WATER QUALITY PATTERNS, INVERTEBRATE AND FISH COMMUNITY STRUCTURE IN THREE SHALLOW BAYS OF LAKE VICTORIA (UGANDA) WITH VARYING CATCHMENT LAND USE



BY

STEPHEN B.K. SEKIRANDA
B.SC. (MAK), M.SC -ENVIRONMENTAL SCIENCE (IHE, DELFT, THE NETHERLANDS)

A THESIS SUBMITTED TO THE GRADUATE SCHOOL FOR THE AWARD OF DOCTORATE DEGREE OF PHILOSOPHY OF MAKERERE UNIVERSITY, KAMPALA (MAK)

JUNE, 2006

DECLARATION

I, Stephen B.K. Sekiranda declare that this thesis is my original work and has not been submitted for a degree in any other University.

Signed: _____ Date: July 14th, 2006

APPROVED BY DOCTORAL SUPERVISORS:

_____ Date: 17th July 2006

Dr. James Okot-Okumu
Makerere University Institite of Environment and Natural Resources (MUIENR)
MAKerere University
P. O. Box 7062, Kampala

_____ Date: 18th July 2006

Associate Professor Fredrick W. B. Bugenyi
Zoology Department, Makerere University
P. O. Box 7062, Kampala

CONTENTS

DECLARATION..... II

DEDICATION..... III

ACKNOWLEDGEMENTS..... IV

GENERAL ABSTRACT..... VI

CHAPTER ONE: GENERAL INTRODUCTION..... 3

CHAPTER TWO: VARIABILTY OF WATER QUALITY IN NEARSHORE AREAS OF THREE BAYS OF LAKE VITORIA LOCATED IN CATCHMENTS OF DIFFERENT HISTORICAL LAND USE..... 45

CHAPTER THREE: COMPOSITIONAL VARIATION OF BENTHIC MACROINVERTEBRATES IN THREE BAYS OF LAKE VICTORIA LOCATED CATCHMENT VARYING IN LAND USE..... 81

CHAPTER FOUR: SPATIAL COMPARISON OF FISH COMMUNITY STRUCTURE BY GIS AMONG THREE BYAYS WITH VARYING CATCHMENTS OF LAND USE, LAKE VICTORIA, UGANDA..... 123

CHAPTER FIVE: CONCLUSIONS, PERCEPTIONS AND IMPLICATIONS FOR CONSERVATION AND MANAGEMENT OF THE LAKE VICTORIA ECOSYSTEM..... 173

DEDICATION

I wish to thank my parents, Gladys Nansikombi and Late Christopher G. Kintu for raising, supporting, educating and loving me. To them, I dedicate this thesis.

ACKNOWLEDGEMENTS

First of all, to name all the people who helped me get this thesis possible is easy, but tough to thank them enough. I will nonetheless try...

I would like to thank Lake Victoria Environment Management Project (LVEMP 1), Uganda for financially supporting this work and for great patience in awaiting its completion.

I am extremely grateful to my supervisors, Dr. J. Okot-Okumu of MIUENR, and Associate Professor, F.W. B. Bugenyi of Department of Zoology, both of Makerere University for their enthusiastic supervision. I was fortunate to have met them at a latter stage of this research, when I transferred from Univeristy of Florida, USA to Makerere University. I could not have imagined having better advisors and mentors for my PhD! They have provided insipiration, helpful reviews and detailed editorial advice, much, of which I adopted in the structrure and organisation of this thesis. I am indebted to Professors Lauren Chapman and Colin Chapman for mentoring me while at University of Florida and continuing to do so at Makerere University, providing care, faculty, direction, editorial amendments and many helpful suggestions to my thesis.

My close friends, who are too many to mention always stood by my side asking over and over again "When will you get it done? Next week? Next Month? When?". I am forever indebted to them for providing unflinching encouragement when it was most required. Colleagues: Dr. Y. Kizito, Dr. L. Ndawula, Dr. F. Wanda and Dr. D. Mbabazi were greatly encouraging in sustaining the effort to complete the writing of the thesis and motivated me in difficult times.

I gratefully acknowledge the logistical support from National Fisheries Resources Reseach Institute (NAFIRRI) that made it possible for me to pursue the research. Great thanks to the following staff of NAFIRRI: P. Gandhi, M. Nsega, J. Naluwairo, B. Sonko, M. Madoi and G. Magezi for providing many kinds of assistance that also facilitated the work. Thanks are

due to the Director, NAFIRRI, Dr. J. S. Balirwa for his perceptive critique and to National Agricultural Research Organisation (NARO) for granting me a study leave.

This thesis would not have been possible without the kind support and assisstance of Makerere University Institute of Environment and Natural Resources (MUIENR) of Makerere University. I thank all teachers who have given me the strength and confidence to realise this doctoral pursuit, especially my examiners for reading the whole thing so thoroughly and for surprisingly an enjoyable Viva.

I am more indebted than I can tell to my wife, Joyce Akumu for undying indulgence and moral support of mutual faith and for putting up with the out of the ordinary.... I will always be indebted to my kids: Shunway Luyiga, Sheehan Caisey K. Tendo and Treasian Sinabulya for maintaining simple and fondest vitality during the fulfillment of this scholarly enterprise.

I would never have finished this thesis, had I not weathered conjecture and nit-picking, but of course, when reason and wit prevail, everthing else is possible. I owe the achievement to God for upholding me to stand tall through thick and thin while executing this study.

Finally, with all my heart and pleasure, I thank all those whose names have been omitted but contributed to the project in one way or another.

Stephen B.K. Sekiranda

GENERAL ABSTRACT

An effort to understand the composition and distribution of benthic invertebrate and fish communities as indication of water quality spectra in three bays: Murchison Bay associated with urban, Fielding Bay with semi-urban and Hannington Bay with rural catchment land use patterns in Victoria Basin is the main purpose of this thesis. In view of the dramatic ecological changes such as unprecedented loss of biodiversity and deterioration of water quality that have happened in Lake Victoria since 1960's, this study introduces biological monitoring as a tool for assessing water quality in Lake Victoria and its environs in the management of the basin waters. As initial recipients of watershed inputs, nearshore areas in the bays were the main focus of the study for assessing water quality changes and the associated macro-invertebrate and fish community components. Water quality and macro-invertebrate and fish assessments in nearshore areas of three bays were conducted eight times between June 2001 and May 2002 at three sites in the respective bays. The sites were Portbell, Nakivubo channel mouth and Kawuku in Murchison Bay; Kakira, Wanyange-Masese and Wanyange in Fielding Bay; and Kitovu, Lwanika and Namavundu in Hannington Bay. The observed water quality, benthic macro-invertebrate and fish diversity and

abundance variables were delineated within the bays and spatial patterns displayed on maps.

Five chapters comprise this thesis. Chapter one offers a general introduction about Lake Victoria, its changes in water quality and fisheries and the conceptual background to thematic areas covered in the subsequent chapters. Chapter two illustrates the spatial patterns of water quality within and among bays relative to catchment urban-rural land use and identifies patterns in trophic states. Chapter three defines spatial and temporal variation of composition and mean densities of benthic macroinvertebrates in the sampled areas of three bays, and use presence or absence of certain taxa to predict the trophic status relative to catchment land use gradient. Chapter four describes and compares at the sample sites, the composition of fish, fish diversity and abundance indices within and among bays. Chapter 5 is a general discussion and conclusions tying up possible correspondence between water quality and biota, and implications of biodiversity and environmental conservation of Lake Victoria ecosystem.

The primary water quality results demonstrated that the extent of eutrophication was highest in Murchison Bay, moderate in Fielding Bay and least in Hannington Bay. The macro-invertebrate assemblage index was sensitive to escalating extent of eutrophication as noted in Murchison bay with low diversity (mainly comprised by *Chironomus sp.*

and seldomly by the *rat-tailed maggot)*, particularly at Nakivubo channel mouth. The other two sites in Murchison Bay, Portbell and Kawuku showed a macro-invertebrate assemblage analogous to that encountered in Fielding and Hannington Bays that was rich and dominated by snails and bivalves. For most fish diversity metrics (especially mean abundance, diversity, evenness and equitability indices), the highest values were shown in Hannington Bay, intermediate ones in Fielding Bay and least ones in Murchison Bay. Dissolved oxygen readings below 2 mg L^{-1} were observed only at Nakivubo channel mouth in Murchison where also conductivity values in the range of 235 to 411 $\mu S\ cm^{-1}$ were recorded. Under these conditions, the mayfly nymphs were absent but prevalent in Fielding and Hannington bays. The same conditions seem to have favoured a Berger- Parker dominance index represented persistently by *Protopterus aethiopicus,* indicating that this fish species can tolerate low oxygen conditions. In other sites in Murchison bay as well as in Fielding and Hannington bays, this index was represented by *Lates niloticus*, *Oreochromis niloticus*, Haplochromines and *Brycinus sadleri*. Conductivity values in Fielding Bay in ranged from 107 to 110 $\mu S\ cm^{-1}$) and from 98 to104 $\mu S\ cm^{-1}$ in Hannington Bay, and dissolved oxygen in both bays was well over 5 mg L^{-1} at all sampling occassions.

The study illustrates that benthic macroinvertebrates are useful for rational biomonitoring programmes within Lake Victoria basin. Such programmes need to be set up, institutionalised and integrated in the management strategies of resource and environmental protection. Currently the platform for biomonitoring is lacking. Results from this study form a basis of developing biocriteria using the benthic macroinvertebrate assemblages for biomonitoring. In case results from this study do not transpose directly to other areas of the basin, it will become imperative therefore to conduct similar surveys on a lake or basin wide scale to verify a lakewide bioassessment criteria and this effort could be complimented by the use of GIS to reach a rapid understanding of the environmental elements of the resource base and resource use patterns in basin. To assess the ecosystem properly, organisms from algae and zooplankton assembalges could also be investigated in the same way so as to develop a whole suite of bioindicators.

CONTENTS

CHAPTER ONE

1.1 GENERAL INTRODUCTION 3
1.1.1 Physical and political background of Lake Victoria 3
1.1.2 Water quality changes in Lake Victoria 9
1.1.3 Fishery and fish diversity changes in Lake Victoria 14
1.2 CONCEPTUAL FRAMEWORK 19
1.2.1 Trophic state and water quality 19
1.2.2 Macroinvertebrates as water quality indicators 21
1.2.3 Measurements of biodiversity: strengths and limitations . 22
1.2. 4 Brief overview of Geographic Information System (GIS). 24
1.3 STATEMENT OF THE RESEARCH PROBLEM 27
1.3.1 Study objectives 28
1.3.2 Rationale of the study 29
1.4 STUDY AREAS AND SAMPLING SCHEME 30
1.4.1 Estimates of non- point total-phosphorus loads into the bays 31
1.5 STRUCTURE OF THE THESIS 33
1.6 REFERENCES 35

LIST OF TABLES

Table 1.1	Lake Victoria surface area, shoreline and basin area per country.....	4
Table 1.2	Lake Victoria annual water balance 1965 – 1990.....	5
Table 1.3	Average inflows to and out flows from Lake Victoria.....	13
Table 1.4	Non point total-phosphorus (TP) loads into Hannington, Fielding and Murchison bays of Lake Victoria.....	33

LIST OF FIGURES

Fig 1.1	Map of Lake Victoria and its catchment in Kenya, Uganda and Tanzania, East Africa.....	4
Fig 1.2	Comparison of wet phosphorus deposition among six regions in the world.....	8
Fig 1.3	Map showing bays and sites where the study was conducted and the surrounding catchment land use pattern.....	31