.— 7.6.

5. DISCUSSION

The results and preliminary interpretations of the analyses must always be verified by measurements directly at the corresponding positions on the ground ("ground—truth data")

The seasonal window (i.e., clear sky) for satellite imaginary over Lake Tanganyika is generally from May to September, although occasional opportunities for cloudless days may occur at other times also. This is fortunate because it corresponds to the season when the upwellings are expected to occur.

The temperature results obtained through satellite images have not yet been checked with fully simultaneous "ground truth" measurements. The results are, however, of the right order (to the nearest degree of C) when compared to the temperatures recorded during the same month and what is indicated in previous literature. Our temperature results are based on the calibration of data and reliability is also limited by the imager itself. More temperature data is also needed from night-time satellite passes to further complement the ground-truth data. We have now ordered night-time images from SAIC and they will be analysed during 1994.

The determination of "chlorophyll" is more problematic compared to the temperature. Instead of "chlorophyll" , we are dealing with a vegetation index which actually describes the reflective colour of the object (the object looks green when red light is absorbed, Fig. 1). The values of the vegetation index are relative, since we have not yet used any calibration "groundtruth" data. The validity of this relative "chlorophyll map" will be clarified by the ground-truth comparisons. Yet it is possible that image correlations with actual chlorophyll a concentrations will be difficult, considering that the Secchi disc values in Lake Tanganyika may vary between 2 and 22 m. A priori there are some doubts about the possibility of detecting chlorophyll a from the NOAA AVHRR images. Nakayama (1994), however, gives promising results for using AVHRR channel 1 for water quality monitoring.

However, an important source of error is the lack of atmospheric correction, which we have not yet done. This atmospheric correction affects both the vegetation index and the temperature. The weather and climate over the long lake vary both daily and seasonally. The lake itself has a length of 650 km, and therefore, we also need local meteorological data to compare different regions of the lake. We shall rely on the meteorological stations of the LTR-Project on and by the lake, around which, the calculated atmospheric corrections are expected to be most accurate.

The satellite data from the littoral zone must be evaluated critically, since those pixels contain information both from the lake and the land.

For the moment, we have established the analysis of the Eurimage images as a routine. We have also received images from the South African station, and we are setting up the analysis routine for them. A different routine is required since the image format is different from that of Eurimage.

Despite much work done in the field of remote sensing and many methods developed for deriving information from raw satellite image data, it is argued that the algorithms are not universal and that regional algorithms are required for getting the desired information in each specific case (Sullivan *et al.*, 1993)

Based on the latest study on the primary production of Lake Tanganyika, the satellite images from the afternoon fly-over, which we have used, are not the best by timing for imaging of the vegetation index. The findings by Salonen & Sarvala (1994) show that the primary production, which according to our hypothesis correlates with the vegetation index, is highest in the morning. Furthermore, the production is highest at the depth of 40 metres, which is too deep to be observed by a passive satellite imager, like NOAA/AVHRR. A similar cause for concern can be found in (Cervantes-Duarte *et al.*, 1993).

To make ground truth measurements and validate the satellite image information, a measurement protocol must be defined. For the time being, the images bought from Eurimage are processed several weeks after their acquisition and therefore, are not very useful at this phase of the study. It would be worthwhile trying to negotiate an agreement with Eurimage for faster delivery of some specified images. Another possible source of images can be found in South Africa, and this seems to be able to deliver the images faster. Therefore, the ground truth calibration should apparently be based on images from this South African source. If the South African receiving station is able to produce the images according to their claim, which states that any NOAA AVHRR image will be mailed within a few days, we can plan the concurrent ground truth and satellite measurements at will. The South Africans, however, prefer an order in advance.

Since the sampling grid (the pixel size) in a AVHRR image is 1.1 by 1.1 km, the ground truth measurements should be related to this. Therefore, the distance between consecutive measurement points should be of the order of 500 m. If conditions on the lake are stable, the time for measurements before and after the passing time of the satellite can be prolonged. On average, the satellite image will be acquired from Lake Tanganyika at 5:00 p.m. and 5:00 a.m. (Burundian time). To get an exact fly—over time for the NOAA satellite, the project has a PC program, which can be used for planning the timetable.

The measurement scheme

The surface vegetation and temperature will be measured over the 500 m x 500 m sampling grid and in several, distant locations over the lake from as many points as possible during the satellite fly—over. The area covered by these measurements depends on the lake surface stability and the vessel available. There should be at least six 1.1 km x 1.1 km squares included. The measurements will be done during the daytime fly-over in the afternoon. The meteorological data will also be recorded at the same time at the meteorological stations around the lake. In Appendix 1, the fly-over times are listed for NOAA—ll.

Based on the news from September 1994, the NOAA-ll satellite imager is no longer in a state of operation. There is a plan to launch a new satellite, NOAA-14, which should replace NOAA-ll by the end of 1994. Another new satellite to be launched in the near future, is ERS—2 of ESA. Both of these satellites should be useful in this project, but the images from the ERS-2 are probably too expensive for the project.

It should be possible to transform the images into some common coordinate system to combine the pixels in the image and the measurement points on the lake. For the moment, we are not able to do this, but the software in the image analysis system is used for this purpose. The vessels on the lake use the accurate satellite global positioning system (GPS) for navigation. The accuracy of the maps, available to us is not reliable.

In Appendix 2, we have listed a few NOAA AVHRR-images available at the moment from ESA. The images, where the lake is seen clearly, and there is coexisting data for the same day from the field stations on the lake, will be ordered and the accuracy of our method will be tested by the end of the year.

In the future, a more accurate measurement of chlorophyll a on the lake surface shall be possible because the acquisition of a more detailed spectrum of ground surface radiation will be possible. This is made possible by the new environmental satellites, whose spectral accuracy will be very high as a result of new iinagers (Ustin, et al., 1991). The launchings of such satellites are expected to be accomplished by the end of the current decade.

Another current possible alternative in data acquisition is spectrum measurement from an aeroplane. This can be realised using current technology and, along with the chlorophyll, it would give many other parameters about the lake surface. In this case, the waters next to lake shore could also be included in the measurements.

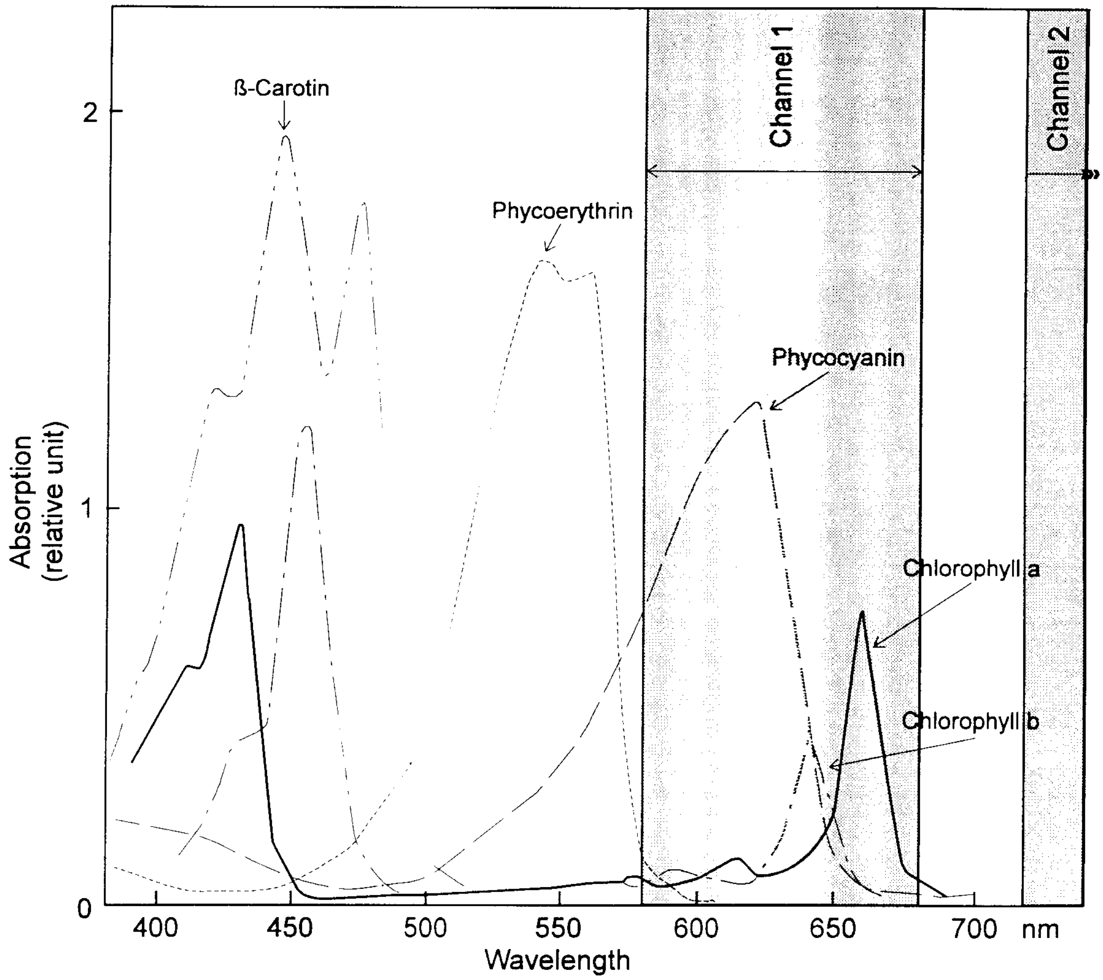


Figure 1. The absorption spectrum of chlorophyll *a* (Hoppe W, et al., 1978), and the NOAA AVHRR channels covering that spectral region.

Figure 2. Enlarged NOAA AVHRR image of the southern part of Lake Tanganyika showing the actual spatial resolution.

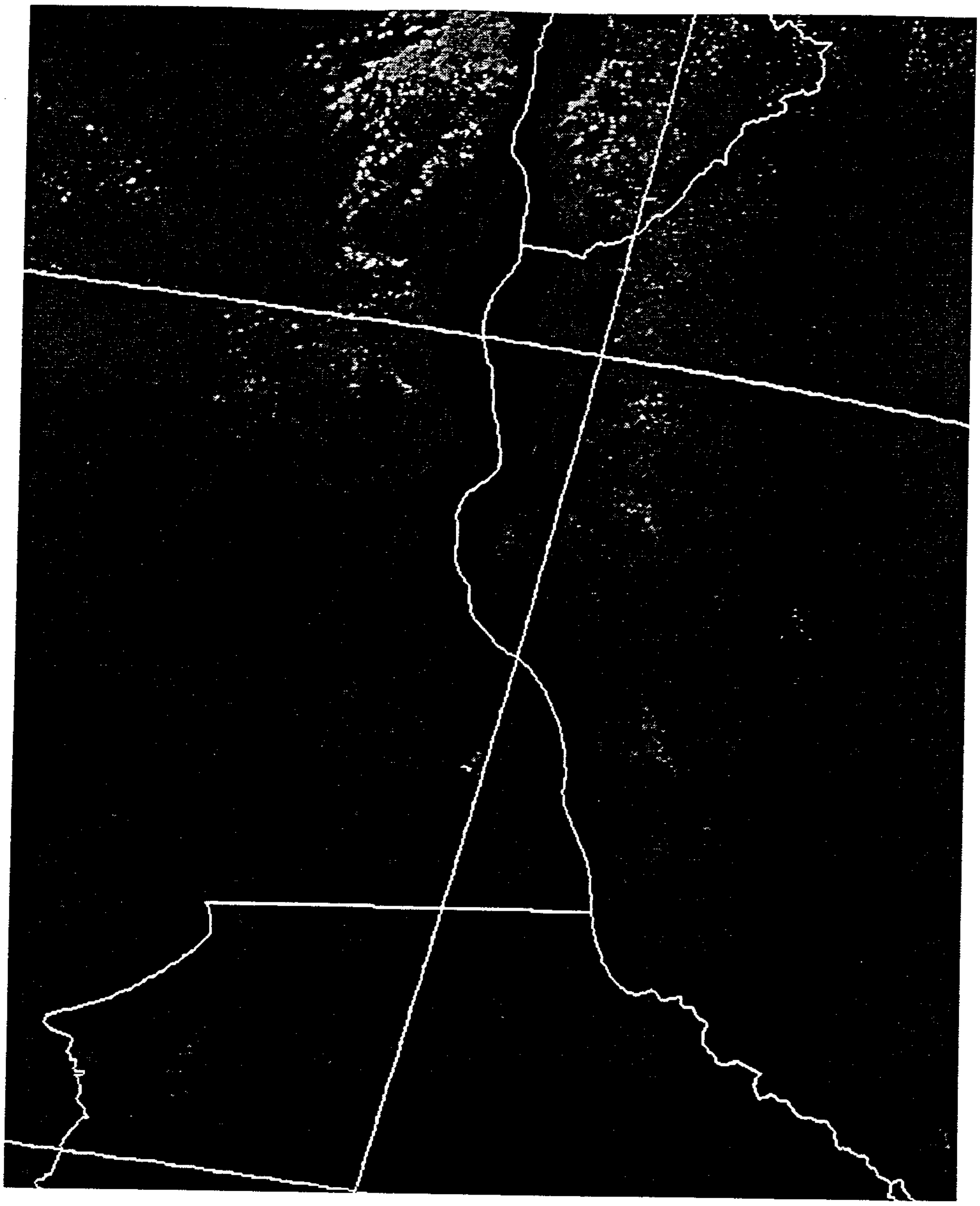


Figure 3. Lake Tanganyika with the overlaid state borders and the 5th and 10th S latitude and the 30th E longitude. (Source: Eurimage).

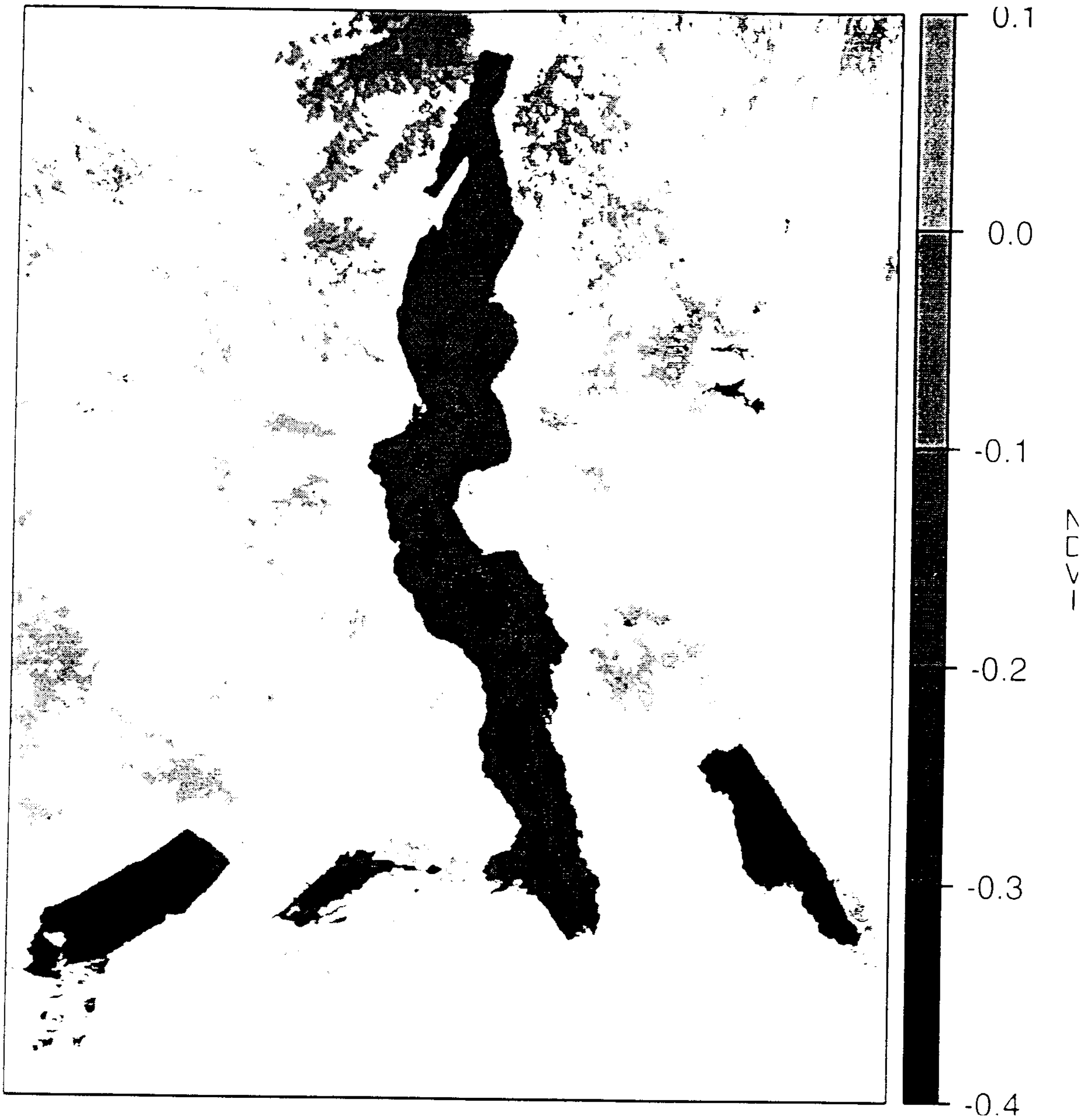


Figure 4. The NDVI distribution of Lake Tanganyika. Computed from the NOAA AVHRR image acquired on 29.6.1991.

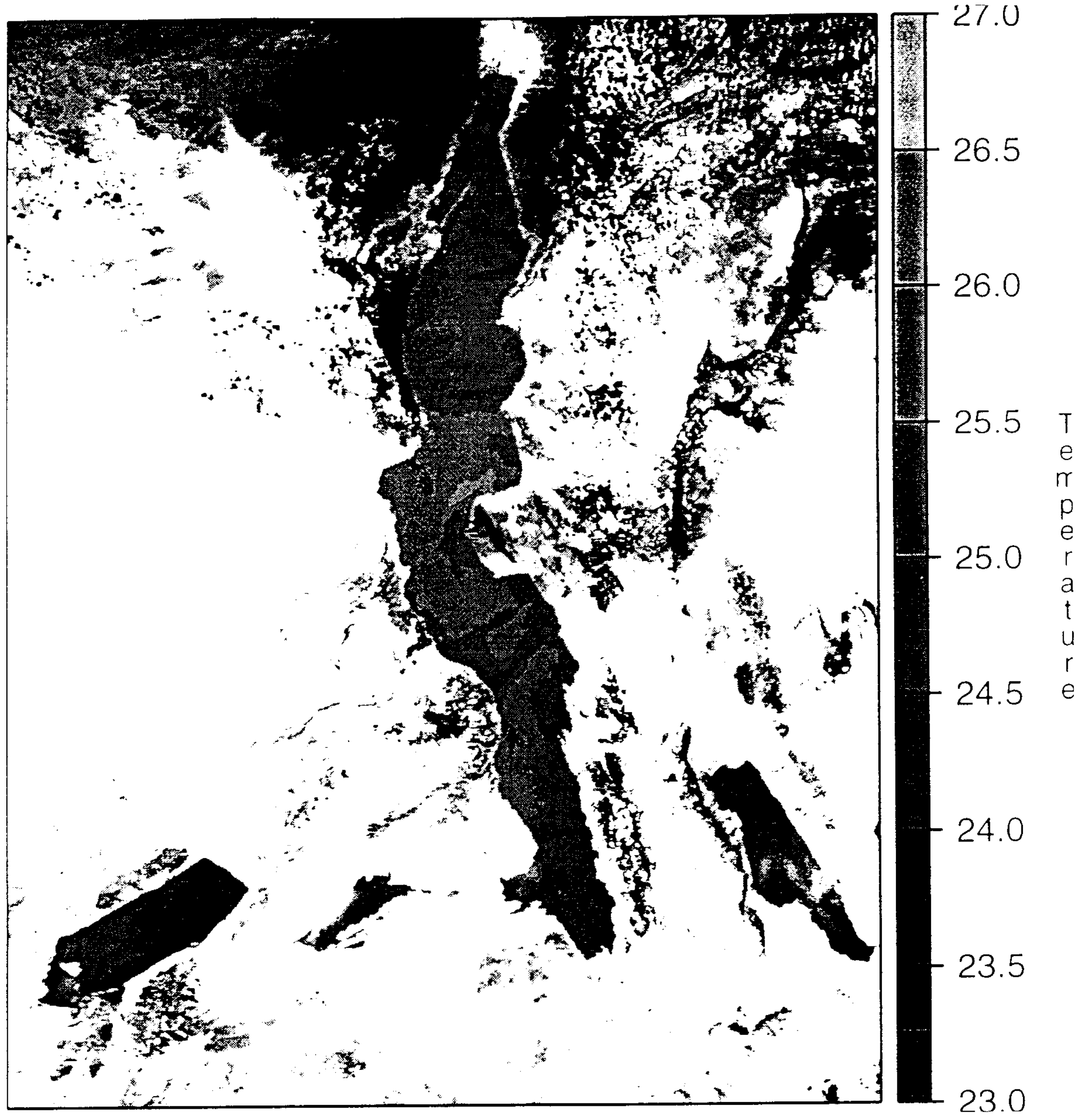


Figure 5. The temperature distribution of Lake Tanganyika. Computed from the NOAA AVHRR image acquired on 29.6.1991

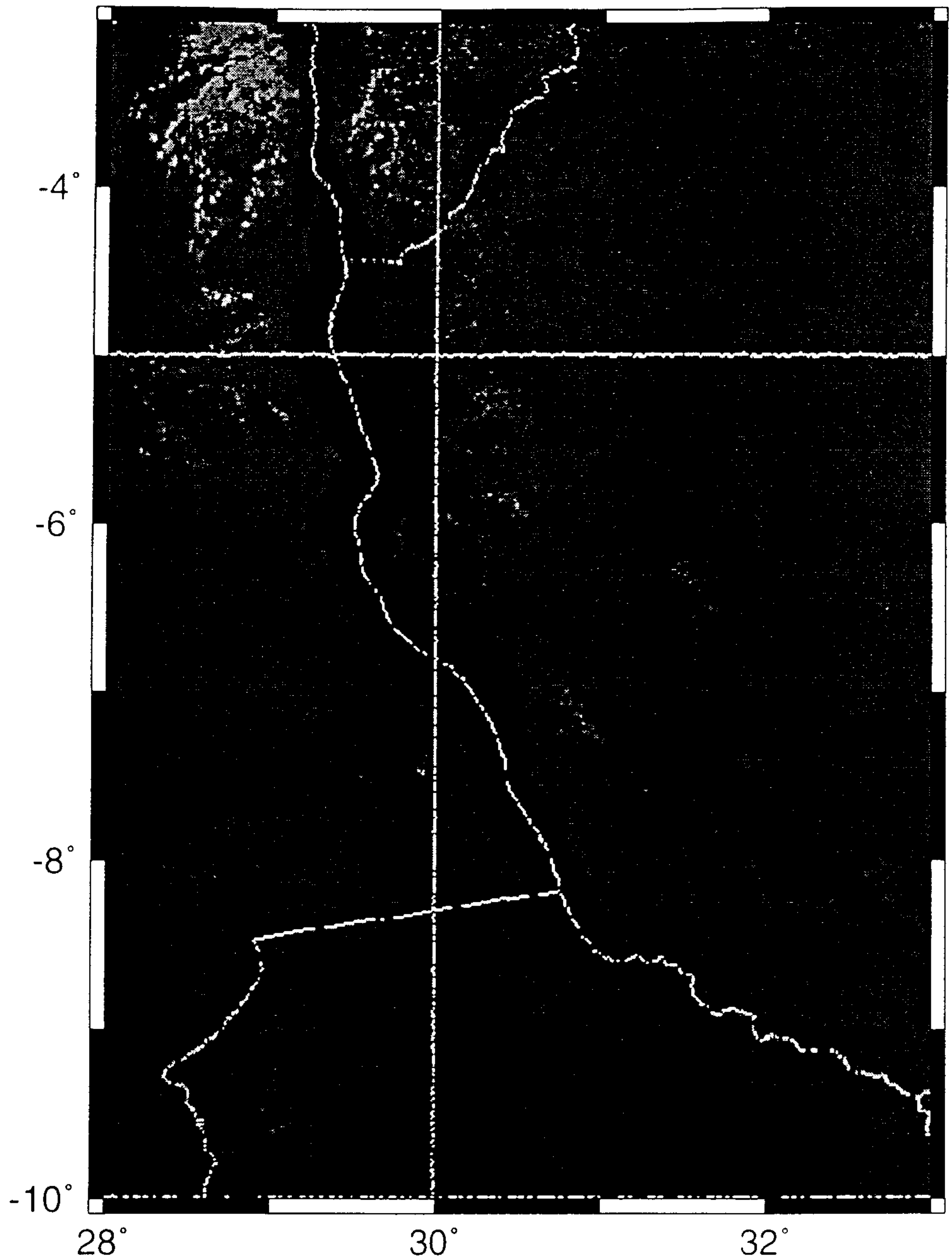


Figure 6. Geometrically corrected image of Lake Tanganyika: Mercator projection (scale 1:5000000). Computed from the NOAA AVHRR image acquired on 29.6.1991.

REFERENCES

American Society of Photogrammetry, 1983. Manual of Remote Sensing (2nd Ed.).

Cervantes-Duarte R., G. Gaxiola-Castro and J.E. Valdez-Holguin, 1993. Relationship between surface chloriphyll and chlorophyll in the euphozone of the Gulf of California: Possible application to estimate promary production with data obtained by remote sensors. CIENC MAR 19:473-490.

Hoppe W., Lohmann W., Markl H., and Zieger H., 1978. Biophysik. ein Lehrbuch. Springer Verlag, Berlin.

Lillesand T.M. and R.W. Kiefer, 1987. Remote Sensing and Image Interpretation (2nd Ed.). John Wiley & Sons, 721p.

Los S.O., 1993. Calibration adjustment of the NOAA AVHRR Normalized Difference Vegetation Index without recourse to component channel 1 and 2 data. International Journal of Remote Sensing, vol. 14, no. 10.

Meaden, G.J. and J.M. Kapetsky, 1991. Geographical information systems and remote sensing in inland fisheries and aquaculture. FAO Fishery Technical Paper 318, FAO, Rome (En): 262p.

Mittenzway K.-H., S. Ullrich, A.A. Gitelson, and K.Y. Kondratiev, 1992. Determination of chlorophyll a of inland waters on the basis of spectral reflectance. Limnol. & Oceanogr. 37: 147-149.

Nakayama M., 1994. Application of satellite remote sensing to estimate lake water quality. Mitt. Internat. Verein. Limnol., 24: 345-347.

Salonen K. and J. Sarvala, 1994. Sources of energy for secondary production in Lake Tanganyika. Objectives, basic approaches and first results ("Carbon-energy budget of Lake Tanganyika"). GCP RAF/271/FIN-TD (En) (in press).

Sullivan, C.W., K.R. Arrigo, C.R. McClain, J.C. Comiso, and J. Firestone, 1993. Distributions of phytoplankton blooms in the southern ocean. Science 262: 1832-1837.

Ustin, S.L., C.A. Wessman, B. Curtiss, E. Kasischke, J. Way and V.C. Vanderbilt, 1991. Opportunities for using the EOS imaging spectrometers and synthetic aperture radar in ecological models. Ecology 72: 1934-1945.

APPENDIX 1: Predicted fly-over times.

DL5KR SatTrack Prediction (V1.3)

```
Satellite          : NOAA 11
Data File          : tle
Element Set Number : 797
Element Set Epoch  : 05-10-94  23:01:36.113 UTC   (1.5 days ago)
Ground Station     : Tanganjika M
Time Zone          : UTC (+0 h)
```

Date (UTC)	Time	Max Elev
Sat 08-10-94	02:53:51	84.3*
	15:33:23	42.7*
Sun 09-10-94	02:41:39	61.6*
	15:21:11	59.7*
Mon 10-10-94	02:29:27	46.9*
	15:08:50	83.0*
Tue 11-10-94	14:56:35	71.7*
Wed 12-10-94	14:44:11	49.0*
Fri 14-10-94	03:20:41	47.7*
Sat 15-10-94	03:08:17	67.4*
Sun 16-10-94	02:55:56	85.5*
	15:35:31	41.7*
Mon 17-10-94	02:43:45	63.0*
	15:23:20	58.3*
Tue 18-10-94	02:31:30	47.8*
	15:10:59	81.2*
Wed 19-10-94	14:58:41	73.4*
Thu 20-10-94	14:46:17	50.1*
Sat 22-10-94	03:22:47	46.7*
Sun 23-10-94	03:10:23	65.9*
Mon 24-10-94	02:58:02	86.1*
	15:37:37	40.7*
Tue 25-10-94	02:45:47	64.5*
	15:25:13	56.9*
Wed 26-10-94	02:33:35	49.0*
	15:13:07	79.3*
Thu 27-10-94	15:00:49	75.0*
Fri 28-10-94	14:48:25	51.3*
Sun 30-10-94	03:24:53	45.7*
Mon 31-10-94	03:12:29	64.4*
Tue 01-11-94	03:00:23	86.1*
Wed 02-11-94	02:47:53	66.0*
	15:27:34	55.5*
Thu 03-11-94	02:35:41	50.2*
	15:15:13	77.7*
Fri 04-11-94	15:02:55	76.7*
Sat 05-11-94	14:50:31	52.4*
Mon 07-11-94	03:26:58	44.8*
Tue 08-11-94	03:14:34	63.0*
Wed 09-11-94	03:02:28	85.7*
Thu 10-11-94	02:49:58	67.6*
	15:29:27	54.1*
Fri 11-11-94	02:37:43	51.4*
	15:17:21	75.8*
Sat 12-11-94	15:05:03	78.2*
Sun 13-11-94	14:52:39	53.6*
Tue 15-11-94	03:29:07	43.9*
Wed 16-11-94	03:16:40	61.6*
Thu 17-11-94	03:04:34	84.8*
Fri 18-11-94	02:52:19	69.2*
	15:31:36	52.9*
Sat 19-11-94	02:39:49	52.7*
	15:19:30	54.7*
Wed 23-11-94	03:31:12	42.9*
Thu 24-11-94	03:18:45	60.1*

Fri 25-11-94	03:06:40	83.5*
Sat 26-11-94	02:54:25	70.9*
	15:33:44	51.6*
Sun 27-11-94	02:41:55	54.0*
	15:21:36	72.3*
Mon 28-11-94	15:09:18	81.2*
Tue 29-11-94	14:56:51	56.0*
Thu 01-12-94	03:33:21	42.0*
Fri 02-12-94	03:20:54	58.8*
Sat 03-12-94	03:08:45	81.9*
Sun 04-12-94	02:56:30	72.6*
	15:35:50	50.4*
Mon 05-12-94	02:44:15	55.2*
	15:23:29	70.8*
Tue 06-12-94	15:11:23	82.9*
Wed 07-12-94	14:58:56	57.2*
Thu 08-12-94	14:46:51	40.6*
Fri 09-12-94	03:35:27	41.1*
Sat 10-12-94	03:23:15	57.4*
Sun 11-12-94	03:10:54	80.1*
Mon 12-12-94	02:58:39	74.2*
	15:37:59	49.2*
Tue 13-12-94	02:46:09	56.6*
	15:25:35	69.2*
Wed 14-12-94	02:34:03	40.8*
	15:13:17	84.1*
Thu 15-12-94	15:01:02	58.6*
Fri 16-12-94	14:48:56	41.6*
Sat 17-12-94	03:37:35	40.1*
Sun 18-12-94	03:25:08	56.1*
Mon 19-12-94	03:13:02	78.3*
Tue 20-12-94	03:00:45	75.9*
	15:40:04	48.1*
Wed 21-12-94	02:48:30	57.8*
	15:27:40	67.7*
Thu 22-12-94	02:36:09	41.7*
	15:15:22	85.4*
Fri 23-12-94	15:03:07	60.0*
Sat 24-12-94	14:50:59	42.6*
Mon 26-12-94	03:27:17	54.7*
Tue 27-12-94	03:15:08	76.7*
Wed 28-12-94	03:02:53	77.5*
	15:42:10	47.1*
Thu 29-12-94	02:50:23	59.2*
	15:29:46	66.2*
Fri 30-12-94	02:38:14	42.6*
	15:17:28	86.2*
Sat 31-12-94	15:05:13	61.4*

APPENDIX 2: 1994 NOAA AVHRR images.

```
* View angle specifies the angle between the sub-satellite vector
* and the swath limit.
*    0 degrees represents the sub-satellite track,
*    55 degrees represents the maximum view angle (3000km total swath)
* NOTE that the AVHRR ground resolution deteriorates with increasing
* view angle. To reduce search time and minimise output listing it is
* recommended that a narrow view angle be specified (e.g. 10 degrees).
*
*Enter maximum view angle:
* Default value(s) :   30,
-----------------------------------------------------------------------
*
* S H A R P   P A R A M E T E R   S E L E C T I O N S
*
* DATE           MIN = 940101   MAX = 941001
* LATITUDE       MIN =   -900   MAX =   -300
* LONGITUDE      MIN =   2900   MAX =   3150
* MAX. ANGLE OF ACQ. =     30   DEGREES
* ACQUIS. MODE       =      3   (1=DAY 2=NIGHT 3=24 HOUR )
* MAXIMUM % CLOUD COVER = 99
* MAXIMUM % SUNGLINT    = 99
* ACQ. STATION CODE =       8
* ACQ. STATION CODE =      11
* ACQ. STATION CODE =      14
* MISSION:  NOAA-11
* MISSION:  NOAA-12
*
*          S H A R P   R E C O R D S   L O C A T E D
*
```

*	No.	DATE	SAT	ORB	D/N	SHARP START	SHARP END	CT	CL	Q L	% CC	% GL	% LA	% SE	% IC	D Q	BL	STA
*	1	940525	11	29203	D	145352	145752	OK	OK	Y	0	0	00	00	00	1	00	NRB
*	2	940517	11	29090	D	145103	145503	OK	OK	Y	0	0	00	00	00	1	00	NRB
*	3	940502	11	28878	D	143408	143808	OK	OK	Y	38	0	56	03	00	1	00	NRB
*	4	940501	11	28864	D	144757	145157	OK	OK	Y	66	0	29	02	00	1	00	NRB
*	5	940424	11	28765	D	143241	143641	OK	OK	Y	56	0	37	04	00	1	00	NRB
*	6	940423	11	28751	D	144511	144911	OK	OK	Y	49	0	44	04	00	1	00	NRB
*	7	940416	11	28652	D	142949	143349	OK	OK	Y	38	0	53	05	00	1	00	NRB
*	8	940415	11	28638	D	144300	144700	OK	OK	Y	69	0	28	00	00	1	00	NRB
*	9	940408	11	28539	D	142803	143203	OK	OK	Y	53	0	40	03	00	1	00	NRB
*	10	940407	11	28525	D	144043	144443	OK	OK	Y	46	0	48	03	00	1	01	NRB
*	11	940306	11	28073	D	142948	143348	OK	OK	Y	67	0	28	02	00	1	00	NRB
*	12	940305	11	28059	D	144309	144709	OK	OK	Y	54	0	42	01	00	1	00	NRB
*	13	940226	11	27960	D	142740	143140	OK	OK	Y	60	0	34	03	00	1	00	NRB
*	14	940217	11	27833	D	143807	144207	OK	OK	Y	58	0	38	01	00	1	00	NRB
*	15	940210	11	27734	D	142220	142620	OK	OK	Y	66	0	28	03	00	1	00	NRB
*	16	940209	11	27720	D	143443	143843	OK	OK	Y	54	0	40	02	00	1	00	NRB
*	17	940125	11	27508	D	141600	142000	OK	OK	Y	77	0	19	01	00	1	00	NRB
*	18	940116	11	27381	D	142727	143127	OK	OK	Y	80	0	17	00	00	1	00	NRB
*	19	940108	11	27268	D	142330	142730	OK	OK	Y	80	0	16	01	00	1	00	NRB
*	20	940722	11	30022	D	144300	144700	**	OK	Y	0	0	00	00	00	0	01	RUN
*	21	940706	11	29796	D	143915	144315	**	OK	Y	0	0	00	00	00	0	00	RUN
*	22	940603	11	29330	D	144548	144948	**	OK	Y	25	0	68	04	00	1	00	NRB
*	23	940603	11	29330	D	144148	144548	**	OK	Y	0	0	00	00	00	1	01	NRB
*	24	940424	11	28765	D	142951	143351	**	OK	Y	0	0	00	00	00	0	02	RUN
*	25	940416	11	28652	D	142741	143141	**	OK	Y	0	0	00	00	00	0	01	RUN
*	26	940330	11	28412	D	143906	144306	**	OK	Y	38	0	56	03	00	1	00	NRB
*	27	940330	11	28412	D	143506	143906	**	OK	Y	47	0	47	02	00	1	00	NRB
*	28	940322	11	28299	D	143328	143728	**	OK	Y	40	0	56	01	00	1	00	NRB
*	29	940314	11	28186	D	143453	143853	**	OK	Y	43	0	53	00	00	1	00	NRB
*	30	940201	11	27607	D	143000	143400	**	OK	Y	66	0	31	01	00	1	00	NRB
*	31	940125	11	27508	D	141456	141854	**	OK	Y	80	0	13	04	00	0	00	RUN
*	32	940124	11	27494	D	142709	143109	**	OK	Y	81	0	14	01	00	1	00	NRB
*	33	940511	11	29005	D	142422	142822	OK	**	Y	48	0	43	05	00	1	00	NRB
*	34	940425	11	28779	D	141950	142350	OK	**	Y	61	0	29	06	00	1	06	NRB
*	35	940417	11	28666	D	141803	142203	OK	**	Y	38	0	45	12	00	1	00	NRB
*	36	940409	11	28553	D	141438	141838	OK	**	Y	44	0	44	08	00	1	00	NRB
*	37	940406	11	28511	D	145245	145645	OK	**	Y	33	0	63	01	00	1	00	NRB

*	38	940331	11	28426	D	142523	142923	OK	**	Y	42	0	48	06	00	1	00	NRB
*	39	940329	11	28398	D	144957	145357	OK	**	Y	54	0	42	01	00	1	00	NRB
*	40	940321	11	28285	D	144805	145205	OK	**	Y	62	0	35	00	00	1	00	NRB
*	41	940315	11	28200	D	142021	142421	OK	**	Y	63	0	27	06	00	1	00	NRB
*	42	940307	11	28087	D	141736	142136	OK	**	Y	41	0	47	08	00	2	00	NRB
*	43	940227	11	27974	D	141523	141923	OK	**	Y	57	0	37	03	00	1	00	NRB
*	44	940219	11	27861	D	141305	141705	OK	**	Y	57	0	35	04	00	1	00	NRB
*	45	940126	11	27522	D	140318	140718	OK	**	Y	48	0	31	17	00	1	00	NRB
*	46	940117	11	27395	D	141329	141729	OK	**	Y	67	0	25	04	00	1	04	NRB
*	47	940115	11	27367	D	143904	144304	OK	**	Y	74	0	23	00	00	1	00	NRB
*	48	940101	11	27169	D	140913	141313	OK	**	Y	30	0	60	07	00	1	00	NRB

*	49	940723	11	30036	D	143200	143600	**	**	Y	0	0	00	00	00	0	00	RUN
*	50	940715	11	29923	D	142945	143345	**	**	Y	0	0	00	00	00	0	00	RUN
*	51	940707	11	29810	D	142720	143120	**	**	Y	0	0	00	00	00	0	01	RUN
*	52	940629	11	29697	D	142511	142911	**	**	Y	0	0	00	00	00	0	01	RUN
*	53	940628	11	29683	D	143700	144100	**	**	Y	0	0	00	00	00	0	00	RUN
*	54	940527	11	29231	D	142806	143206	**	**	Y	0	0	00	00	00	0	01	RUN
*	55	940519	11	29118	D	142521	142921	**	**	Y	0	0	00	00	00	0	00	RUN
*	56	940511	11	29005	D	142257	142657	**	**	Y	0	0	00	00	00	0	00	RUN
*	57	940503	11	28892	D	142100	142500	**	**	Y	0	0	00	00	00	0	01	RUN
*	58	940425	11	28779	D	141813	142213	**	**	Y	51	0	30	11	00	0	01	RUN
*	59	940417	11	28666	D	141541	141941	**	**	Y	20	0	48	27	00	0	01	RUN
*	60	940409	11	28553	D	141330	141730	**	**	Y	37	0	43	15	00	0	00	RUN
*	61	940409	11	28553	D	141220	141620	**	**	Y	29	0	39	26	00	1	00	NRB
*	62	940401	11	28440	D	141121	141521	**	**	Y	26	0	49	19	00	0	01	RUN
*	63	940323	11	28313	D	142010	142410	**	**	Y	23	0	58	14	00	0	00	RUN
*	64	940315	11	28200	D	141750	142150	**	**	Y	47	0	33	15	00	0	00	RUN
*	65	940313	11	28172	D	144608	145008	**	**	Y	67	0	30	01	00	1	00	NRB
*	66	940307	11	28087	D	141534	141934	**	**	Y	35	0	43	18	00	0	00	RUN
*	67	940227	11	27974	D	141311	141711	**	**	Y	61	0	28	07	00	0	02	RUN
*	68	940126	11	27522	D	140243	140643	**	**	Y	50	0	25	20	00	0	01	RUN
*	69	940118	11	27409	D	140019	140419	**	**	Y	65	0	16	13	00	0	00	RUN
*	70	940117	11	27395	D	141201	141601	**	**	Y	64	0	24	08	00	0	01	RUN
*	71	940109	11	27282	D	141238	141638	**	**	Y	45	0	47	04	00	1	00	NRB
*	72	940109	11	27282	D	140944	141344	**	**	Y	57	0	34	06	00	0	00	RUN
*	73	940101	11	27169	D	140629	141029	**	**	Y	36	0	44	15	00	0	01	RUN

THIRD JOINT MEETING
OF THE LTR'S
COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

KIGOMA (TANZANIA), 28–30.11.1994

PRESENTATION OF SSP RESULTS: FISH GENETICS

by L. Kuusipalo

1. INTRODUCTION

Purpose of this subcomponent is to estimate the level of genetic identity between local fish populations. Genetic diversification reflects local adaptations of shoals, and stresses the need for separate management plans. The species studied were *Limnothrissa miodon, Stolothrissa tanganicae, Lates stappersii, L. mariae, L. angustifrons* and *L. microlepis.* Results for *L. miodon* and S. *tanganicae* are now available.

2. MATERIAL AND METHODS

For sampling the lake was divided into six zones, from North to South: I: Rusizi delta; II: Malagarasi delta; III: Mahale; IV: Moba; V: Nsumbu; and VI: Chituta. The actual sampling sites are shown in Figure 1. Numbers of individuals sampled during dry season are shown in Appendix 1, and those during rainy season in Appendix 2.

Whole individuals of species *L.* miodon and S. *tanganicae,* and muscle pieces from *Lates* species were stored on equal volume of pure alcohol. Hardened samples were shipped to Finland and analyzed in the University of Joensuu. DNA was extracted using non–poisonous salting method. Structural differences in DNA were studied by multiple copying of various fractions of the total DNA. Total DNA consists of thousands of base pairs, and 10 base pair long primers were used to start the copying from random sites. This method, called RAPD, is more sensitive than protein electrophoresis, but less expensive than DNA–fingerprinting, and it is used in increasing numbers in population genetics. Three primers (Operon technologies) were used for each species. RAPD analysis results individual band profiles on an agarose gel, and these bands, each representing one dominant allele, were coded to 1 (present) and 0 (absent). All studied individuals were clustered by their similarity with the computer, and ordered to a diagram. The calculations were done with the programs RAPDPLOT and ordination with PHYLIP. Genetic similarity was estimated using the 'fraction of matches' formula M = NAB/ NT, where NAB is the total number of mates in individuals A and B (i.e. both bands present or absent) and NT is the total number of loci scored in the overall study. An M value of 1 indicates that two individuals have identical patterns; a value of 0 indicated that two individuals had completely different patterns.

3. RESULTS

Storing method was traditional, but handling for shipping is a new application. Alcohol soaked samples were packed in plastic bags and shipped without the total quantity of spirit. Shipping costs were decreased without any damage to the quality of samples.

DNA extraction was performed with salting method, an application from research based on blood samples. Salting method produced high quality DNA without using poisonous organic detergents. PCR amplification in RAPD procedure worked well with all species. In a small test was examined the possibility to use combined population samples, by uniting individual DNA:s, but this produced unrepeatable patterns due to heterogenous DNA. Clustering of samples was done without predictions of populations, because it is impossible to know if sampling areas really do represent populations.

3.1 *Limnothrissa miodon*

Eleven populations from all areas and two seasons, except dry season samples from Mahale, were analyzed. *L. miodon* samples were amplified in RAPD procedure with primers OPB-Ol, OPA-09 and OPA-18. Total number of bands observed was 61. Figure 2 shows the diagram resulting from clustering of all studied individuals.

3.2 *Stolothrissa tanganicae*

S. tanganicae populations from six localities and two seasons, except dry season samples from Mahale, were analyzed. The samples were amplified using primers OPA-18, OPC-02 and OPC-08. The total number of bands observed was 60. Figure 3 shows the clustering diagram.

3.3 *Lates stappersii*

L. stappersii populations from nine localities were analused. Missing sampling areas were Mahale and Malagarasi (rainy season only). The primers used were OPC-08, OPC-13 and OPC–19. Total number of bands was 58. Computer analyses are unfinished.

3.4 ***Lates mariae***

Five study areas are represented with adequate samples, four of them by only one season. Primers used were OPA–07, OPC–05 and OPC–08. Total number of bands was 52. Computer analyses are unfinished.

3.5 ***Lates angustifrons* and *L. microlepis***

Samples from *L. angustifrons* and *L. microlepis* are incomplete. More samples are needed from all areas except Nsumbu. Primers OPC-02, OPC-05 and OPA-07 have been used to distinguish over 50 bands. Coding for computer has not been completed.

4. CONCLUSIONS

Smith’s H values for the total *Limnothrissa* population varied from locus to locus, which refers to subpopulation division. All samples without population codes were grouped using the Nei and Li (1985) similarity index and fraction of matches (Black 1994) calculations in the RAPDPLOT program. Individual data was then grouped accordingly and transformed to allele frequency data, suitable for analysis with the BIOSYS program. The level for individuals uniting to one group was a genetic identity greater than 87.5%.

Based on the fraction of matches index (number of same present and absent fragments) the number of populations was 8:

group 1.	19 dry	season	Malagarasi	
	4 d.	“	Moba	
	1 d.	“	Rusizi	total 24
group 2.	17 d.	“	Chituta	
	17 rainy	season	Chituta	
	15 d.	“	Nsumbu	
	12 d.	“	Rusizi	total 61
group 3.	30 r.	“	Malagarasi	
	19 r.	“	Mahale	
	11 r.	“	Moba	
	4 d.	“	Nsumbu	total 64
group 4.	14 r.	“	Chituta	
	9 r.	“	Nsumbu	total 23
group 5.	20 r.	“	Nsumbu	total 20
group 6.	16 d.	’	Moba	
			117	
	8 d.	“	Rusizi	total 24
group 7.	27 r.	“	Rusizi	
	4 r.	“	Moba	
	1 d.	“	Numbu	total 32
group 8.	13 r.	“	Moba	
	1 r.	“	Rusizi	total 14

Genetic identity (Nei’s unbiased) between populations varied between 0.735 and 0.923. As these groups are selected by the presence and absence of bands, the populations are easily identifiable by their banding profiles. In 11 loci, the differences between populations were fixed, so that in some populations all individuals posessed the fragment that was absent from all members of another population. The percentage of loci polymorphic in populations varied from 36.1 to 57.4. The F(ST) estimated for this population division is 0.289. The effective migration rate (Nm) is 0.6.

The shared absence of a band actually provides more information regarding similarity (both homozygote recessives) than does the shared presence of that band (heterozygote or homozygote dominant). In Apostol *et al.,* 1993 the separation of full siblings was clearer when using M than when using S. Nei and Li's similarity index S is recommended when comparing different species. For intraspecific comparisons, it is recommended that the values of S and M be compared (Black, 1994).

The analysis of results has not been completed as some technical problems have slowed down the work. Most genetic programs are planned for a smaller amount of variants and some previous idea of the number of existing populations. Computer analysis is proceeding, and more details will be available in the near future.

Samples have been taken from areas wide apart, but it is not known, if samples are really from one population only. Further knowledge of actual habits and movements of fishes in the lake will help in reaching the final conclusions.

In future, the sampling for missing species and localities should continue according to Appendix 3. Additional samples from the west coast of the lake should be taken during cruises in the Malagarasi, Mahale and Moba study areas.

Samples were also grouped with SPSS hierarchial cluster analysis using furthest neighbor-joining. In all tests for clustering the populations from two to nine clusters, the percentage of grouped cases correctly classified was over 90. Discriminant analysis is a method for classifying observation into classes based on one or more quantitative variables. Statistical methods are based on various mathematical means, although variants can be added to the analysis one by one. Results from clustering and discriminant analysis do support the division into subpopulations, although phylogenetic analysis probably reveals more accurate and detailed grouping.

Also, genetic measures used to estimate the division into subpopulations showed that this division is a plausible explanation.

Smith's H statistics varied from locus to locus in the total population. This points to population substucturing, because inbreeding would also affect the value of H, but to a similar manner in all loci. H is an unbiased estimator of half the difference between the expected and observed proportion of heterozygotes.

As the breeding of pelagic clupeids may occur throughout the year (Coulter, 1961), eggs are sinking slowly (Coulter, 1991), and transparent larvae are very common in the plankton (Coulter, 1970). Combined with the latest knowledge on turbulences and movements of water bodies in the lake, the estimation of the number of populations should be done cautiously, combining knowledge from breeding sites. Isolation during breeding is enough for genetic differentiation, and the selection of individuals that take part in breeding results from selective and adaptive pressures of this breeding population. Analysis of the results is complex, as there were no prior suspicions of the possible divisions of populations. More samples from different localities are required, and samples, especially from breeding stocks and fry, are necessary.

5. REFERENCES

Black, W.C.IV 1993: RAPDBIOS, A fortran program to convert RAPD-PCR files to BIOSYS (DATYP=3) files. Colorado State University, USA.

Black, W.C.IV 1994: RAPDPLOT 2.3, A fortran program for analysis of genetic relationships using RAPD-PCR markers. Colorado State University, USA.

Coulter, G.W. 1961: Lake Tanganyika Research. Annual Report, Joint Fisheries Research Organisation, Zambia, 10:7–30.

Coulter, G.W. 1970: Population changes within a group of fish species in Lake Tanganyika following their exploitation. Journal of Fish Biology, 2:329-353.

Coulter, G.W. 1977: Approaches to estimating fish biomass and potential yield in Lake Tanganyika. J.Fish Biol.ll:393-408.

Coulter, G.W. 1991: Pelagic fish. In: Lake Tanganyika and its Life. Ed. by G.W. Coulter. Natural History Publications, Oxford University Press. pp.111-138.

Nei, M. and Li, W.H. 1985: Mathematical model for studying genetic variation in terms of restriction endonucleases. Proc. Natl. Acad. Sci. USA 76:5269–5273.

Figure 1. Sampling areas and sites in Lake Tanganyika

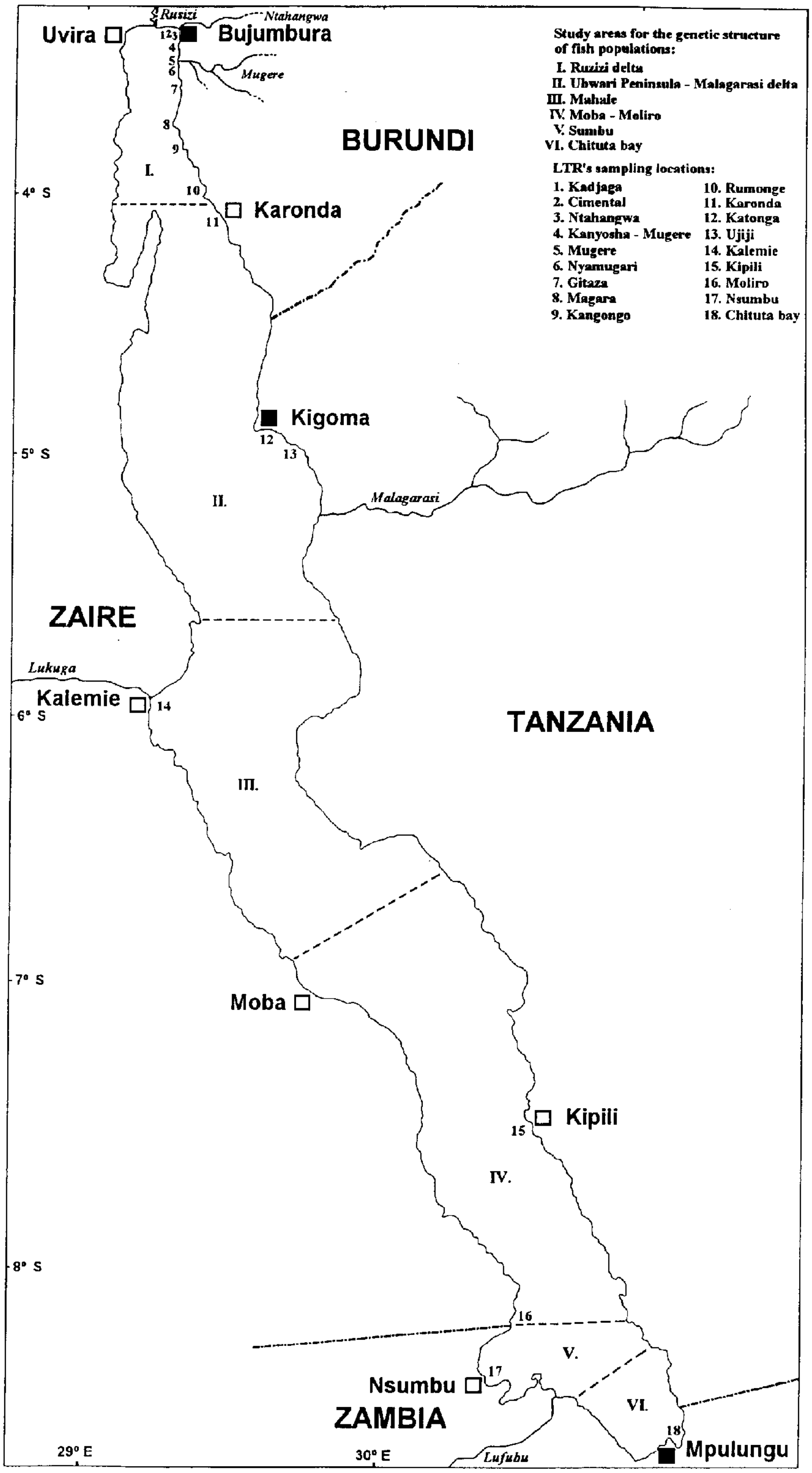
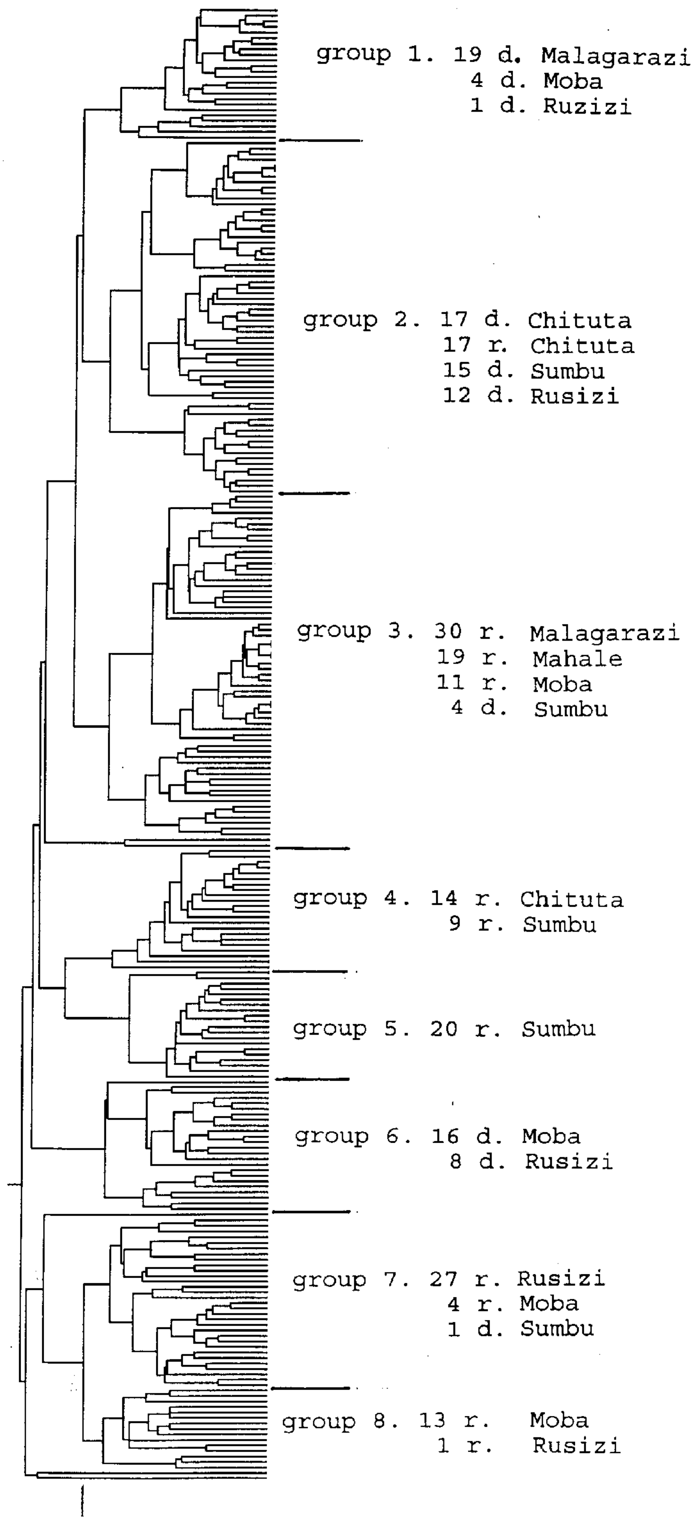


Figure 2. UPGMA-clustering of *Limnothrissa miodon* samples



Appendix 1. Genetic samples, dry season

			GENETIC SAMPLES LTR FIRST SAMPLING 1993					
COUNTRY	DATE	LOCATION	SPECIES	DISTANCE FROM SHORE	DEPTH	# SPECIMENS	GEAR	ZONE
TANZANIA	06.16.93	· KIGOMA (Katonga)	Lates stappersii	> 500 m		30		Malagarazi
TANZANIA	06.15.93	KIGOMA (Katonga)	Limnothrissa miodon	> 500 m		30		Malagarazi
TANZANIA	06.22.93	KIGOMA (Katonga)	Lates mariae 1	> 500 m		7		Malagarazi
TANZANIA	06.16.93	KIGOMA (Katonga)	Stolothrissa tanganicae	> 500 m		30		Malagarazi
TANZANIA	06.24.93	KIGOMA (Katonga)	Lates mariae 2	> 1000 m		5		Malagarazi
TANZANIA	07.19.93	KIGOMA (Katonga)	Lates mariae 3	> 1000 m		6		Malagarazi
TANZANIA	07.13.93	· KIPILI	Lates stappersii	100-150 m		30		Moba
TANZANIA	07.11.93	KIPILI	Stolothrissa tanganicae	50-70 m		30		Moba
TANZANIA	07.11.93	KIPILI	Limnothrissa miodon	50-70 m		30		Moba
BURUNDI	07.08.93	· MAGARA	Luciolates stappersii			30	LIFTNET	Ruzizi
BURUNDI	07.06.93	? KAGONGO	Stolothrissa tanganicae			30	PURSE SEINE	Ruzizi
BURUNDI	07.08.93	MAGARA	Stolothrissa tanganicae			30	LIFTNET	Ruzizi
BURUNDI	07.08.93	MAGARA	Limnothrissa miodon			17	LIFTNET	Ruzizi
BURUNDI	07.08.93	MAGARA	Limnothrissa miodon			15	LIFTNET	Ruzizi
BURUNDI	07.06.93	· RUMONGE	Limnothrissa miodon			7	BEACH SEINE	Ruzizi
BURUNDI	07.20.93	? NTAHANGWA	Lates mariae (1)		25 m	1	GILLNET	Ruzizi
BURUNDI	08.03.93	? KANYOSHA-MUGERE	Lates mariae (2)		40 m	1	GILLNET	Ruzizi
BURUNDI	07.13.93	? MUGERE	Lates mariae (3)		30 m	2	GILLNET	Ruzizi
BURUNDI	07.06.93	· RUMONGE	Lates mariae			20	BEACH SEINE	Ruzizi
BURUNDI	07.06.93	RUMONGE	Lates angustifrons			15	BEACH SEINE	Ruzizi
BURUNDI	07.06.93	RUMONGE	Lates microlepis			3	BEACH SEINE	Ruzizi
ZAMBIA	6-7.93	CHITUTA BAY	Limnothrissa miodon			32		Chituta
ZAMBIA	6-7.93	CHITUTA BAY	Stolothrissa tanganicae			32		Chituta
ZAMBIA	6-7.93	CHITUTA BAY	Lates mariae			31		Chituta
ZAMBIA	6-7.93	CHITUTA BAY	Lates angustifrons			16		Chituta
ZAMBIA	6-7.93	CHITUTA BAY	Luciolates stappersii			30		Chituta
ZAMBIA	6-7.93	· NSUMBU	Limnothrissa miodon			30		Sumbu
ZAMBIA	6-7.93	NSUMBU	Stolothrissa tanganicae			30		Sumbu
ZAMBIA	6-7.93	NSUMBU	Lates mariae			30		Sumbu
ZAMBIA	6-7.93	NSUMBU	Lates angustifrons			30		Sumbu
ZAMBIA	6-7.93	NSUMBU	Lates stappersii			30		Sumbu
					Total:	660		

(1) sample taken between rivermouths of Ntahangwa and Mugere
(2) sample taken in front of rivermouth Mugere (11 km south of Bujumbura)
(3) sample taken in front of rivermouth Ntahangwa (in Bujumbura town)
ALL SAMPLES TAKEN BY LTR STAFF EXCEPT FOR SAMPLES 1,2 and 3 ABOVE TAKEN BY Dr. L. DEVOS (BELGIUM/CEPGL CRRHA PROJECT)

Appendix 2. Genetic samples, rainy season

COUNTRY	DATE	LOCATION	SPECIES	DISTANCE FROM SHORE	DEPTH	#SPECIMENS	GEAR	ZONE
		GENETIC SAMPLES of LTR	SECOND SAMPLING (Oct.-Nov. 1993)					
*TANZANIA	03.11.93	KIGOMA (Katonga)	Stolothrissa tanganicae	>1500m		30	Lift net	Malagarasi
*TANZANIA	16.11.93	KIPILI	Stolothrissa tanganicae	50m		30	Beach seine	Moba
*TANZANIA	03.11.93	KIGOMA (Katonga)	Limnothrissa miodon	>1500m		30	Lift net	Malagarasi
*TANZANIA	19.11.93	KIPILI	Limnothrissa miodon	60m		31	Beach seine	Moba
*TANZANIA	19.11.93	KIPILI	Lates stappersii	600m		30	Lift net	Moba
*TANZANIA	20.10.93	KIGOMA (Ujiji)	Lates mariae	150m		19	Beach seine	Malagarasi
*TANZANIA	29.12.93	KIGOMA (Ujiji)	Lates mariae	150-200 m		26	Beach seine	Malagarasi
*TANZANIA	22.12.93	KIGOMA (Ujiji)	Lates angustifrons	>2000m		5	Purse seine	Malagarasi
*BURUNDI	08.10.93	MAGARA	Luciolates stappersii			10	LIFTNET	Ruzizi
*BURUNDI	05.11.93	KITAZA	Luciolates stappersii			20	LIFTNET	Ruzizi
*BURUNDI	09.11.93	KARONDA	Luciolates stappersii			15	LIFTNET	Ruzizi
*BURUNDI	07.11.93	KARONDA	Stolothrissa tanganicae			15	LIFTNET	Ruzizi
*BURUNDI	12.11.93	NYAMUGARI	Stolothrissa tanganicae			30	LIFTNET	Ruzizi
*BURUNDI	09.11.93	KARONDA	Limnothrissa miodon			15	LIFTNET	Ruzizi
*BURUNDI	12.11.93	NYAMUGARI	Limnothrissa miodon			30	LIFTNET	Ruzizi
*BURUNDI	05.10.93	MUGERE (@)	Lates mariae		32 m	1	GILLNET	Ruzizi
*BURUNDI	09.11.93	KARONDA	Lates mariae			1	GILLNET	Ruzizi
*BURUNDI	15.12.93	KADJAGA	Lates mariae			6	BEACH SEIN	Ruzizi
*BURUNDI	17.11.93	CIMENTAL	Lates mariae			8	BEACH SEINE	Ruzizi
*BURUNDI	19.11.93	KADJAGA	Lates mariae			8	BEACH SEINE	Ruzizi
*BURUNDI	21.11.93	NYAMUGARI	Lates mariae			6	GILLNET	Ruzizi
*BURUNDI	19.11.93	KADJAGA	Lates angustifrons			1	BEACH SEINE	Ruzizi
*BURUNDI	23.11.93	KADJAGA	Lates angustifrons			2	BEACH SEINE	Ruzizi
*BURUNDI	23.11.93	KADJAGA	Lates microlepis			1	BEACH SEINE	Ruzizi
*ZAIRE	15.11.93	KALEMIE	Stolothrissa tanganicae			30	LIFTNET	Mahale
*ZAIRE	15.11.93	KALEMIE	Limnothrissa miodon			20	LIFTNET	Mahale
*ZAIRE	18.11.93	MOLIRO	Lates mariae		4-5 m	32	DIVING NET	Moba
*ZAMBIA	04.11.93	CHITUTA BAY	Limnothrissa miodon			31	Beach seine	Chituta
*ZAMBIA	16.11.93	NSUMBU	Limnothrissa miodon			32	Beach seine	Nsumbu
*ZAMBIA	05.11.93	CHITUTA BAY	Lates mariae			30	Gill net	Chituta
*ZAMBIA	17.11.93	NSUMBU	Lates mariae			30	Gill net	Nsumbu
*ZAMBIA	05.11.93	CHITUTA BAY	Lates angustifrons			4	Gill net	Chituta
*ZAMBIA	10.11.93	CHITUTA BAY	Lates angustifrons			10	Gill net	Chituta
*ZAMBIA	10.11.93	NSUMBU	Lates angustifrons			30	Gill net	Nsumbu
*ZAMBIA	09.11.93	CHITUTA BAY	Lates stappersii			31	Purse seine	Chituta
*ZAMBIA	18.11.93	NSUMBU	Lates stappersii			33	Lift net	Nsumbu
*ZAMBIA	10.11.93	CHITUTA BAY	Lates microlepis			2	Purse seine	Chituta
*ZAMBIA	17.11.93	NSUMBU	Lates microlepis			21	Beach seine	Nsumbu
*ZAMBIA	10.11.93	CHITUTA BAY	Stolothrissa tanganicae			24	Beach seine	Chituta
*ZAMBIA	16.11.93	NSUMBU	Stolothrissa tanganicae			34	Beach seine	Nsumbu
					Total:	764		

(@) Sample taken in front of rivermouth Mugere (11 km south of Bujumbura).

Appendix 3. Future sampling for genetic studies

	Limnothrissa m.		Stolothrissa t.		Lates stappersi		Lates mariae		L. angustifrons		L.microlepis	
	dry	rainy	dry	rainy	dry	rainy	dry	rainy	dry	rainy	dry	rainy
Rusizi	-	-	-	-	-	-	6	-	15	27	27	29
Malagar.	West	West	West	West	West	30	12	-	30	25	30	30
Moba	30	West	30	West	30	30	30	30	30	30	30	30
Mahale	West	West	West	West	West	West	30	-	30	30	30	30
Nsumbu	-	-	-	-	-	-	-	30	-	-	30	9
Chituta	-	-	-	-	-	-	-	-	17	16	30	28

THIRD JOINT MEETING
OF THE LTRS
COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

Kigoma (Tanzania), 28—30.11.1994

PRESENTATION OF SSP RESULTS: FISHERIES STATISTICS

by
E.J. Coenen

1. INTRODUCTION

The immediate objective of the fisheries statistics subcomponent is the following: to improve/standardize/coordinate the existing fishery statistics data collection systems of the 4 riparian countries, but especially to standardize and coordinate the (timely) reporting on annual frame (FS) and catch assessment surveys (CAS) results and to provide additional information for the medium and long run objective.

In the medium and long run, and in order to obtain the necessary information for the formulation of a future fishery management plan for Lake Tanganyika, these results, comprising reliable estimates of local and lake-wide catch/effort and CPUE figures (fishing mortality or effective fishing effort) should complement and be integrated with especially the results of the hydroacoustics subcomponent (determination of the temporal and spatial distribution and abundance of pelagic resources) and also those from the fish biology (biological production patters) and other subcomponents.

2. MATERIALS AND METHODS

Two different kinds of activities have to be discerned:

- assistance (logistic, financial, technical, organizational) to ongoing surveys in the four riparian countries (although LTR activities in Zaire are limited to prevailing unstable political situation);

— organisation of extra activities to collect supplementary information not covered by the ongoing surveys.

Concerning the first kind of activities, they cover:

(1) assistance to the organisation and execution of ongoing FS and CAS data collection, analysis and reporting;
(2) logistic and technical assistance to national fisheries statistical units;
(3) local staff training, etc.

Regarding the second kind of activities, these comprise mainly the following:

(4) gathering, checking, and compilation of past and present data concerning fisheries statistics in project data bank/documentation center;
(5) regular additional census (ground and aerial FS) on the numbers of fishermen, boats, etc. (nominal fishing effort) including a planned lake wide simultaneous FS in February 1995;
(6) organisation of a Workshop on Fisheries Statistical Coordination and Standardization and of regular meetings of the fishery statistical coordinators of the 4 riparian countries;
(7) coordination of standardized reporting on annual FS and CAS results to enable the compilation of overall Lake Tanganyika fisheries statistics;
(8) collection and reporting on supplementary fishery statistics *(e.g.* industrial statistics in Kalemie, Zaïre; continuous monitoring of fish landing site(s) and daily kapenta (clupeid) splitting in Mpulungu, Zambia);
(9) extraction of fishery statistical data from the fish biology subcomponent sampling;
(10) reporting, through Technical Documents, on national and lake wide aspects of Lake Tanganyika fisheries statistics;
(11) field missions to national and local fisheries statistical offices and field stations to discuss, organize, collect data, etc. regarding fisheries statistics activities mentioned above.

3. RESULTS

While detailed analyses for several topics still have to be finalized, the following preliminary overall and country results/indications/trends were recorded/noted:

3.1 Assistance to the organisation and execution of ongoing FS and CAS data collection, analysis and reporting

– Burundi, October 92 FS: 604 catamarans, 67 apollos, 298 canoes; since mid-sixties about 80 % increase in total fishing effort while total catches only increased by 50 % (TD/18);

– Burundi, CAS 92–93: 1992 – 24,560 tonnes; 1993 – 15,565 tonnes; this decline, and also for CPUEs, was apparent for all types of fishing due to reduction in total fishing effort; catch dominated by Clupeids (67–69.1 %) and *Lates stappersii* (28.7–31.6 %); probable local overfishing, catch level for 1992 close to minimum potential yield estimate (92 versus 90 kg/ha/year, respectively)(TD/24)

– Tanzania, GAS 93: LTR Kigoma assisting first decentralized GAS data input by Kigoma Region/District Fisheries Officers;

- Zambia, FS/CAS June-July 94: LTR/DOF Mpulungu execution; for preliminary results, see 3.5;

- Zaïre: no ongoing standardized lake wide FS/CAS activities, only some localized data collection; incomplete historical data; assistance to MECNT staff for collection of fisheries statistics from industrial units in Kalemie (see also 3.8);

3.2 Logistic and technical assistance to national fisheries statistical units

Apart from Bujumbura, main assistance was given to Lake based field stations:

– Burundi: unit based in Fisheries Department Headquarters, Bujumbura; FAO developed software (using dBaseIII) for data processing;

- Tanzania: unit based in Fisheries Division Headquarters, Dar es Salaam; decentralized TANFISH software data input in Lake Tanganyika Regions since 1993 (see also 3.1);

– Zambia: unit based in Fisheries Department Headquarters, Chilanga (Lusaka); Mpulungu is main station on Lake Tanganyika (see also 3.1);

- Zaïre: unit based in Fisheries Department Headquarters, Kinshasa; support to Kalemie MECNT staff (see also 3.1).

3.3 Local staff training, etc.

Continuous in-service training (field operations; collection, checking, compiling, analyzing, reporting of fisheries statistical data) carried out by LTR staff during SSP field and office activities in the 3 main LTR stations (Bujumbura, Burundi; Kigoma, Tanzania; Mpulungu, Zambia) around Lake Tanganyika.

3.4 Gathering, checking, and compilation of past and present data concerning fisheries statistics in project data bank/documentation center

First compilation of past and present country fisheries statistical data was given in TD/16 with update for Burundi in TD/24; several other aspects of Lake Tanganyika fisheries statistics were reported in various TDs and TRM4s (see 3.10 and 3.11). Numerous publications and data files on Lake Tanganyika fisheries statistics are already available in the Regional Documentation Center, Bujumbura and continue to be collected; lake wide and individual country data compilations also available as computer files. An updated summary on the present knowledge concerning Lake Tanganyika is given hereafter:

– Lake wide **total catches** for Lake Tanganyika, as well as for the 4 riparian countries, show an increasing trend since the early fifties and are estimated to attain levels of 130000 to 170000 tonnes during recent years (Fig. 1);

— As a result, the overall **average catch/ha/year** increased from about 4 kg in 1953 up to 51 kg/ha/yr in 1992; for Burundi, showing some signs of local overfishing, this even amounts to 94.5 kg/ha/yr in 1992 which is near the lower level of the estimated fish potential of the Lake (90–140 kg/ha/yr); the average catch/ha/yr for Zambia, Tanzania and Zaire in 1992 amounts respectively to 69, 60 and 34 kg/ha/yr (Fig. 2);

— Lake wide **total value** of the catches landed in 1991 is estimated to amount to about 26 x 106 US **$** or an average landing price per kg of fish of about 0.15 US **$** (Burundi contributing the major part i.e. about 10 x l0~ US **$** and an average price per kg of 0.41 Us **$** kg);

— Total lake wide **fishing effort**, expressed as total number of all types of fishing units, <u>hardly changed</u> since the early seventies, varying between <u>10000 and 12000 fishing units</u> (Fig.3). A considerable reduction in the total number of fishing units in Tanzania during the last decade (7700 down to 3200) was compensated for by an almost equivalent increase in Zaïre (4000 up to 7150); at present, it is estimated that there are about 7400 traditional units, 2000 artisanal liftnet units, 1000 scoopnet units (Tanzania), 200 kapenta seines (Zambia) and about 50 industrial units; fishing around the Lake is done by an estimated <u>40000 fishermen</u>; this means that probably several hundred thousand people are involved in fisheries related activities (fish processing, trade, transport, boat building, gear supply and repair, etc.);

— However, and very important, is the fact that the **composition of the fishing fleet** changed considerably: the not very productive traditional subsistence fishing diminished in favour of much more productive artisanal and industrial fishing units; as a result, and also due to the use of more efficient fishing gear, average annual catches per fishing unit of about 3 tonnes/yr/unit in the early fifties increased to an overall average of about 14 tonnes in 1992, with annual peak averages in Burundi (Fig. 4) and Zambia around 30 tonnes/yr/unit;

- the <u>unit of effort</u>, defined as the fishing effort exercised by one fishing unit, its crew and gears, is completely different for different types of fishing units; the major types of units are:

traditional units, catamaran and apollo liftnet units, ‘kapenta’ (clupeids) beach seine units (Zambia), and industrial units. therefore, the **Catch per Unit of Effort** (CPUEs) for these different units vary considerably in time and space, but, as a rule of thumb, the following average CPUE values can be used:

* industrial unit: 1000 kg/night (300 for Burundi)
* artisanal liftnet unit: 100 kg/night
* kapenta seine (Zambia): 100 kg/night
* traditional unit: 25 kg/night

More detailed CPUE values, per type of fishing unit, and its variation in time and space, are given in various publications and TDs.

- due to the continuous expansion of light fishing at night (artisanal liftnet units, kapenta seines, scoop nets, industrial) targeting especially the Clupeids *(Stolothrissa tanganicae, Limnothrissa miodon)* and *Lates stappersii,* overall **catches are mainly composed of these 3 species.** They show fluctuating abundances in space and time (daily, monthly, yearly, multi-annual cycles) and abundances for the 2 clupeid species and *L. stappersii* are negatively correlated. For the industrial fishing in Burundi, e.g., the Clupeids are in general more abundant while for the industrial fishing in Zambia, since 1986, *L. stappersii* became the most abundant (Figs. 5a and b, 6a and b and 7).

- using the CEDA (Catch Effort Data Analysis) 1.0 package, some **Deterministic Recruitment/Production** (DRP) models were tried on available Burundi catch/effort data of *Luciolates stappersii* for the period 1976-1993. Since our data did not completely fulfill all the assumptions of the models used, the results obtained have to be considered with a lot of caution. Two sets of data were used: the industrial and the artisanal catch/effort data (see Fig. 7b). Using the 3 DRP models (Schaefer, Fox and Pella-Tomlinson), best fits were obtained with the Pella-Tomlinson Model assuming that production or recruitment are related to the unexploited population size K and the intrinsic growth rate r. Best fits were also obtained using the Log Transform Error Model; Shape Parameter z between 0.5 and 1; Initial Proportions (stock size in the first data year as a proportion of the unexploited stock size) between 0.8 and 0.95; Time Lags (taking into account the age at what time fish recruits to the fishery) of 0 to 3; and CPUE timing “Middle”. The following estimated ranges for the *Luciolates stappersil* stocks fished by the industrial and artisanal fisheries in Burundi were obtained (see abbreviations below *)

K = 21510—48246 tonnes (95% conf.lim.: 15902—110549 tonnes);
MSY = 3340-9135 tonnes/year (present catch levels 4-6000 t.);
B1993 = 10755—22663 tonnes:
r = 0.243—1.335 (Mpulungu: 0.614—1.913, Pearce 1992)
q = 0.0000160—0.0000169 per boat night (industrial fishery)
q = 0.000248—0.000322 per artisanal unit (artisanal fishery)

K = carrying capacity or unexploited stock size
MSY = Maximum Sustainable Yield
$= rK(l+z)^{-1/z}(l-(l+z)^{-l/z})$
B = Biomass
$= K(l+z)^{-1/z}$
r = intrinsic growth rate
q = catchability = fishing mortality/unit of effort

3.5 Regular census (ground and aerial FS) on the numbers of fishermen, boats, etc. (nominal fishing effort), including a planned lake wide simultaneous FS in February 1995

- first ever lake wide aerial FS Lake Tanganyika, 29.09–03.10.92, its results being reported in TD/09, TD/l0 and FM/l:

* total of 13976 single boat units of which 2464 units were composed as 1232 catamarans and 21 as 7 trimarans; Burundi: 1802,
Tanzania: 3839, Zambia 765 and Zaire 7570 boat units; average number of boat units per km of shoreline: 8;
* total of 459 fish landing sites according to different size classes were recorded (B:34; T: 127; Zam: 41; Zaï: 257); on the average 1 landing site per 4 km of shoreline;
* shoreline composed of rock (43 %), sand (31 %), rock/sand (21 %) and marshy zones around river estuaries (5 %).

- second lake wide aerial FS Lake Tanganyika. 19-21.05.93: its final results are not yet available.

- Zambia, FS/CAS 6.06-9.07.94: LTR/DOF Mpulungu execution (Mwape,1994)

* total of 83 permanent (except 1) fishing villages;
* total of 525 fishing units, operated by 2082 fishermen, and 19 transport boats;
* 24 purse seiners, 5 liftnet units and 109 beach seine units using 850 fishing lamps; 1133 gill nets, 61 handlines, 12 longlines.

- preparation of first simultaneous (ground–approach) FS, planned in February 1995: final meeting of the fisheries statistical coordinators of the 4 countries planned to take place 12-13.12.1994 in Bujumbura.

3.6 Organisation of a Workshop on Fisheries Statistical Coordination and Standardization and of regular meetings of the fishery statistical coordinators of the 4 riparian countries

- Workshop on the Coordination and Standardization of Fisheries Statistics for Lake Tanganyika, Bujumbura 26-30.07.1993: major recommendations included the need for standardized annual national reporting of FS and CAS results (forms and definitions were adopted) because the possibility to try to adopt a uniform fisheries statistical data collection system was unanimously rejected; need for regular FS, including a simultaneous one in February 1995, and for regular meetings of the national fisheries statistical coordinators (see TD/ll).

- Annual meetings of the fishery statistical coordinators of the 4 riparian countries: first one to take place in Bujumbura, second week of December 1994 to prepare 02.95 simultaneous FS and to discuss annual and general fisheries statistics for Lake Tanganyika (see also 3.5).

3.7 Coordination of standardized reporting on annual FS and CAS results to enable the compilation of overall Lake Tanganyika fisheries statistics

- Following the recommendations of the Statistical Workshop in July 1993 (see 3.6), Burundi prepared its standardized fisheries statistical result outputs for 1993 (see also TD/24) ; they were sent to the Directors of Fishery and the fisheries statistical coordinators of the 3 other countries and to the CIFA Subcommittee for Lake Tanganyika, FAO, Rome; standardized result outputs of the other 3 countries have not yet been received.

— Pre—1993 overall Lake Tanganyika fisheries statistics compilations were prepared and reported in various TDs (see 3.10).

3.8 Collection and reporting on supplementary fishery statistics (e.g. industrial statistics in Kalemie, Zaïre; continuous monitoring of fish landing site(s) and daily kapenta (clupeid) splitting in Mpulungu, Zambia)

— Since October 1992, LTR is monitoring the collection of industrial fisheries statistical data from Kalemie, Zaïre with the help of a Kalemie based industrial fisherman (DD) . Since July 1993, after strengthening the links with the ECN Subregional Coordinator of Kalemie, parallel ECN data on the industrial fishing were also received. A first compilation of data, up to 11.93, was published in TD/16. Total 1993 industrial catch was estimated at about 1000 tonnes, with an average CPUE of 866 kg/night/unit. The bulk of the catch was mainly composed of *Lates stappersii* (92 %) and Clupeids (7 %) for the period observed. A comparison with ECN statistics revealed that the latter only represent 42 % of the total catch and 92 % of the total fishing trips as recorded by DO. Out of the 14-17 units, of which on the average about 10 units were active in 1992, only 5—6 units were still active in 1994 due to lack of spare parts and diesel, the difficult political/economic situation of the country, etc. and the fact that in 1994 several units moved to Zambia. Kalemie industrial catch statistics for the period 12.93 - 6.94 indicate that the 1994 total catch will probably not exceed 500 tonnes, that the CPUE amounts to 903 kg/night/unit and that the catch was mainly composed of *Lates stappersii* (97 %) and Clupeids (1 %)

- because of the fact that Zambia’s fisheries statistical data collection system does not have a continuous monitoring of fish landing beaches but 3-4 one monthly CAS/FS rounds per year (which, due to unclear reasons, were not executed since 1993) LTR recently decided to start a continuous CAS monitoring of Katasa beach near Mpulungu and maybe later of another landing site in Nsumbu area (see also TRAM 53) . A daily catch recording form was designed and total enumeration/sampling of fishing units started on 25.09.94, 3 times per week. As a result, monthly variations in catch, effort, CPUE, species composition, etc. can now be recorded and rough extrapolations made for all fish landings for Lake Tanganyika, Zambia.

— at the same time, LTR/Mpulungu started a daily kapenta (clupeids) splitting (determination of the composition

Limnothrissa versus *Stolothrissa)* of a 1 kg sample of clupeids taken from one of the 5 industrial companies in Mpulungu.

3.9 Extraction of fishery statistical data from the fish biology subcomponent sampling

Since July 1993, weekly fish samples are taken from artisanal units, industrial units, beach seines, etc. at several LTR stations and substations around the Lake. Apart from data to be used for the fish biology subcomponent (length frequency, maturity, sex, etc.), also some fishery statistical data were extracted and compiled on a monthly basis for those stations and fishing units where enough samples were taken to obtain significant results regarding CPUE, species composition, etc. As an example, we give the summary characteristics of the catamaran liftnet units sampled from 7.93 to 6.94 in the upper northern basin (Bujumbura-Uvira) , in Karonda (70 km south of Bujumbura) and in Kigoma (Tanzania)

PARAMETER	BUJA-UVIRA	KARONDA	KIGOMA
N	218	80	139
KG/Fish.Unit	48	142	128
KG/Haul	19.5	63.0	54.7
KG/Light	9.3	18.9	18.7
Hauls/Fish.U	2.3	2.3	2.2
Lights/F.U.	5.8	7.8	6.6

From the table above, it is clear that much less fish is caught by catamarans in the northern basin (due to local overfishing) than in the more southern fishing grounds. Figures 8 to 10 show the monthly variation in average catamaran catch per night and the 95 % confidence limits for the 3 areas sampled.

The monthly species composition was arrived at by extrapolating the sample composition (Figs. 11 to 16)

— in Buja/Uvira, Clupeids show their minimum abundance during 10-11.93 and another minimum during 3.94; in general, *Stolothrissa tanganicae* (STA) is more abundant throughout the year except during 11-12.93 when *Limnothrissa miodon* (LMI) is the major species; similar abundances were observed for the Burundi CAS 93 (see TD/24);
— in Karonda, Clupeids show one important minimum abundance during 10.93; in general, Clupeids are principally composed of STA except during 9 and 11.93 (LMI);

- in Kigoma, Clupeids show their minimum abundance during 2-3.94 and another minimum during 10.93; here, Clupeids are almost exclusively composed of STA throughout the year.

As mentioned before, abundance peaks of Clupeids are negatively correlated with those of *Lates stappersii* (LST). In general, abundance trends look more or less similar for the above stations, although LMI is more abundant in the northern basin with a broad shallow sandy littoral belt than in Kigoma where the littoral belt is narrow and steep. The maximum abundance of LMI in the liftnet catches during 11.93 is most probably due to the observed (feeding) movements of LMI to the pelagic zone during October—November (Coulter, 1991) after a probable spawning in August—September (fish biology observation, 1993) in shallow waters. Thus, spawning behaviour might also play a role in movements of Clupeids from the littoral to the pelagic zone, or vice versa, and thus for their availability to be caught by liftnets.

Unfortunately, Mpulungu data for the above period are not available, mainly because there were major problems in sampling unsorted catches.

3.10 Reporting, through Technical Documents, on national and lake wide aspects of Lake Tanganyika fisheries statistics

Since March 1993, even before the end of the preparatory phase of LTR, the reporting on Lake Tanganyika fisheries statistics started; the following TDs were prepared:

* TD 9 and 10: First aerial FS results;
* TD 11: Report on the First Workshop on the Coordination and Standardization of Fisheries Statistics for Lake Tanganyika;
* TD 15: Report on the historical data of the Fisheries, Fisheries Statistics, Fishing Gear and Water Quality of Lake Tanganyika, Tanzania;
* TD 16: Report on the (semi-) industrial fishing on Lake Tanganyika, with special emphasis on the industrial fishing in Kalemie, Zaire and a compilation of lake wide fisheries statistical data;
* TD 17: Report on LTR’s Second SSP Assessment Meeting;
* TD 18: Report on the October 1992 FS results on Lake Tanganyika in Burundi, with a comparison with past surveys;
* TD 24: Report on the 1992-93 CAS results for Lake Tanganyika, Burundi.

3.11 Field missions to national and local fisheries statistical offices and field stations to discuss, organize, collect data, etc. regarding fisheries statistics activities mentioned above various national fisheries statistics headquarters and regional offices were visited for this purpose and were reported on in several travel reports (TD/5, TD/12, TD/19)

* TRAM 8 : Kigoma, historical data on fisheries statistics for Lake Tanganyika, Tanzania;
* TRAM 10: Chilanga and Mpulungu, historical data on fisheries statistics for Lake Tanganyika, Zambia;
* TRAM 12: Lake wide aerial FS travel report; Kigoma, historical data; Kalemie, collection of data on industrial fishing;
* TRAM 23: Assessment of fisheries statistical system in the Kigoma and Rukwa Regions/Districts, Tanzania;
* TRAM 29: Fisheries statistics identification mission Uvira, Kalemie, Moba, Bukavu, Zaire;
* TRAM 31: First SSP subcomponents assessment meeting, Kigoma, Tanzania;
* TRAM 43: Check on the progress of decentralized TANFISH CAS data computer entry in Kigoma Region/District; second SSP

subcomponents assessment meeting, Kigoma, Tanzania;
* TRAM 50: Discuss various aspects of data collection, compilation and reporting of CAS data from Lake Tanganyika, Tanzania; preliminary discussions on the preparation in Tanzania of the simultaneous FS in February 1995;
* TRAM 53: Check of progress of the fisheries statistics activities in Mpulungu station, Zambia.

4. CONCLUSIONS

The above outlined summary of results is still preliminary as part of the data still have to be analyzed, as more years of data are needed, as links have to be made with the results of other subcomponents and with fishery hydroacoustical data to be obtained during lake wide cruises with the R/V Tanganyika Explorer in 1995.

The major conclusion is probably the fact that lake wide catches are still increasing due to more and more efficient artisanal fishing units which exploit principally the 3 main pelagic species. Some parts of the Lake are already heavily exploited (northern part of the Burundi waters, Mpulungu area in Zambia) and the proper management of the fishing effort there seems urgent and indispensable. In Burundi, a natural shift of fishing effort towards the more southern fishing areas has already been observed since several years. In Zambia, the solution would be to oblige part of the Mpulungu industrial (and maybe also artisanal) units to move to the the Nsumbu area, but therefore better access roads, infrastructures (e.g. electricity supply), etc. should be developed for this area in order to allow fishing companies to establish themselves there (Pearce, 1992)

The main part of the Lake however, in Tanzania and Zambia, is still underexploited and available for the (managed) introduction of more fishing effort (artisanal units).

The follow-up of future trends in fish catches, CPUEs, etc. can only be monitored through the collection of reliable fisheries statistics. Unfortunately, up to this date, the importance of fisheries statistics and the resulting monitoring of a free animal protein resource (worth millions of dollars) is still undervalued (compared to the agricultural sector)

Moreover, due to present severe budget constraints affecting all riparian countries, the collection of fisheries statistics is too often considered as the last priority when budgets have to be allocated.

Therefore, the existing fisheries statistical systems should be reinforced (rather than neglected) and more importance should be given to the establishment of recurrent annual budgets to run fisheries statistical field and headquarters operations, supervision of beach recorders, elaboration of standardized fisheries statistical result outputs and regular meetings of the fisheries statistics coordinators (as decided by the July 93 Statistical Workshop) to enable an adequate lake wide monitoring of the fisheries resources of Lake Tanganyika. The planned coordinators'meeting and the first lake wide simultaneous ground FS are only one of the first steps towards this objective.

5. REFERENCES

Coenen, E.J., Report on the First Workshop on the Coordination
1993 and Standardization of fisheries statistics for Lake Tanganyika (Bujumbura, 26–30 July 1993) . FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/1l (En): lOp., 5 ann.

Coenen, E.J., Rapport sur le Prémier Atelier Statistique sur
1993 la Coordination et la Standardisation des Statistiques des Pêches pour le lac Tanganyika (Bujumbura, 26-30 juillet 1993). FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika.
GCP/RAF/271/FIN-TD/1l (Fr): l1p., 5 ann.

Coenen, E.J., Field guide containing maps of the Lake
1993 Tanganyika shoreline / Guide de terrain contenant des cartes de la côte du lac Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake. Tanganyika. **GCP/RAF/271/FIN-FM/O1 (En & Fr): 88p**.

Coenen, E.J. (ed.), Historical data report on the Fisheries,
1994 Fisheries Statistics, Fishing Gears and Water Quality of Lake Tanganyika (Tanzania). FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/15 (En & Fr): 115p.

Coenen, E.J. Semi-industrial fishing on Lake Tanganyika, with
1994 special reference to the fisheries statistics of the industrial fishing fleet of Kalemie (Zaïre), 10.92-11.93. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/16 (En): 39p.

Coenen, E.J. Frame Survey results for Lake Tanganyika, Burundi
1994 (28–31.10.1992) and comparison with past surveys. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN–TD/18 (En): 26p.

Coenen, E.J. & E. Nikomeze, Lake Tanganyika, Burundi, results
1994 of the 1992-93 Assessment Surveys. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN–TD/27 (En): 26p.

Coenen, E., G. Hanek & P. Kotilainen, Shoreline classification
1993 of Lake Tanganyika based on the results of an aerial Frame Survey (29.09.92 - 03.10.92). FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN–TD/1O (En): 11p.

Coenen, E.J., G. Hanek & P. Kotilainen, Classification de la
1993 ligne côtière du lac Tanganyika basée sur les résultats de l'Enquête Cadre Adrienne (29.09.92 – 03.10.92). FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika. **GCP/RAF/271/FIN-TD/lO: 13p**.

Coenen, E.J. & G. Hanek, Report on LTR's Second Scientific
1994 Sampling Programme Assessment Meeting, Kigoma, 11 12.04.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN–TD/17 (En): 20p.**

Coulter, G.W. (ed.), Lake Tanganyika and its Life.
1991 Natural History Museum Publications, Oxford University Press, London Oxford & New York:354 p.

Hanek, G. (ed.), Reports of Travel 01-15 of Project GCP/RAF/271/
1992 FIN. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN–TD/05 (En): 89p.**

Hanek, G. (ed.), Reports of Travel 16-30 of project GCP/RAF/271/
1993 FIN. FAO/FINNIDA Research for the management of the Fisheries on Lake Tanganyika. **GCP/RAF/275/FIN–TD/12 (En): 96p.**

Hanek, G. (ed.) Reports of Travel 31-45 of project GCP/RAF/271/
1994 FIN. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN-TD/19 (En): 71p.**

Hanek, G., E.J. Coenen & P. Kotilainen, Aerial Frame Survey of
1993 Lake Tanganyika Fisheries. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN–TD/09 (En): 29p.**

Hanek, G., E.J. Coenen & P. Kotilainen, Enquête Cadre Adrienne
1993 des Pêcheries du lac Tanganyika. FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika. **GCP/RAF/271/FIN-TD/09 (Fr): 29p.**

Mwape L.M., Frame Survey Lake Tanganyika (Zambian waters), 6.06-
1994 9.07.1994. FAO/FINNIDA Recherche pour l'Aménagement des Pêches au lac Tanganyika. Draft report, October 1994: 10 p.

Pearce, M.J., The development of the pelagic fisheries since
1992 1980 and its effect on the pelagic fish stocks in the south of Lake Tanganyika. Final Report, Department of Fisheries Zambia, August 1992, Mpulungu: 129 p., 42 tabs, 61 figs.

Fig. 1: Historical evolution of total catch, per country, for Lake Tanganyika

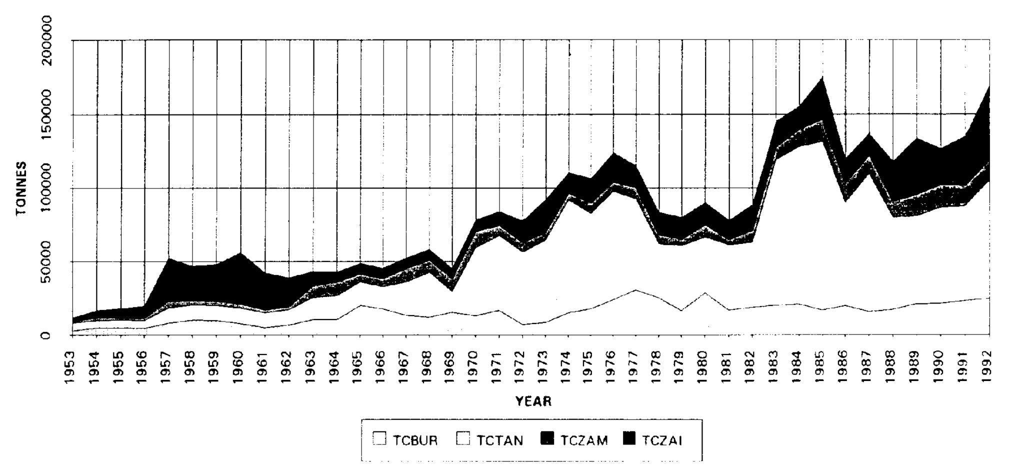


Fig. 2: Historical evolution of annual CPUEs, per country, for Lake Tanganyika

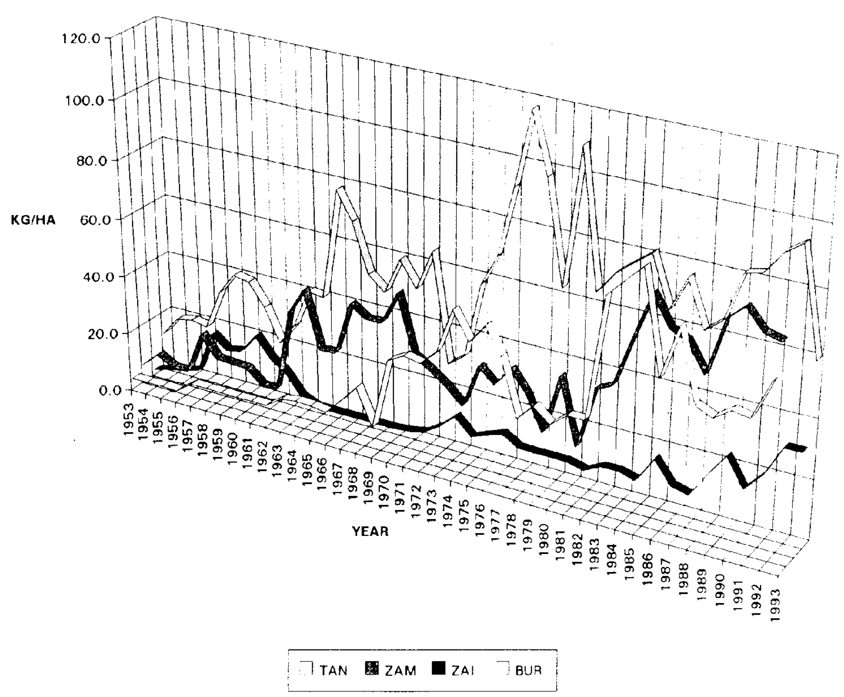


Fig. 5a: Monthly variations in industrial catch composition, Mpulungu, Zambia (1984-94)

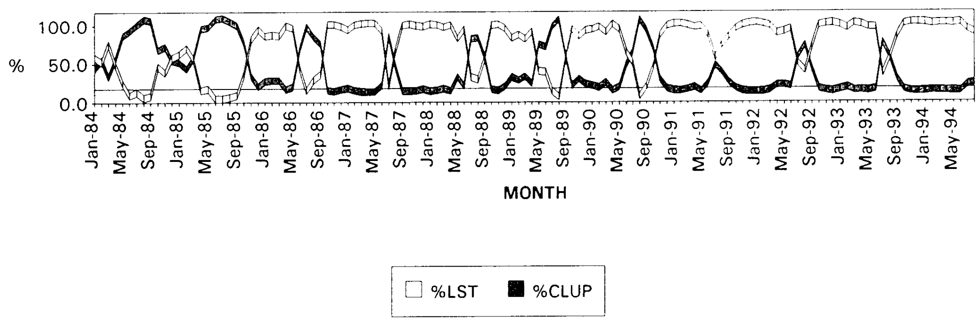


Fig. 5b: Monthly variations in industrial catch composition, Burundi (1984-94)

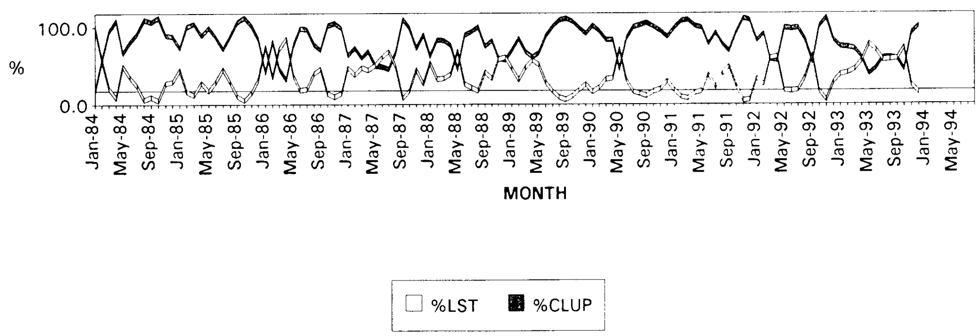


Fig. 3: Reconstruction of the evolution of fishing effort, per country, for Lake Tanganyika

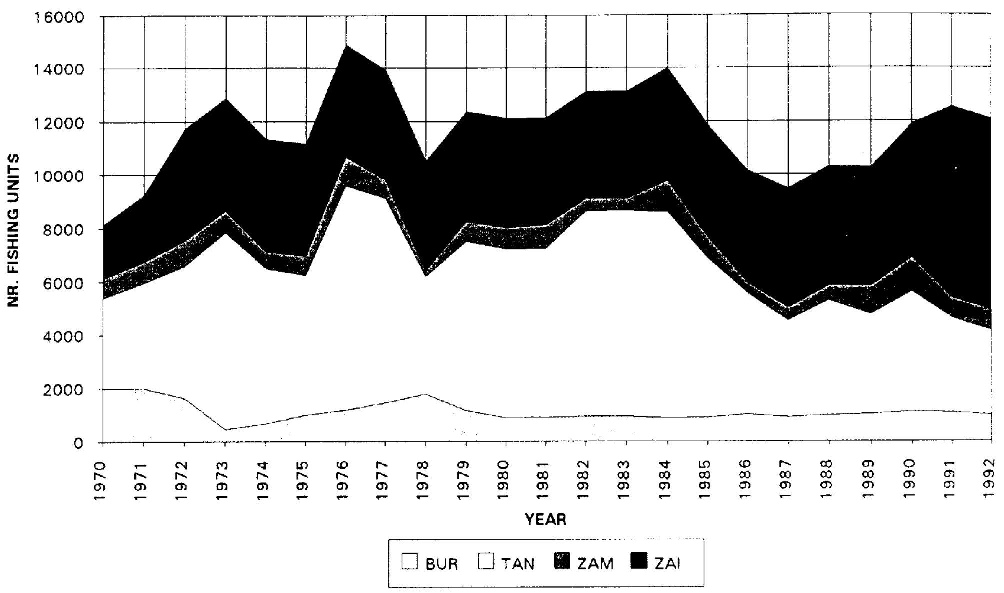


Fig. 4: Evolution of annual fishing unit CPUE, Burundi, Lake Tanganyika

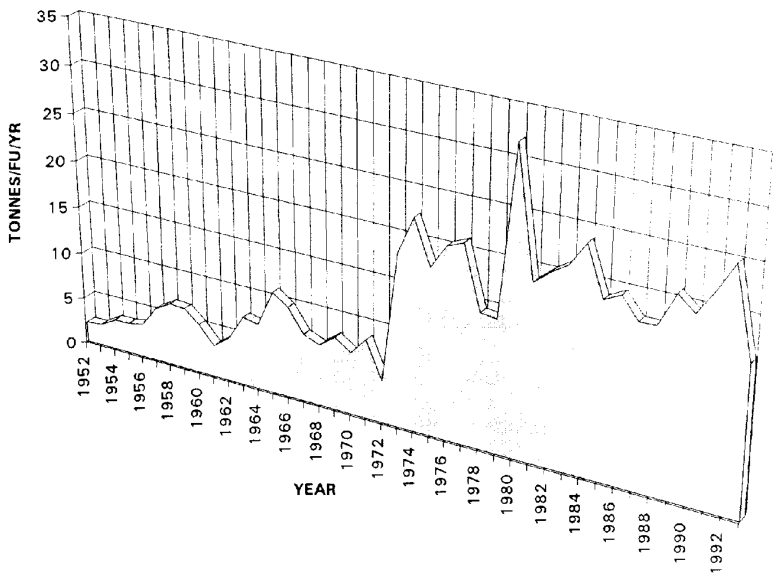


Fig. 6a: Yearly variation in industrial catch composition, Burundi (1956-1993)

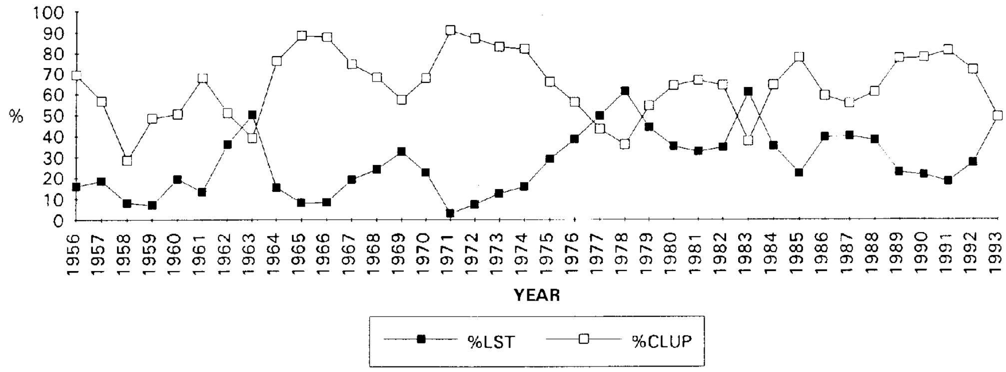


Fig. 6b: Yearly variation in industrial catch composition, Mpulungu, Zambia (1963-93)

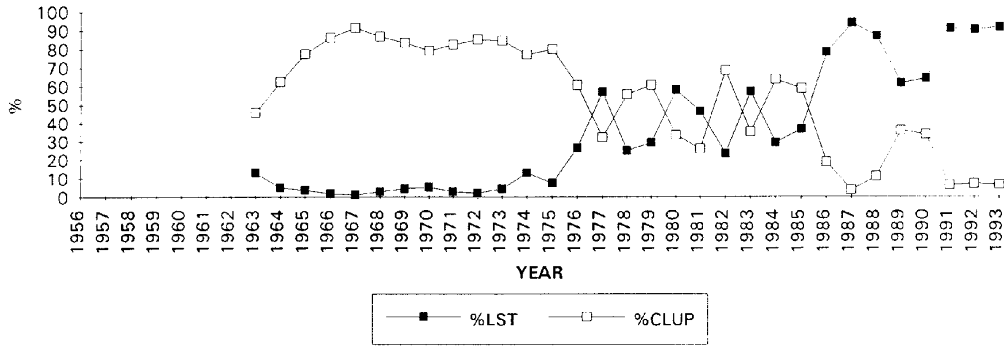


Fig. 7: Yearly variation in artisanal liftnet catch, Burundi (1974-1993)

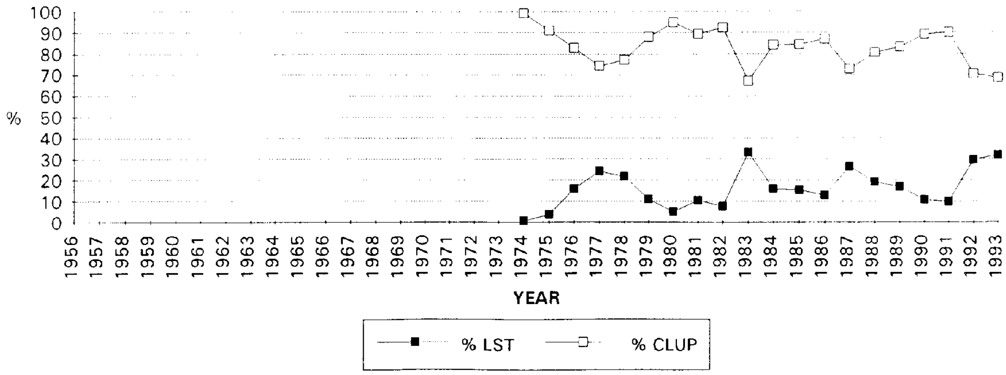


Fig. 7b: Example of CEDA analysis of industrial catch/ effort data for *Luciolates stappersii*, Burundi (1976-1993).

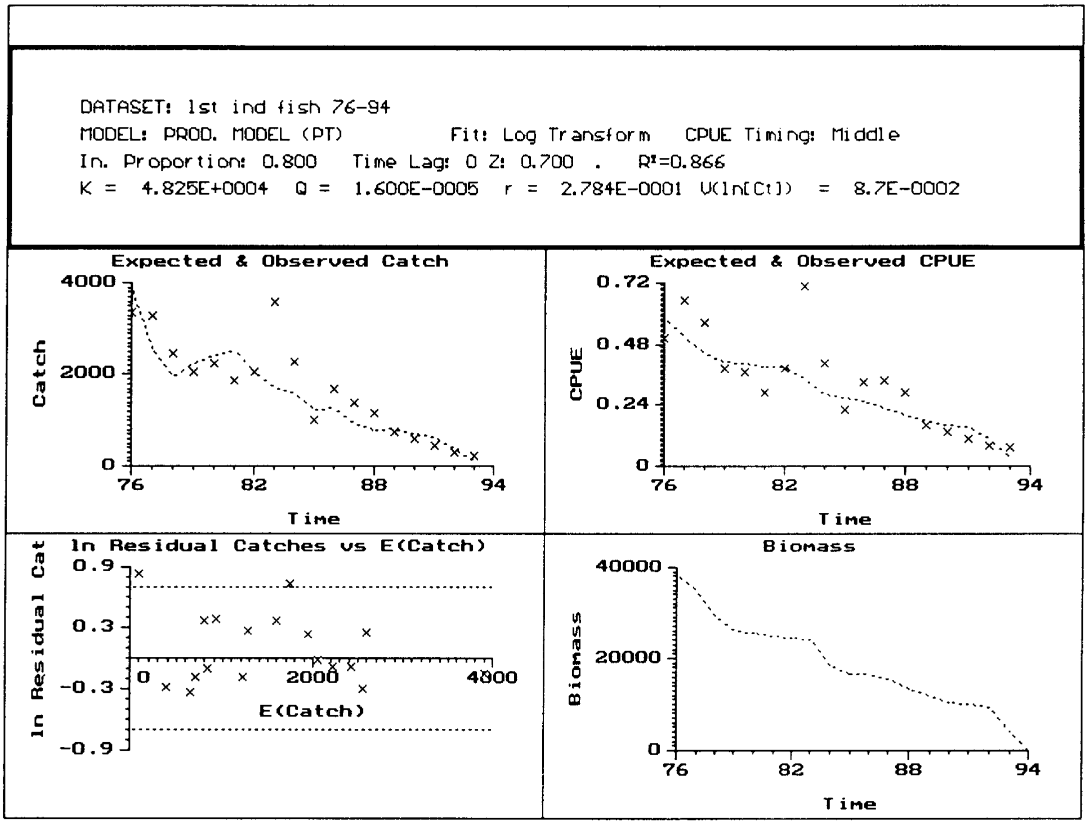


Fig. 8: Monthly variation in average catamaran catch/night and 95 % confidence limits, Bujumbura-Uvira

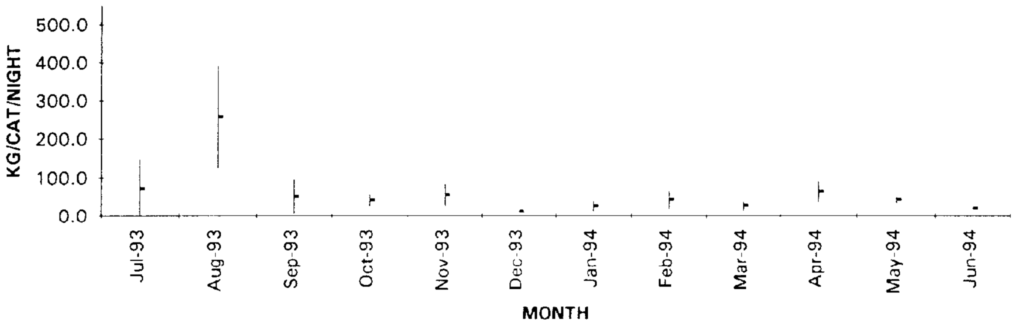


Fig. 9: Monthly variation in average catamaran catch/night and 95 % confidence limits, Karonda

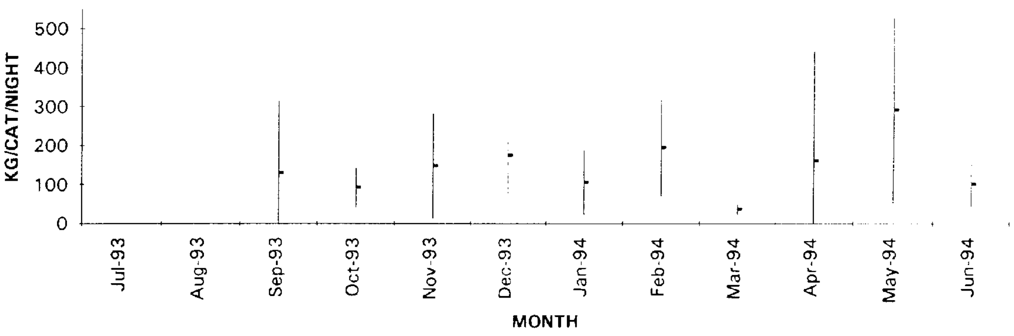


Fig. 10: Monthly variation in average catamaran catch/night and 95 % confidence limits, Kigoma

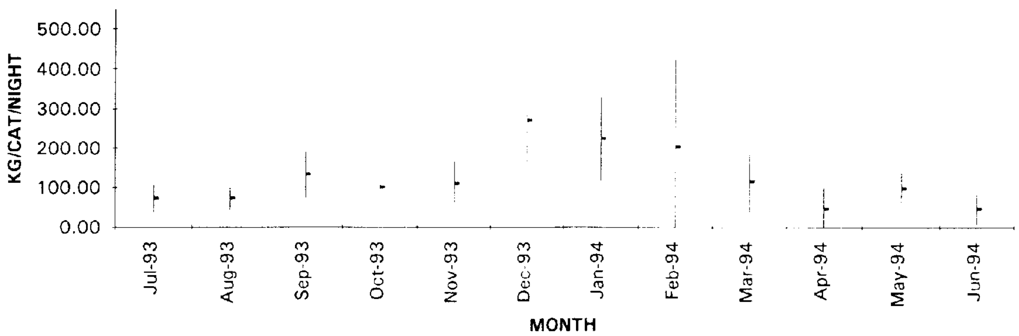


Fig. 11: Monthly species composition, Buja-Uvira

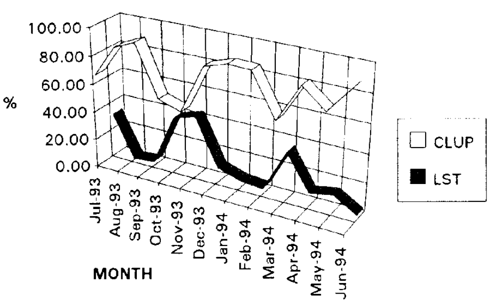


Fig. 12: Monthly species composition, Buja-Uvira

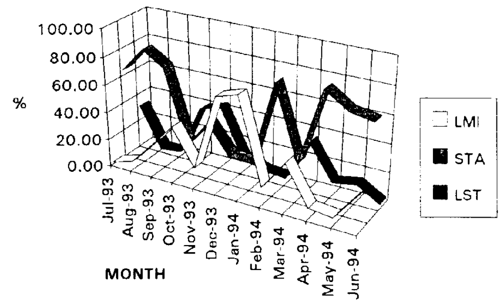


Fig. 13: Monthly species composition, Karonda

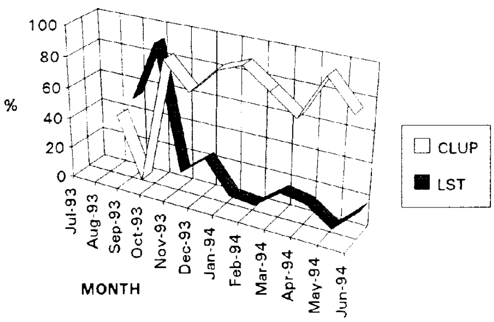


Fig. 14: Monthly species composition, Karonda

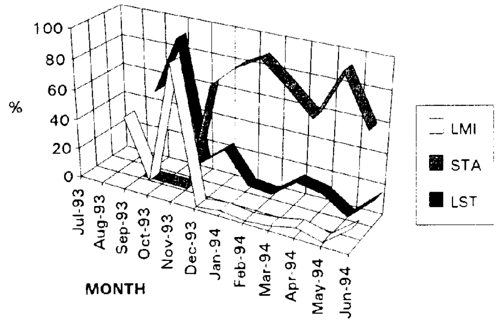


Fig. 15: Monthly species composition, Kigoma

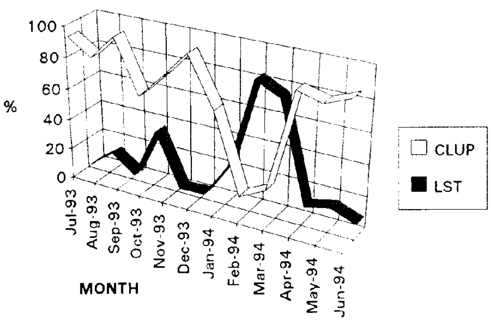
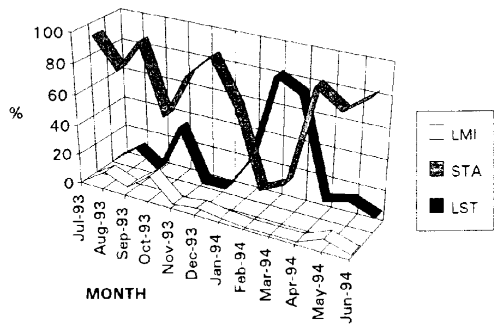


Fig. 16: Monthly species composition, Kigoma



THIRD JOINT MEETING OF THE LTR'S COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

Kigoma (Tanzania), 28–30.11.1994

LTR SCIENTIFIC COORDINATORS REPORT: SUMMARY OF SSP RESULTS AND PROPOSAL OF SSP FOR 1995

1. INTRODUCTION

This report gives the outlines of the LTR Project's Scientific Sampling Programme (SSP) and the main results obtained in 1993-1994. The period reported here covers the first full year of research which was started in every research subcomponent and all locations as planned. The scientific programme was initiated ahead of the schedule, before completing the project's preparatory phase. This was made possible by facilitating the field activities at the nine main sampling centres. The local scientists and technicians were effectively trained to carry out the planned tasks, and the overall coordination of the demanding, multifaceted programme was successfully accomplished.

The active participation of the counterpart institutions in the four riparian countries, local scientists and the field coordinators of the programme has lead to several modifications and improvements in the activities, both in the field and in the laboratory. The problems encountered have been recorded and respective improvements discussed, and finally decided upon, in regular meetings between the field personnel. The entire SSP was evaluated, and the data analyses and reporting in particular were discussed in the SSP Assessment Meeting during 11-12 April, 1994, in Kigoma, Tanzania (Coenen and Hanek, 1994).

In December 1993, four new Associate Professional Officers, increased the number of LTR's field staff. LTR's international team of experts have also allocated a considerable amount of time and effort in carrying out the programme in all of its components. In its present form, sampling and analyses of the hydrodynamic, meteorological, limnological and fish biology data of Lake Tanganyika involve a joint effort of more than 120 persons representing 14 nations. Handling and reporting of such a large amount of information and data will require further special arrangements. Also, the counterparts' active participation in reporting is encouraged. The final scientific reporting will be handled first in the LTR's Coordination Committee and the International Scientific Committee, and then, published through the subcomponent leaders and the Scientific Coordinator in Finland.

For detailed presentation of the aims of each subcomponent, a reference is made to the respective report (LTR/93/3) of the LTR Coordination Committee meeting in Lusaka in 1993. The activities of each subcomponent were discussed in the detailed reports prepared by the respective component leaders.

2. ACTIVITIES IN EACH RESEARCH COMPONENT

2.1 Hydrological modelling

Aims

To understand the upwelling (downwelling) phenomena of the nutrient rich deep waters and their possible effects on the coastal/pelagic biological production and, eventually, ecosystem structure, fish production, fish stocks and fisheries. The hydrodynamic processes are also used to describe the spatial and temporal fluctuations in water quality.

Activities and results

The activities are discussed in detail in the respective report by Podsetchine and Huttula (1994). The three-dimensional numerical circulation model of the lake includes the following variables: the three components of velocity vectors, the free surface water level and the temperature field. The main driving forces are time—dependent, wind— induced shear stresses and the surface heat flux. The model is hosted in the VAX/VMS computer and the CONVEX C3480 supercomputer in Finland.

At the present stage of hydrological modelling, only the barotropic flow is considered, and the vertical temperature stratification is not taken into account. The simulation of the stratified situation is currently being calculated.

Initially, the steady-state, lake-wide flow patterns under the four main wind directions were obtained. In the surface layers down to a depth of 50 m, the simulated flow follows mainly the wind. At greater depths, the influence of wind decreases, and a complicated structure of water currents emerges. The calculated currents are directed mainly opposite to the wind direction at the depth of 1000 m for the southerly and northerly winds, and at the depth of 500 m for the westerly and easterly winds.

The vertical components of water velocity are small compared to the horizontal flow that may even reach 19 cms' in places. For the ecosystem structure and functions, however, both components are important. The calculated surface vertical velocity reaches its maximal value of 140 $mday^{-1}$ in the case of a spatially constant southerly wind. The initial hypothesis called for a single upwelling area at the southern end of the lake. It has been difficult to find any regularity in the distribution of zones of upwelling and downwelling, and apparently they are more common towards the east coast in the case of southerly winds. There seems to be great patchiness in the lake surface structure in this respect, which is also revealed by the remote sensing data. The southern end of the lake apparently works as the mixing engine for the lake.

The report by Huttula and Podsetchine (1994) covers the work involved and the results obtained towards the hydrological model in more detail and more extensively.

Plans for 1995

The plans involve development of the 3-D hydrodynamical model, and the calibration of the model with field data.

Special attention will be given to the development of more realistic approximations of the near surface wind field. The wind fields will have to be measured aboard the new research vessel during actual cruises. Stratification effects and currents induced by density variations may somehow alter the barotropic flow patterns. The process of model tuning to already collected data, that is model calibration, especially for the non-steady wind conditions will require additional efforts. Only then can the model be verified with an independent set of observational data for selected periods.

Attention is also required towards development of a user–friendly environment for easier handling of the very large amount of data produced by the model, in order to make the model usage simpler and analyses of results more illustrating. The feasibility of transfer of the model code to PC environment needs a special study. The completed model will be used to estimate the transport rates and probable directions of biological particles such as suspended organic matters, phyto– and zooplankton, fish eggs and larvae. Also the vertical movements of nutrients from deep layers to the surface can thus be estimated.

In 1995, three major hydrodynamic, lake–wide cruises covering both dry and rainy seasons will be made with the *R/V Tanganyika Explorer.* Water current measurements, CTD profiles, and meteorological surveys will be included. Basic hydrodynamic parameters are measured and wind observations are done also during the fish biology and limnology study cruises.

For the full-sized hydrodynamic model building and testing, and for the description of materials flows in Lake Tanganyika, the support and cooperation of the GEF programme is needed.

2.2 Remote sensing

Aims

To understand the spatial and seasonal distribution of the upwelling phenomena in relation to surface temperatures and possibly to vegetation indices, and to map the pelagic production patterns. These patterns will be related to the hydrodynamic model and subsequent impacts on ecosystem structure.

Activities and results

The analyses of AVHRR NOAA-l1 data were continued at the Department of Applied Physics, University of Kuopio, and the Technical University of Lappeenranta, Finland. The data from NOAA-1l from the latter half of 1994 (i.e. after July) are not available any more because of a mechanical fault in the satellite itself (a new NOAA-14 satellite may become available in 1995). The computer program used has been improved, e.g. by applying the geometrical correction that is required due to the variable angel of the satellite position in relation to the lake and earth curvature. The atmospheric correction has not yet been made, for which local meteorological data will be needed (the atmospheric correction is not needed for temperature scanning).

The data for pictures are obtained now with delays of several weeks, which makes simultaneous collection of ground—truth data impossible. The comparisons have to be made afterwards only, based on existing past data.

The particular properties of Lake Tanganyika waters, with high clarity and Secchi-disc values make the use and interpretation of the vegetation index somewhat dubious, though new future techniques may slightly improve the situation. The phytoplankton component undergoes rapid vertical changes by migration and/or chlorophyll inactivation, and thus diel timing of the image is crucial, with the early hours of the day being the most promising (cf. Salonen and Sarvala 1994a, b).

The surface temperature data obtained appear realistic; they also refer to the high degree of patchiness of water surface properties over the entire lake, as also predicted by the hydrodynamic model. The surface temperature data make an important component in the validation of the hydrodynamic model.

The new planned environmental satellites also open new possibilities for environmental monitoring (in the future, it may also be possible to run a sensor over the lake in an aeroplane). Further details of the results obtained are given in Parkkinen *et al.,* 1994 a, b.

Plans for 1995

Ground-truth data will be collected especially during the forthcoming lake-wide cruises of the research vessel *R/V Tanganyika Explorer.* The data will be related to the development of the hydrological model. The most pertinent data concern surface temperature, but the possible usefulness and availability of the 'vegetation index' data will also be considered.

2.3 Fish and zooplankton biology

Aims

The main aims were towards understanding the stock size variations and basis of production of pelagic fish species, and the horizontal and vertical migrations as well as reproduction biology and recruitment of pelagic fish. The population dynamics and life-histories of the main zooplankton crustaceans and their role in the pelagic production chain are also important components in the calculations towards fish production.

Activities and results in fish biology

Preliminary population analyses are being done to support preliminary stock assessment and studies of population dynamics of two pelagic clupeids *(Limnothrissa miodon* and *Stolothrissa tanganicae)* and the predatory Nile perch species *Lates stappersii* and other *Lates* spp. The sampling and analysing schemes introduced by Aro (1993), modified later by Mannini (1993), included sampling of catches by gear, fishery type and by species, and the analysis of basic population parameters such as length frequencies and reproduction stages. Preliminary results of the fish and fishery biology analyses have been presented by Mannini and Aro (1994).

Based on the weekly sampling of artisanal units (for analysis pooled on monthly basis) and on the monthly sampling of commercial units, the pelagic fish species composition seems currently simplified; for instance, in the Burundi waters *L. stappersii* represent about 30% in the catch (by weight), the two clupeids a little less than 70%, and others (incl. *Lates* spp.) the remaining 2%. In Kalemie, Zaïre, the industrial catch in 1993 was mostly *Lates stappersii* (92%), while the clupeids made only 7% (Mannini and Aro 1994). The CPUE has been declining, at least through the 1980's, especially for the industrial fishery, though the situation probably is better for the artisanal fishery.

The strong presence of both *Stolothrissa* and *Limnothrissa* immature age classes in all catches indicates the northern end of the lake (except off Uvira) apparently serves as a nursery area for the clupeids. Alternatively, the gear used in the

Burundian waters select young fishes in higher amounts than in the middle or southern part of the lake where the adult fishes were relatively more numerous in the catches. The environmental variables and cues controlling or affecting the timing of reproduction of clupeid species are still incompletely known.

The data analysed so far, are clearly insufficient for detailed study of gear-specific catch compositions, trends therein, or gear-selective fishing mortality. According to preliminary analyses, the beach seines and liftnets operated in-shore exploit relatively more of the younger individuals of stocks than the liftnets and purse seiners operated in the open pelagic zones. The size composition in the catches of the latter gear type was more even. The size structures of the catches even at the same or nearby sites seem to vary greatly from month to month, but sampling over a large area during future cruises may resolve this problem.

The clupeid fish otolith samples have been collected and sent to Finland for analyses.

Plans for 1995

Catch analyses will be continued to cover at least a second full year of study. Selectivity studies on various gear will be completed. First estimations of total mortality will be done and the catch curves in various parts of the lake will be provided (Mannini and Aro 1994). Independent estimates of growth rates can be obtained by the analyses of fish otoliths. It will be seen whether the food/stomach contents analyses of fish obtained by commercial catches are useful and reliable enough for study.

Three main hydroacoustic cruises, including integrated trawling and zooplankton studies, will be done in 1995, starting in January. The other two cruises are planned for May–June, and September–October in order to cover the major seasons.

Activities and results in zooplankton studies

Weekly zooplankton sampling was conducted at permanent localities off four field stations in Bujumbura, Kigoma, Kipili and Mpulungu. For the methods, see Kurki (1993), Vuorinen (1993), and Kurki and Vuorinen (1994).

After completing one year SSP, the LTR project has already obtained more zooplankton data, collected in a systematic way covering comprehensively various parts of Lake Tanganyika, than ever before.

The distributions of the two pelagic crustacean groups differ somewhat. The calanoid copepoda occur throughout the lake, while the cyclopoids are more numerous in the north. This also indicates lower zooplankton production in the south than in the north. Temporal variation in individual numbers at any one site seems to be rather modest. The zooplankton abundancies recorded may indicate real differences between the major areas, but may also suggest that the sampling sites do not represent only pelagic areas but contain some sort of littoral effect in the north. The mid-lake area is still poorly documented, but the situation should improve with the future cruises of the *R/V Tanganyika Explorer.*

Seasonal fluctuations in zooplankton densities are due to reproduction cycles of plankton organisms themselves and also to increased fish predation which is followed by recruitment of new year class of clupeids. According to the findings in Bujumbura and Mpulungu, zooplankton reproduction mainly takes place in September –October, whereas in Kigoma the only clear reproduction peak was observed in April. Increased predation by clupeids may have caused a rapid decline in zooplankton abundance in Kigoma in September.

The vertical distribution of zooplankton assemblages revealed what was also observed in primary production (cf. Salonen and Sarvala 1994a, b). Due to photoinhibition of primary production in the uppermost 40 metres during the daytime, and due to plankton organisms' active escape from fish predation, the peak densities of zooplankton were commonly found at 20 and 40 m. In Bujumbura and Kigoma the zooplankton occupied the depths of 0–80 m, whereas in Mpulungu the zooplankton even reached the depth of 220 m.

According to the first analyses of the 24-hrs samples, both the *Tropodiaptomus simplex* adults and copepodites (Copepoda) showed clear diel vertical migration, with maximum densities occurring deeper than 100 m during the daytime, at 20 m at sunset, but again at 100 m by sunrise (in Bujumbura). In other parts of the lake the descending and ascending patterns were of a similar nature but covered greater depth ranges.

Plans for 1995

Considering the patchiness of the lake structure, the weekly sampling procedure for zooplankton has been reconsidered. To cope with the high small-scale variability characteristic of zooplankton abundance, three replicate vertical net hauls (instead of a single haul) have been taken from each sampling area since August 1994. To improve the reliability of zooplankton data, the within-station variance of replicate net hauls should be worked out. In addition, the catching efficiency of the vertical net hauls should be checked against simultaneous Limnos–tube samples representing the same water column.

Zooplankton culture experiments are planned for 1995 (as a consultancy), and determinations of carbon content for the major developmental stages are also required. Then the first estimates of zooplankton biomass and production (= fish food production) can be calculated.

To maintain the ongoing zooplankton SSP, some improvement of Copepoda species identification at every station is required, and more manpower for sampling and analyses particularly in Bujumbura is needed.

In 1995, the studies onboard the R/V *Tanganyika Explorer* on predation-prey relationships between the clupeids and zooplankton will be initiated. Prey selection studies will be included in the routine SSP in the field stations. To study the horizontal and vertical distributions of the zooplankton communities, three lake–wide cruises will be done in connection with trawling and hydroacoustic surveys.

2.4 Genetic structure of pelagic fish

Aims

Analysis of the possible discreteness of pelagic fish stocks and their migrations by methods of analyses of population genetic structures.

Activities and results

Six populations of *L. miodon, S. tanganicae, Lates stappersii, L. mariae, L. augustifrons* and *L. microlepis* were studied by the RAPD (Random Amplified Polymorphic DNA) method to reveal possible differences between populations or ‘stocks’. The maximum sample size per population was thirty individuals.

The *L. miodon* populations were tested on 60 DNA primers. The strains or ‘stocks’ of Malagarasi and Moba share some characters that are missing elsewhere. Also the strains from Chatitu and Nsumbu express some characters not found among the others. It is possible that at least the northern strains are genetically separated from the southern ones. The situation concerning the separateness *S. tanganicae* strains or ‘stocks’ is still open.

A canonical functions analysis revealed consistent differences between each of the clupeid strains or ‘stocks’. The full interpretation of this analysis and its implications are still open.

The DNA-method apparently is reliable in identifying even the fry specimens of the two clupeid species (Kuusipalo 1994a, b)

Plans for 1995

Some additional sampling may be required in 1995, especially connected to the cruises, whereby simultaneous fish samples can be obtained from different parts of the lake.

2.5 Limnology and carbon/energy budget

Aims

In addition to the earlier general aim of describing the basic limnology of Lake Tanganyika, this subcomponent involves the following two particular objectives: (1) to obtain a more reliable estimate for phytoplankton primary production, and (2) to evaluate the importance of Dissolved Organic Matter (DOM) for planktonic food chains and in carbon cycling. The measurements of basic limnological data also indicate, e.g. availability of nutrients to organisms and they may reveal possible physical phenomena that contribute to the formulation of the hydrodynamic model.

Activities and Results

The limnological sampling programme was continued at each field station. It included: (1) weekly or fortnight sampling, (2) intensive sampling during a 24-h cycle, and (3) seasonal sampling at the same site as the intensive sampling, once every three months.

The results of chemical limnological measurements show ranges that are in agreement with earlier published results, but because the measurements now have been conducted at three stations (off Bujumbura/Uvira, Kigoma, Mpulungu) in coordination over several seasons, a new dynamic view over a wide geographical area has been attained.

The stratification (appearing in the upper metalimnion) is sometimes almost absent at the southern end of the lake, during the dry season, although weak stratification can still be observed at the northern end. Thus the southern end seems to function as a major mixing site for lake water.

Initial analysis of the chemical data shows rhythmic variations in their concentrations at different depths, giving indications of two types of internal waves. The periods of 3 days and 26-33 days are in agreement with earlier published records (by Coulter), though now they are validated by using many more parameters.

In general, Lake Tanganyika seems to be of the oligotrophic type in its surface layers but eutrophic in its deeper layers. The water mixing will, at certain times of the year, generate a fast growth of plankton and bacteria, followed by a local surge of upper components of the food web. This may also be related to the high degree of patchiness noted by several authors.

For further results of physical and chemical limnology, see Plisnier (1994). One should note that there is a general dearth of long–term observational series of limnological parameters in any tropical waters, and thus continuation of the chemical limnology programme on Lake Tanganyika should be continued, within the limits of manpower constraints, during 1995 and perhaps even later.

Methods for primary production measurements have been tested under field conditions at Lake Tanganyika (cf. Salonen and Sarvala 1994a, b).

A preliminary experiment in April 1994 revealed, among other things, that in the vertical profiles the maximum fluorescence of chlorophyll occurred deep in the epilimnion, at

40–60 m. Under strong solar radiation the fluorescence in the upper layers dropped rapidly, often below detection limits. Apparently, a good part of the primary production takes place in deeper waters, and there is a strong temporal and vertical variation, connected with photoinhibition. The 1994 experiments suggest that earlier published results for primary production in Lake Tanganyika most probably are underestimates. Further measurements must there–fore cover the whole productive layer. The possible implications of ecosystem patchiness were already referred to in the context of the hydrological model, limnology, and zooplankton sampling.

Plans for 1995

The plan for 1995 includes, partly according to Salonen and Sarvala (1994a), the following components:

* Phytoplankton primary production
* Mineralization of organic matter
* Growth rate measurements of bacteria and protozoa
* Biomass determinations (incl. POC, phytoplankton, bacterioplankton, chlorophyll *a)*
* Dissolved Organic Carbon (DOC)
* Nutrient ratios (N:P)
* Accessory measurements (incl. solar radiation, light penetration, spectral distribution by depth, methane flow, iodine).

Pilot tests of accessory measurements to calculate phytoplankton primary production will still be performed in 1994 combined with lake-wide surveys. The surveys to the areas not covered with the regular SSP at field stations will be undertaken during hydrodynamic studies, i.e. three times a year in major seasons.

2.6 Fishery statistics

Aims

The LTR Project, as the immediate objective, aims at improved, standardized and coordinated fishery statistics data collection systems of the four riparian countries (Coenen, 1994). In particular, it means standardized and coordinated reporting on annual frame and catch assessment surveys. As the medium– and long–run objective, the collected information will be used in formulation of a future fishery management plan and policy for Lake Tanganyika. These results on catch and catch per unit effort relationships will be combined with those of hydroacoustic and experimental trawl surveys and of fish biology studies.

Activities and results

Project activities have included assistance to ongoing surveys in the four countries (organisation assistance, technical assistance, training) and organisation of extra activities (data bank/ documentation center, ground and aerial frame surveys, workshops, standardized reporting, extra data collection, etc.) to collect supplementary information not covered by the ongoing surveys.

Preliminary results indicate that since the mid-sixties, there has been about an 80% increase in total fishing effort in Burundi, while total catches only increased by 50%. Decreased total catches and unit catches for all types of fishing suggest possible local overfishing in Burundian waters.

In other countries, hardly any pronounced trends can be found due to insufficient data or incomplete data processing. Lake–wide annual total catches have increased since the 1950's, and are estimated at 130,000 to 170,000 tonnes during recent years (Mannini, 1994).

The estimated total fish yield of Lake Tanganyika shows, however, increasing long–term trends in both absolute and relative (annual catch per area) terms. The total fishing effort has remained relatively unchanged, although it is very important to note that the composition of the fishing fleets has also changed considerably. The traditional subsistence fishing units whose annual catches were about 3 tonnes have been replaced by (advanced) artisanal and industrial units with annual catches of 14 tonnes per unit.

Logistic and technical assistance, local staff training, and standardized reporting on annual frame surveys and catch surveys all are bound to improve the collection of local and national fisheries statistics in each country; these have been serious constraints for regional fisheries planning. The collection of fisheries statistics should be reinforced and given higher priority also in the management budgets of the four riparian countries.

3. SUMMARY AND THE MAIN FOCUS FOR 1995

Among the subcomponents of the LTR, the building of the hydrodynamic model is now best advanced. Its results already point out novel views concerning the driving forces affecting biological production and of the distribution of upwelling/ downwelling areas and internal seiches and water movement at large. The remote sensing temperature data also reveal the high degree of water surface patchiness and local dynamism, which have numerous implications for the ecosystem structure, the level and control of biological production, and even for the ways the sampling programmes have to be executed.

We may consider it a major and important finding that the main depth of primary production appears to be deeper than previously thought, which will also change the old estimates of the 'upside-down' trophic structure of the Lake Tanganyika ecosystem. The surface layers appear relatively oligotrophic while the deeper layers (40-60 m and down) may be named even 'eutrophic'. This observation may finally 'normalize' the lake's trophic structure, and can give a firmer basis for the final estimation of zooplankton and fish production.

Still, Lake Tanganyika has many special features that have to be taken into account. One apparent reason for its relatively high biological production is its relatively weak stratification, and especially the southern end of the lake serves as a mixing engine. That is, the entire water column (but also noting the high degree of patchiness) seems to contribute to production. How the daily vertical migrations of the ecosystem and/or its components further add to this effect remains to be documented in the next phase of research. We still know little about the role of predator-prey interactions, the microbial loop, and the contribution of the dissolved carbon (including methane from the deeper layers), to name just a few of the remaining open questions.

So far the main research activities have covered the lake areas relatively close to the shore. The future cruises with *R/V Tanganyika Explorer* will make it possible to cover the mid-lake areas and thus study their functional relationship with the near-shore waters. This relationship would be an important element also for the estimate of the fish production and fishery potential for the entire lake. (The mid-parts of the lake are not currently being fished.) The activities so far have not included echo–sounding or stock assessment, which can be only executed onboard the research vessel.

The current building blocks for the lake-wide fisheries management scheme are mostly based on the existing fisheries statistics. It is only in the later phases of the project that the biological inputs, with some safety, can be introduced and discussed in relation to fisheries management. The contributions of the LTR project also involve the building and recommendations concerning the administrative structures that are needed for regional fisheries management; this work has involved research and surveys concerning the fisheries themselves and fisheries administration in the four riparian countries, not to forget the strong training component.

The research conducted by the LTR finally aims at producing such fisheries-related and biological inputs and monitoring parameters that could be used as the signals and indicators that direct future fisheries management planning and the conservation of this important aquatic resource. The project's lifetime admittedly is too short to cover possible long-term (i.e. several years') cycles in the pelagic fish stocks, and the reasons for them, which creates a certain risk for future fishery assessment and management.

As a summary, the focus for the research in 1995 will concentrate in the following general topics and actions:

1. Hydrodynamic modelling

* Development of the 3-D hydrodynamic model
* Calibration of the model with field data

2. Nutrient cycling

* Limnological monitoring
* Hydrodynamic modelling
* Remote sensing

3. Temporal dynamics and horizontal distribution of the pelagic production

* Limnology: chlorophyll, primary production, DOC, nutrient ratios (especially C:N:P) in plankton+fish
* Zooplankton community structure and production
* Remote sensing

4. Fish production assessment

* Food—web analyses
* Predatory—prey interactions
* Vertical migrations in the fish-zooplankton community
* Resource allocation in the fish community: bioenergetic modelling of food consumption

5. Fish population dynamics and stock assessment

* Reproduction cycles and recruitment
* Catch size and composition
* Population analyses: growth, age structure, mortality
* Stock assessment: catch curves and yield—recruit analyses

6. Fisheries

* Regional distribution of fishing activities
* Catch composition and fluctuations
* Gear type classification
* Catch per unit effort (CPUE) analyses

7. Fisheries management

* Harmonization of fisheries statistics
* Initiation of management policy

4. REFERENCES

Aro, E., Guidelines for sampling pelagic fish catches on
1993 Lake Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN-FM/04 (En): 25p.**

Coenen, E.J., Presentation of SSP Results: Fisheries
1994 Statistics. Third Joint Meeting of the LTR's Coordination and International Committees, Kigoma (Tanzania), 28-30.11.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **LTR/94/3.7**

Coenen, E.J. & G. Hanek. Report on LTR's Second Scientific
1993 Sampling Programme Assessment Meeting, Kigoma, 11 12.4.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN—Td/17 (En): 20 p.**

Huttula, T., P. Kotilainen, A, Peltonen & V. Podsetchine.
1994 Presentation of SSP Results: Hydrology. Third Joint Meeting of the LTR's Coordination and International Committees, Kigoma (Tanzania), 28-30.11.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **LTR/94/3.1**

Kurki, H., Field Notes on Zooplankton. FAO/FINNIDA Research
1993 for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN-FM/09 (En): 26p.**

Kurki, H. & Vuorinen, I. Presentation of SSP Results:
1994 Zooplankton Biology. Third Joint Meeting of the LTR's Coordination and International Committees, Kigoma (Tanzania), 28-30.11.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **LTR/94/3.3**

Kuusipalo, L. Assessing Genetic Structure of Pelagic Fish
1994a Populations of Lake Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN-FM/23 (En): 13p.**

Kuusipalo, L. Presentation of SSP Results: Fish Genetics.
1994b Third Joint Meeting of the LTR's Coordination and International Committees, Kigoma (Tanzania), 28-30.11.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **LTR/94/3.6**

Mannini, P. & E. Aro. Presentation of SSP Results: Fish
1994 Biology. Third Joint Meeting of the LTR's Coordination and International Committees, Kigoma (Tanzania), 28-30.11.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **LTR/94/3.4**

Parkkinen J., V. Tuomainen, L. Patomaki, O.V. Lindqvist,
1994a **& H. Mölsä.** Designing Satellite Image Analysis for the Lake Tanganyika Research Project. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/21 (En): 28p.

Parkkinen 3., V. Tuomainen, L. Patomaki, O,V. Lindqvist,
1994b **& H. Mölsä.** Presentation of SSP Results: Remote Sensing. Third Joint Meeting of the LTR's Coordination and International Committees, Kigoma (Tanzania), 28—30.11.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
LTR/94/3 .5

Plisnier, P.-D., Presentation of SSP results: Limnology.
1994 Third Joint Meeting of the LTR's Coordination and International Committees, Kigoma (Tanzania), 28-30.11. 1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
LTR/94/3.2a

Podsetchine, V. & T. Huttula. Hydrological modelling:
1994 Activity Report for the Period of 0l.0l.-30.04.94. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD (En).

Salonen, K. & J. Sarvala. Sources of Energy for Secondary
1994a Production in Lake Tanganyika: Objectives, Approaches and Initial Experiences. Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN-TD/26 (En) (In preparation).

Salonen, K. & J. Sarvala. Presentation of SSP Results:
1994b Carbon-Energy Budget. Third Joint Meeting of the LTR's Coordination and International Committees, Kigoma (Tanzania), 28-30.11.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
LTR/94/3.2b

Vuorinen, I., Sampling and counting zooplankton on Lake
1993 Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN—FM/06 (En): 19p.

THIRD JOINT MEETING
OF THE LTR'S
COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

KIGOMA (TANZANIA), 28—30.11.1994

MANAGEMENT OF LAKE TANGANYIKA'S

FISHERIES RESOURCES

by G. Hanek

1. LAKE TANGANYIKA CHARACTERISTICS AND FISHERIES UPDATE

1. Lake Tanganyika is situated at an altitude of 773 m, in the north-south direction, between the latitudes of 3°20' and 8°48' S and the longitudes of 29°03' to 31°12' E. The lake is 673 km long from north to south and has a maximum width of 48 km. With a maximum depth of 1,470 m, Lake Tanganyika is the second deepest lake in the world. Its average depth is 570 in and the lake volume is estimated to be some 18,800 km^3. The lake is shared by four riparian States *i.e.* Burundi, Tanzania, Zaïre and Zambia. The total length of its shoreline was estimated to be about 1,850 km, shared as follows: Burundi: 159 km or 9%; Tanzania: 669 km or 36%; Zaïre: 795 km or 43%; and Zambia: 215 km or 13% of the total (Hanek et al., 1993). The type of shoreline substrate has been classified as follows: 31 % of sand, 21% of rock/sand, 43% of rock and 5% of marsh (Coenen *et al*., 1993).

2. Lake Tanganyika harbours the most diverse cichlid and non—cichlid fauna of the large African lakes. It is composed of remarkable and genetically diverse benthic and pelagic fish communities. The benthic community consists of almost 300 fish species, with over two thirds of them being endemic. The pelagic fish community, on which the fishery of Lake Tanganyika is principally based, is composed of six endemic, non—cichlid species. These are the two schooling clupeids, *Limnothrissa miodon* (Boulenger, 1906) and *Stolothrissa tanganicae* Regan,

1917, and their major predators, *i.e.* four members of the genus *Lates* (Centropomidae): *L. stappersii, L. angustifrons, L. mariae,* and *L. microlepis.*

3. The potential yield of Lake Tanganyika, whose surface is 32,900 km^2 (Welcomme, 1972; Vanden Bossche and Bernacsek, 1990), was estimated anywhere between 295,000 to 460,000 tonnes, assuming a potential yield estimate at 90 kg/ha/year (Mikkola and Lindqvist, 1989) and/or at 140 kg/ha/year (Coulter, 1981).

4. Lake Tanganyika fisheries have been described before. Consequently, only a brief summary of its characteristics and an overall update are presented here in order to facilitate a better comprehension of its present status.

5. Most fishing is done at night as virtually all fishing methods (purse seines, lift nets, beach seines, scoop nets, etc.) rely on clupeids being attracted to fishing lamps. This is the reason why fishing activities practically cease every month during full moon. Fishing activities are also adversely affected by strong winds and/or rain which diminish light intensity and thus the fish gear effectiveness.

6. There are three recognizable types of fisheries on Lake Tanganyika i.e. traditional, artisanal and industrial.

7. The latter started in 1954, when a number of mainly Greek nationals introduced the purse seine net. A typical industrial fishing unit consists of a 16 to 20 m long steel purse seiner, a purse seine net which is carried by a smaller steel boat, 5 lampboats and a crew of 30 to 40 fishermen. A number of these industrial fishing units was established around the lake over the years. Presently, there are 10 semi–active units in Burundi, 3 in Kigoma, 16 in Mpulungu, 4 in Moba, and 17 in Kalemie. The number of these units is decreasing in Burundi where 23 units were active in 1976 (Bellemans, 1991). It remains almost constant in the other countries, although recently a number of Kalemie based units moved to Zambia.

8. The artisanal fishery is carried out in the northern portion of the lake by mainly catamarans and to some degree trimarans, although the latter disappeared totally from Burundi (Bellemans, 1991). A typical fishing unit catamaran consists of two (three for trimarans) mainly wooden plank hulls, with an average of 5–6 lamps/unit, lift net, and an average of 4.7 fishermen/catamaran.

Since the introduction of these units in the late 1950's, a sustained growth of these units was registered: (1) in the period from 1962 to 1972 an average of some 3.3 catamarans entered the fisheries on a monthly basis; (2) from 1972 to 1978 the growth was even more intensive when almost 11 catamaran units entered every month; and (3) over the last 12 years an average of 0.4 units entered monthly. The efficiency of the fleet has increased through: (a) the introduction of larger nets; (b) the use of larger canoes; (c) an increase of the light intensity; (d) their motorization; and (e) through the introduction of 'Apollo' lift-nets whose fishing power is nearly equivalent to an industrial fishing unit (Bellemans, 1991). There were respectively 604 and 67 active catamarans and appolos in Burundi in 1992 (Coenen, 1994), 739 of these units in Kigoma and Rukwa Regions of Tanzania (Chakraborty *et al.,* 1992) and some 45 catamarans in Uvira and Fizi zones, Zaïre (Maes *et al*., 1991). There are virtually no catamarans in the southern portion of the lake (e.g. 5 in Zambia in 1994; Mwape, 1994). There, the large majority of fishing units are beach seine units operating at night in association with lights, targeting the clupeids (Hoekstra and Lupikisha, 1992).

9. The <u>traditional fisheries sector</u> is basically a subsistence fishing activity. A wide variety of fishing gear is used (gill nets, hook and line, scoopnet, longlines, traps, mosquito nets, etc.); while these fishing techniques are generally inefficient, this sector absorbs a large number of people around the lake.

10. The <u>fishing pressure</u> was estimated, lakewide, by recording the density of fishing craft (Hanek *et al.,* 1993). A total of 13,976 canoes was counted. The highest density of canoe per kilometer of shoreline was recorded in Burundi (11.3 canoes/km or a total of 1,802 canoes), followed by Zaïre (10.3 canoes/km or 7,570 canoes), Tanzania (6.0 canoes/km or 3,839 canoes) and Zambia (3.6 canoes/km or 765 canoes).

11. During the same study (Hanek *et al.,* 1993) a total of 459 <u>fish landing sites</u> was recorded as follows: 34 in Burundi, 127 in Tanzania, 257 in Zaïre and 41 in Zambia. Most fish landing sites around the lake (192 or 41.8%) were classified into Category II i.e. having between 11 and 30 canoes each. Further, some 147 or one third of all fish landing sites around Lake Tanganyika were classified into Category I i.e. having between 1 and 10 canoes each. Largest percentage of largest fish landing sites *i.e.* those with more than 81 canoes each was recorded for Burundi where 8 such sites are located.

12. The <u>density of fish landing sites</u> per 10 km of shoreline's length was also calculated. The average density of landing sites for the entire Lake Tanganyika was 2.5 fish landing sites per 10

km of shoreline or 1 landing site each 4 km of shoreline. By country, the density per 10 km was as follows: 2.1 in Burundi, 1.9 in Tanzania, 3.2 in Zaïre and 1.9 in Zambia (Hanek *et al.,* 1993)

13. The total fishing effort is considerable. According to the Frame Survey (FS) results of October 1992 (Coenen, 1994), the fishing fleet on Lake Tanganyika in Burundi was composed of 13 purse seiners, 671 liftnet units (604 catamarans and 67 apollo units) and 298 traditional fishing units. In addition, there were 36 additional purse seiners active as follows: 3 in Tanzania, 16 in Zambia and 17 in Zaïre. Furthermore, the results of the first ever aerial frame survey (Hanek *et al.,* 1993) indicate the number of canoes for the three other riparian states as follows: 3,839 for Tanzania, 765 for Zambia and 7,570 for Zaïre.

14. A major decline of the catch per unit effort (CPUE) was recorded over the last ten years for the industrial as well as the traditional fisheries for Burundi (Coenen and Nikomeze, 1994). For example, the average CPUE/night for the industrial fishery in Burundi decreased from 1173 kg/night/unit in 1983 to 150 kg/night/unit in 1993, making it hardly profitable. On the other hand, the artisanal liftnet fishery, due to the use of bigger nets, better fishing lamps and the choice of more productive fishing grounds in the south, manages to maintain or even increase its CPUE at a profitable level. For example, the CPUE for 'Apollos' stood at 300 kg/night/unit in 1993 (Coenen and Nikomeze, 1994)

15. The fish species composition and its fluctuation was also determined. In 1993, in Burundi, the Clupeids accounted for 67%, *Lates stappersii* for 31.6%, other *Lates* spp. for 0.2%, and others for 1.2% of the total catch. Clupeids are generally the most abundant species, although monthly fluctuations in species composition exist, especially when they are compared with the other dominant species, *L. stappersii.* For example, in 1992, *L. stappersii* was more abundant than the Clupeids in Burundi during the periods February-April and September-October. On the other hand, the Clupeids represented almost 100% of the total catch during the period November—December (Coenen and Nikomeze, 1994)

16. The total overall fish catch for Lake Tanganyika for 1992 was estimated to amount to 167,000 metric tonnes, shared as

follows: Burundi: 24,000 tonnes, Tanzania: 80,000 tonnes, Zaïre: 50,000 tonnes and Zambia: 13,000 tonnes (Coenen, 1994).

17. The value of the catch has been determined only for Burundi and Tanzania (Coenen and Nikomeze, 1994; Tanzania Annual Report Fisheries Division, 1992). By extrapolation, it is estimated that the value of the catch of Lake Tanganyika was in the region of US$ 26 million in 1992 (Coenen, 1994).

18. Social and economic importance of Lake Tanganyika fisheries is considerable. Over 40,000 fishermen as well as several hundred thousand persons are involved in the fisheries related activities *i.e.* fish processing and marketing (Coenen, 1994). Consequently, if the dependents of these people are included, one could state that the fisheries of Lake Tanganyika supports well over one million people.

19. Considerable differences exist in the level of fisheries infrastructure around the lake. There is an extensive and costly infrastructure (cold stores, processing plants, refrigerated trucks, etc.) in Mpulungu, Zambia and to some extent in Kalemie, Zaïre. No such facilities are available elsewhere, including the large cities of Bujumbura and Kigoma. While a detailed inventory of fisheries infrastructures of Lake Tanganyika is regularly made (Hanek, 1993 a,b), its overall value still has to be determined.

20. Fish processing is not well developed around the lake. Clupeids are either sold fresh or sundried. Improved methods to preserve them in brine and dry them on racks were developed but are almost never used. Consequently, only in Mpulungu and to some degree in Kalemie the processing, cleaning, brining, freezing and sometimes smoking of particularly *L. stappersii* takes place. Recently, canning of clupeids as well as of *L. stappersii* was developed in Zambia.

21. Fish marketing of catches in excess of local needs is difficult and complex. With the exception of Burundi and the Uvira and Fizi regions of Zaïre, most roads are tangential to the lake. Furthermore, the shores are steep and few roads link the populations around the edges of the lake. This particularly applies to the extensive shores of Zaïre and Tanzania. Clupeids are thus traded along the coast, using ‘water–taxis’ or particularly *M/V Liemba* and *M/V Mwongozo* which ply regularly to and from Mpulungu and Bujumbura. Major outlets for dry fish are: the ‘Copperbelt’ complex of large towns in Zambia, the large Zairian cities of Lumumbashi, Bukavu and Goma, and Rwanda.

2. MANAGEMENT OF LAKE'S FISHERIES RESOURCES: PRESENT STATUS

22. Over the years, the four riparian States have introduced their own regulations aimed at controlling either the quantitative or qualitative dimensions of fishing effort. These, however, have never been introduced in the 'lake—wide' context and, due to poor design and very limited enforcement capabilities, the effectiveness of those which were introduced is quite insignificant. The efforts made to date to manage the Lake's fisheries resources are now detailed together with a summary of areas where lakewide harmonization is possible and/or desirable.

23. For a long time now, it is generally accepted by the authorities of each riparian State that, due to the unique characteristics of the Lake's resources (the most important fish species are all migratory), the only sensible approach must be 'regional' in nature. Regional cooperation among riparian States exists in the context of regional, intergovernmental organizations such as SADC, PTA and CEPGL, as well as in the context of joint bilateral commissions. However, these institutions are generally concerned with more macro—economic and political aspects and are seldom geared to act as coordinating mechanisms for specific fisheries management activities (Gréboval, 1990).

24. This void was dealt with by the Third Meeting of the Committee for Inland Fisheries of Africa (CIFA)[1] which consequently established, in 1977, the Sub-Committee for Lake Tanganyika; its main objective was to formulate a regional research project. The overall purpose of the regional project was given as the coordination of fisheries research and the promotion of international collaboration in the management of the shared resources of Lake Tanganyika as a means to stimulate fishery development. The Sub-Committee for Lake Tanganyika's First Session was held in Lusaka, Zambia in 1978.

25. The concerns related to the harmonization of fisheries legislation were voiced during the 3rd Session of CIFA's Sub-Committee for Lake Tanganyika[2] in 1985. At that time, the Sub-Committee acknowledged the priority need to harmonize fisheries legislation and development policy. While a detailed compendium of fisheries legislation in each riparian state was prepared (FAO, 1989), no real progress has been made since. The slowness

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[1] Report of the third meeting of the Committee for Inland Fisheries of Africa, FID/R 210, recommendation 77/2.

of the process indicates that, despite the common interests involved, there are certain limiting factors that cannot be ignored (Bonnucci, 1990). There are three forms of obstacles to legislative harmonization: (i) legal: while Tanzania and Zambia possess an Anglo–Saxon legal framework, Burundi and Zaïre operate within the Roman civil law system; (ii) technical: the lack of biological knowledge on the resource and fisheries of the Lake; differences in fishing practices and fisheries development in the four riparian States; and (iii): political: Lake Tanganyika is not only a fishing ground but also a border and a place of communication and trade. It is difficult, therefore, for any related agreement not to be wide–reaching (Bonnucci, 1990).

26. The following sections provide examples of different approaches and differences to/in the management of Lake Tanganyika fisheries by different riparian States and thus clearly show the desirability for harmonization of their approach.

27. There were several efforts to harmonize the collection and analysis of fisheries statistical data. Unfortunately, no legislation currently in force prescribes particular procedures for the establishment of statistical data. In practice, each State employs its own method which makes any comparison impossible and undermines the credibility of the data obtained in spite of the fact that ‘the introduction of the principle of integration in the national fisheries statistical systems so as to ensure that the produced statistics are comparable at various levels’ and other recommendations were proposed by the four riparian States during the Workshop on Fishery Statistics for Lake Tanganyika (FAO, 1984). Further, the Fourth Session of CIFA Sub–Committee for Lake Tanganyika[3] examined this issue and recommended that: (i) a study be conducted on the possibility of proposing alternate, more cost effective, methods of statistical collection; and (ii) the regional research project for Lake Tanganyika take the lead in coordinating any necessary action to standardize the collection, compilation and analysis of statistical data.

28. In addition, the Fourth Session of the Sub-Committee[4] also discussed a proposal of the delegation of Burundi dealing with the conditions of access to the fisheries on Lake Tanganyika. As

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[2] Report of the third session of the Sub-Committee for Lake Tanganyika, FIPL/R355, para 6.

[3] Report of the fourth session of the Sub-Committee for Lake Tanganyika, FIPL/R403, para 13.

[4] Report of the fourth session of the Sub-Committee for Lake Tanganyika, FIPL/R403, para 33.

with the other recommendations, no concrete action was ever taken. Consequently, it could be stated that, despite the above proposal, together with a host of others, no concrete action/s was/were ever taken and all hopes were placed on putting in place the regional research project.

29. There is a great diversity among riparian States with regard to fishing categories. Burundi classifies its fisheries as industrial, artisanal and traditional. Zaïre recognizes recreational and individual fishing, taking into account the type of craft and gear used. There is no comparable classification in Tanzania nor Zambia, although the fee exacted in Tanzania depends on the type of craft employed.

30. Mainly due to the differences outlined above, there exists a considerable disparity in license fees, particularly for industrial fisheries.

31. Considerable disparities are noted in the area of conservation measures as well. For example, concerning the minimum mesh size and prohibited gear: (i) in Burundi and Zaïre fishing is prohibited with mesh sizes inferior to 4 mm and the use of beach seines is prohibited; (ii) in Zambia a minimum mesh size of 120 mm for monofilament nets is set and 10 mm for all other types of nets and the use of beach seine is authorized; and (iii) in Tanzania the use of monofilament nets is prohibited in all national inland waters (Bonnucci, 1990).

32. Access of a State’s vessels to waters under the jurisdiction of other States is similarly unharmonized. At present, three of the four States have no provisions regarding access of foreign vessels to their waters. The exception is Tanzania which strictly prohibits access to foreign fishing vessels unless provided for by law or by international agreement.

33. Similarly, and although all national legislations allow research operations in their waters, these are, nevertheless, subject to prior authorizations (Bonnucci, 1990).

34. Lastly, and while there is considerable convergence in the legal provisions of each riparian State considering the introduction of non–indigenous species, several clarifications are required *i.e.* the definition of the term ‘indigenous species’, etc. (Bonnucci, 1990).

3. TOWARDS MANAGEMENT OF LAKE TANGANYIKA FISHERIES RESOURCES

35. As apparent from the above and even before even attempting to propose what is so obviously needed *i.e.* a Lake Tanganyika Fisheries Management Plan, it is essential to ensure that management objectives and strategy are clearly defined. The objectives must be clearly specified and constraints recognized. Generally, a fisheries plan should be a relatively simple document, containing no more details than are required for the sort of management and development decisions that are anticipated for the fishery (Christy, 1990).

36. A basic plan should include the following: (i) a description of the fishery including estimates of the resource and of fishing effort; (ii) a statement of management objectives for the fishery, particularly whether fishing effort should be increased or decreased; (iii) a description of the management and licensing measures required to achieve the objectives; and (iv) a statement of needs *i.e.* specify needs for further information as well as the means of obtaining them (Christy, 1990).

37. In addition, it is essential that each riparian State has sufficient confidence in its knowledge of the shared resources of Lake Tanganyika so as to be able to assess the effects of sharing them as there is no incentive for cooperation in management unless there is an information system that guarantees each riparian State its proper share of the fishery benefits (Kapetsky, pers. comm.)

38. The process of an actual fisheries planning must involve the fishing and general community as much as possible in order to both: (i) benefit from knowledge and perception of people directly concerned with the fishery; and (ii) ensure fishermen eventual acceptance of the decisions that will eventually flow from the plan (Christy, 1990).

39. In addition, appropriate institutional requirements, legislative framework, information systems, research requirements and an eventual management unit all have to be specified and/or developed in order to ensure putting such a plan in place.

40. Consequently, the role of LTR in achieving most prerequisites for the formulation of such a plan is essential as it is, in fact, its *raison d'être.*

41. The need for a lakewide fisheries research project became clear after several fisheries research and development projects

had shown that independent, uncoordinated research programmes on the lake cannot be expected to provide the required knowledge and data. Consequently, and while first discussed in 1966, the first project document for such a project was proposed during the First Session of CIFA's Sub-Committee for Lake Tanganyika[5] in 1978. After numerous modifications, the first regional fisheries research project, entitled 'Research for the Management of the Fisheries on Lake Tanganyika', now known as LTR, became fully operational in January 1992.

42. Fundamentally, LTR is to provide the information required to formulate a fisheries management plan. LTR's Project Document calls for execution of its five year long programme in two phases *i.e.* (i) 18 months long preparatory phase, and (ii) 3.5 years long execution phase.

43. LTR's preparatory phase was successfully completed; briefly, all required infrastructure was put in place, local and international staff were both recruited and trained, equipment ordered and LTR's Coordination and International Scientific Committees established.

44. LTR execution phase consists of coordination and execution of a complex multi-disciplinary research programme (=SSP); its design was fully tested and subsequently modified/refined accordingly. Its demanding execution started as scheduled, In July 1993. It has six major subcomponents as follows:

(i) hydrological modelling: studies the upwelling and downwelling phenomena of the nutrient rich waters and their effects on the pelagic biological production; it also includes water current measurements and the collection of meteorological data;

(ii) remote sensing: studies the spatial and seasonal distribution of the upwelling phenomena in relation to surface water temperature;

(iii) fish and zooplankton biology: numerous parameters are collected: fish length frequency distribution, maturity stages and numerous other classic parameters of the 6 target pelagic species, weekly and intensive zooplankton sampling down to 300 m, etc;

(iv) genetic structure of pelagic fish: to determine possible genetic discreteness of pelagic fish stocks;

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[5]Report of the first session of the Sub-Committee for Lake Tanganyika, CIFA/80/5, paras 6-9.

(v) limnology and carbon/energy budget: numerous parameters are measured at regular intervals down to 300 m; and

(vi) fisheries statistics: are collected and analyzed, and annual Catch Assessment Surveys and Frame Surveys reporting standardized.

45. The above outlined activities will be complemented by a hydroacoustic studies and integrated sampling surveys for the other subcomponents which will start immediately after the commissioning of *R/V Tanganyika Explorer* is completed *i.e.* in January 1995. A series of lake–wide hydroacoustic cruises will be carried out in order to estimate the biomass of the different target fish species. The latest hydroacoustic equipment has been already installed on board of *R/V Tanganyika Explorer.* Similarly, the mid–water pelagic trawl was also received and the training of the crew is to start shortly.

46. Regular sampling and data entry/analysis takes place, simultaneously, at 3 main LTR stations in Bujumbura (Burundi), Kigoma (Tanzania) and Mpulungu (Zambia). Partial sampling is also done at 6 LTR sub–stations as follows: in Karonda (Burundi), Kipili (Tanzania), Nsumbu (Zambia) and in Uvira, Kalemie and Moba (all in Zaïre)

47. Sampling frequency is the following: (i) regular weekly sampling is carried out for hydrodynamics, limnology, zooplankton, fisheries biology and statistics; (ii) intensive sampling (=24 hours cycle) takes place every 6 weeks for limnology and zooplankton; and (iii) seasonal sampling is carried out for limnology and fish genetics; and (iv) regular surveys are organized regarding fisheries statistics.

48. Considerable inputs are required to execute our SSP as more than 120 persons are involved in data collection, analysis and reporting.

49. The amount of data collected by LTR automatic meteorological and hydrological instruments and by LTR staff is considerable; over 4 megabytes of data/information are received every month. Consequently, the management of LTR’s data banks is a complex task.

50. The analysis of the data collected during the first 12 months of SSP is now being carried out at all LTR stations around the lake as well as in several Finnish Universities and Scientific Institutes. Detailed technical presentations will be

given to the members of LTR Coordination and International Scientific Committees during the 3rd Joint Meeting of LTR Committees which will be held in Kigoma, Tanzania from 28 to 30 November 1994.

4. CONCLUSIONS

51. Given the above, it should be apparent that LTR already has a great deal of data as well as a good understanding of the Lake Tanganyika fisheries. In fact, LTR should be in position to propose an interim fisheries management plan proposal soon and a comprehensive one on schedule i.e. after completing its execution phase at the end of 1996, if indeed allowed to execute its SSP fully and providing its existing budgetary constraints are resolved soon.

52. It would also seem that numerous actions can be taken even now. For example, it would seem logical, that particularly the disparities detailed in paragraph 31 above *i.e.* standardization of the prohibitions regarding fishing gear could be dealt with by the authorities of the four riparian States under their existing powers without delay. Further, already published data (Coenen and Nikomeze, 1994) clearly indicate that further entry of industrial fishing units is unwise, particularly in Zambia. It is also evident that particularly the southern portions of both Tanzania and Zaïre territorial waters of Lake Tanganyika can sustain additional fishing effort providing that appropriate infrastructures are put in place followed by corresponding fisheries development of their respective artisanal fisheries.

53. It is also clear and in fact indispensable to strengthen the role of members of both LTR Committees. Particularly those representing the four concerned States must be involved more closely. Resultingly, it would seem desirable to increase the frequency of both LTR Committees meetings, particularly during 1995 and 1996, so that they can take active part in the formulation of a fisheries management plan, particularly in expressing the views of their respective Governments.

54. It must be underlined as well that while LTR will provide considerable biological information regarding Lake Tanganyika's pelagic fisheries resource and, as stated before, propose a comprehensive fisheries management plan, it is clearly outside LTR's scope to resolve all problems.

55. The role of other projects, particularly that of GEF project 'Pollution Control and Other Measures to Protect Biodiversity of Lake Tanganyika' should not be neglected. It would appear that this particular project should be starting

shortly. As there is a number of common interests it is recommended that GEF/N.Y. is invited to participate, as observer, in the 3rd Joint Meeting of LTR Committees.

56. As detailed in paragraphs 35, 36, 37 and 38 above, the implementation of a fisheries management plan will demand a number of complementary measures ranging from proposing the required institutional and legal framework to designing the eventual management entity, etc. They will all compel additional financial commitments and resources and all are clearly outside of LTR's Terms of Reference.

57. It should be noted that during the most recent Session of CIFA's Sub-Committee for Lake Tanganyika[6], held in 1993 in Lusaka, the Sub–Committee examined current problems of fishery development and management, and noted that the major constraint was the lack of a permanent mechanism and institution for fisheries management on the lake. It subsequently recommended that the riparian States make concerted efforts to establish the Lake Tanganyika Fisheries Commission (LTFC) with a mandate to undertake research programmes, harmonize and implement fishery management measures, as well as to coordinate fisheries regulations.

58. Many valuable lessons were learned during the establishment of the Lake Victoria Fisheries Organization (LVFO). As similar actions will be required during the establishment of the LTFC, it is recommended that the LTR Committee members representing the United Republic of Tanzania be given the prominent role due to their experience in establishing the LVFO.

59. It must be emphasized once again that no management plan can succeed without the active participation of the fishing community. Provisions should be made, therefore, to associate its representatives in the process at the earliest possible opportunity.

60. Lastly, and in view of the above, it is now proposed that: (i) members of both LTR Committees consider this document as a baseline document to be discussed during the forthcoming 3rd Joint Meeting of LTR Committees; (ii) at that time, they will be requested to name one person from each participating State who will be responsible for the coordination and subsequent preparation of each State's statement which should clearly specify each State's priorities, preferences and positions, including the views of the representatives of their fishing

[6] Report of the sixth session of the Sub-Committee for Lake Tanganyika, FIPL/RSO1, para 15.

communities, regarding the format and scope of the Lake Tanganyika Fisheries Management Plan; (iii) they, together with two representatives of the fishing communities (one for the artisanal fisheries community and the other for the traditional fisheries) for each State will be invited to take part in LTR's Workshop on Fisheries Management of Lake Tanganyika now scheduled for June 1995; (iv) it follows that the results of this Workshop *i.e.* draft Fisheries Management Plan for Lake Tanganyika will be presented to the 4th Joint Meeting of LTR Committees.

5. REFERENCES

Bellemans, M.S., Historique des pêcheries artisanales et
1991 coutumières au Burundi de 1952 ~ 1991.
PNUD/FAO BDI/90/002, Raport de terrain No. 5, 54 p.

Bonnucci, N., The outlook for the harmonization of Lake
1990 Tanganyika fisheries legislation. In: Gréboval, D. (ed.), Principles of Fisheries Management and Legislation of Relevance to the Great Lakes of East Africa: Introduction and Case Studies. UNDP/FAO Regional Project for Inland Fisheries Planning (IFIP), **RAF/87/099—TD/05/90 (En) : 41 p.**

Coenen, E.J., Frame Survey results for Lake Tanganyika, Burundi
1994 (28-31.10.1992) and comparison with past surveys. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN—TD/18 (En): 26 p.

Coenen, E.J., G. Hanek and P. Kotilainen, Shoreline
1993 classification of Lake Tanganyika based on the results of an aerial frame survey (29.09.—03.l0.1992). FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN—TD/l0 (En): 11 p.

Coenen, E.J. and E. Nikomeze, Lake Tanganyika, Burundi, results
1994 of the 1992-1993 Catch Assessment Surveys. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika.
GCP/RAF/271/FIN—TD/24 (En): 27 p.

Coulter, G.W., Biomass, production and potential yield of the
1981 Lake Tanganyika pelagic fish community. **Trans. Am. Fish. Soc., 110:325—35.**

Chakraborty, D., E.O. Lyimo and N.C. Shila, Fisheries
1992 inventories in Lake Tanganyika. **URT/87/016, Field Document No. 10, 28 p.**

Christy, L.C., Principles of fisheries legislation. In: **1990** Gréboval, D. (ed.), Principles of Fisheries Management and Legislation of Relevance to the Great Lakes of East Africa: Introduction and Case Studies. UNDP/FAO Regional Project for Inland Fisheries Planning (IFIP), **RAF/87/099—TD/05/90 (En) : 41 p.**

FAO, Compendium of Fisheries Legislation in Lake Tanganyika. FAO
1989 Fisheries Management and Law Advisory Programme, **FL/IOR/87/20 Rev. 1, 128 p.**

Gréboval, D. (ed.), Principles of Fisheries Management and
1990 Legislation of Relevance to the Great Lakes of East Africa: Introduction and Case Studies. UNDP/FAO Regional Project for Inland Fisheries Planning (IFIP), **RAF/87/099—TD/05/90 (En) : 41 p.**

Hanek, G. (ed.), 1992 Lake Tanganyika Fisheries Directory.
1993 FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN—TD/08 (En & Fr): 63 p.**

Hanek, G. (ed.), 1993 Lake Tanganyika Fisheries Directory/
1993 Repertoire des pêches du lac Tanganyika 1993. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN—TD/14 (En & Fr): 69 p.**

Hanek, G., E.J. Coenen and P. Kotilainen, Aerial frame survey of
1993 Lake Tanganyika Fisheries. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. **GCP/RAF/271/FIN—TD/09 (En): 29 p.**

Hoekstra, T.M. and J. Lupikisha, The artisanal capture fisheries
1992 of Lake Tanganyika, Zambia: major socioeconomic characteristics of its fishermen and their fishing units. UNDP/FAO Regional Project for Inland Fisheries Planning (IFIP) , **RAF/87/099—TD/41/92 (En) : 93 p.**

Maes, M., K. Leendertse et Mambona Wa Bazolana, Recensement des
1991 unités de pêche zaïroise dans la partie nord du lac Tanganyika. Projet Regional PNUD/FAO pour la Planification des Pêches Continentales (PPEC). **RAF/87/099—WP/09/91 (Fr) : 61 p.**

Mikkola, H. and O.V. Lindqvist, Report on a Project Mobilization
1989 Mission. Preparatory phase GCP/RAF/271/FIN, FAO, Rome, July 1989: 104 p.

Mwape, L.M., Frame survey Lake Tanganyika (Zambian waters),
1994 6.06.-9.07.1994. FAO/FINNIDA Research for the Management of the Fisheries on Lake Tanganyika. Draft Report, October 1994: 10 p.

Vanden Bossche, J-P. and G.M. Bernacsek, Source book for the
1990 inland fishery resources of Africa. **Vol. 1. CIFA Tech. Pap. (18/l):411 p.**

Welcomme, R.L., The inland waters of Africa. **CIFA Tech.Pap.**
1972 **(l):117 p.**

RESEARCH FOR THE MANAGEMENT OF THE FISHERIES ON LAKE TANGANYIKA

GCP/RAF/271/FIN

Annex 1

THIRD JOINT MEETING OF THE LTRS COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

Kigoma (Tanzania), 28.30.11.1994

LIST OF PARTICIPANTS

BURUNDI

Ir. R. KANYARU	Directeur	Ministère de l'Agriculture et de l'Elevage Département de la Pêche et de la Pisciculture B.P. 1850 Bujumbura, BURUNDI
Dr. B. NYAKAGENI	Conseiller	Ministère de l'Agriculture et de l'Elevage Département de la Pêche et de la Pisciculture B.P. 1850 Bujumbura, BURUNDI

TANZANIA

Mr. T.W. MAEMBE	Director	Ministry of Tourism, Natural Resources and Environment Fisheries Division P.O. Box 2462 Dar-es-salaam, TANZANIA
Prof. P.O.J. BWATHONDI	Director General	Tanzania Fisheries Research Institute P.O. Box 9750 Dar-es-salaam, TANZANIA

ZAIRE

Mr. KALIBU MINO KAHOZI	Directeur	Service National de Promotion et de Développement de la Pêche B.P. 12.348 Kinshasa, ZAIRE
Dr. GASHAGAZA MASTA MUKWAYA	Directeur de Recherche	Centre de Recherche Hydrobiologique B.P. 73 Uvira, ZAIRE

ZAMBIA

Mr. H.G. MUDENDA	Director	Ministry of Agriculture, Food and Fisheries Department of Fisheries P.O. Box 350100 Chilanga, ZAMBIA
Dr. R. MUBAMBA	Assistant Director (Fisheries)	Ministry of Agriculture, Food and Fisheries Department of Fisheries P.O. Box 350100 Chilanga, ZAMBIA

OBSERVERS

Mr. A. AGBENONCI	Assistant Resident Representative (Programme)	UNDP B.P. 1490 Bujumbura, BURUNDI
Prof. G. NTAKIMAZI	Professor	Faculty of Sciences University of Burundi B.P. 2700 Bujumbura, BURUNDI
Dr. L. DE VOS	Project Manager	CRRHA B.P. 6177 Bujumbura, BURUNDI
Mr. R. BEARE	Chief Technical Adviser	URT/90/005 P.O. Box 671 Bukoba, TANZANIA

Mr. J.M. KAYUNGI	Skipper	URT/90/005 P.O. Box 671 Bukoba, TANZANIA

LTR RESEARCHERS

Prof. O.V. LINDQVIST	LTR Scientific Coordinator	University of Kuopio P.O. Box 1627 FIN-70211 Kuopio, FINLAND
Dr. G. HANEK	LTR Coordinator	LTR B.P. 1250 Bujumbura, BURUNDI
Dr. H. MOLSA	LTR Deputy Scientific Coordinator	University of Kuopio P.O. Box 1627 FIN-70211 Kuopio, FINLAND
Mr. E.J. COENEN	LTR Biostatis- tician	LTR B.P. 1250 Bujumbura, BURUNDI
Dr. P-D. PLISNIER	LTR Liinnologist	LTR B.P. 1250 Bujumbura, BURUNDI
Prof. J. SARVALA	Professor	Department of Biology University of Turku FIN-20500 Turku, FINLAND
Dr. T. HUTTULA	Senior Scientist	Tampere Water and Environment District P.O. Box 297 FIN-33101 Tampere, FINLAND
Mr. P. MANNINI	LTR Fisheries Biologist	LTR B.P. 1250 Bujumbura, BURUNDI
Mr. K.I. KATONDA	Director	TAFIRI P.O. Box 90 Kigoma, TANZANIA
Mr. D. CHITAMWEBWA	Researcher	TAFIRI P.O. Box 90 Kigoma, TANZANIA

Mr. A. KALANGALI	Researcher	TAFIRI P.O. Box 90 Kigoma, TANZANIA
Mr. A. KIHAKWI	Researcher	TAFIRI P.O. Box 90 Kigoma, TANZANIA
Mr. N. KISSAKA	Researcher	TAFIRI P.O. Box 90 Kigoma, TANZANIA
Ms. H. KURKI	LTR APO-Biologist	LTR B.P. 1250 Bujumbura, BURUNDI
Ms. L. KUUSIPALO	Doctorate Student	Department of Biology University of Joensuu P.O. Box 111 FIN-80100 Joensuu, FINLAND

FAO

Mr. S. NAJAM	FAO Deputy Representative	FAO TEXCO Building, Pamba Road P.O. Box 2 Dar-es-salaam, TANZANIA
Ms. D. BLESSICH	Project Operations Officer	FAO, FIDO (NF-305) Viale delle Terme di Caracalla 00100 Rome, ITALY
Dr. J. KAPETSKY	Senior Fishery Resources Officer	FAO, FIRI (NF-503) Viale delle Terme di Caracalla 00100 Rome, ITALY
Mr. G. SSENTONGO	Fishery Liaison Officer	FAQ, FIPL (NF-411) Viale delle Terme di Caracalla 00100 Rome, ITALY

SECRETARIAT

Dr. G. HANEK	LTR Coordinator	LTR B.P. 1250 Bujumbura, BURUNDI

Mr. E.J. COENEN	LTR Biostatis- tician	LTR B.P. 1250 Bujumbura, BURUNDI
Dr. P-D. PLISNIER	LTR Limnologist	LTR B.P. 1250 Bujumbura, BURUNDI
Mr. P. MANNINI	LTR Fisheries Biologist	LTR B.P. 1250 Bujumbura, BURUNDI
Ms. B. BARICAKO	LTR Senior Secretary	LTR B.P. 1250 Bujumbura, BURUNDI

RESEARCH FOR THE MANAGEMENT OF THE FISHERIES ON LAKE TANGANYIKA

GCP/RAF/271/FIN

Annex 2

THIRD JOINT MEETING OF THE LTR'S COORDINATION AND INTERNATIONAL SCIENTIFIC COMMITTEES

Kigoma (Tanzania), 28-30.11.1994

AGENDA

Item 1: Opening ceremony and election of the Chairman

Item 2: Adoption of the agenda

Item 3: Review of progress on recommendations of the Second Meeting of the Committees

Item 4: LTR Coordinator's Report: summary of LTR's 1994 activities

Item 5: Presentation and discussion of SSP results

Item 6: LTR Scientific Coordinator's Report: summary of SSP results and proposal of SSP programme for 1995

Item 7: Management of Lake Tanganyika's Fisheries Resources

Item 8: 1995 Cruise Schedule for *R/V Tanganyika Explorer*

Item 9: Evaluation Mission of LTR

Item 10: Date and venue of the next meeting

Item 11: Any other matters

Item 12: Adoption of the report