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Diversity and abundance of invertebrates in the Victoria basin lakes and their role in fishery production

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Abstract

A field study was carried out on zoplankton communities in the Victoria basin lakes (Victoria, Nabugabo lakes, Koki lakes and Wamala) between 1997 and 2001. The objective of the study was to determine the composition, distribution and abundance of zooplankton and their role in fishery production. Field sampling was carried out once every quarter in selected inshore and offshore areas of the lakes. Samples were taken with Nansen type nets of 0.25 m mouth opening and 50-100 um mesh opening and a 5-litre Schindler trap. A total of 50 species was recorded within the basin lakes. Rotifers had the highest diversity with 13-22 species. Cyclopoids contained 7, Calanoids 2, and Cladocerans 9 species. The most widely distributed species were *Thermocyclops neglectus, Moina micrura* and several rotiferan species. Rotifers were numerically most abundant in lakes Mburo, Kachera, Nabugabo and Wamala while copepods dominated in Victoria-Sio, Kayugi and Kayanja. However, copepods had the highest dry weight in all the basin lakes. In Lake Victoria, copepods dominated the communities both inshore and offshore, while rotifers were nearly non-existent offshore. A historical perspective showed higher abundance of Calanoids and Cladocerans during the 1960s than in the 1990/2000 communities. These changes are believed to be associated with drastic changes in lake trophy and fish faunal composition over the last four decades. Higher zooplankton densities offshore occurred in the Victoria, Nabugabo and Kachera. Species diversity was higher offshore in Victoria-Sio, Nabugabo and Wamala. Seasonal abundance in Lake Victoria showed peak abundance during May, coinciding with the onset of the annual mixing period. Copepods dominated in the diets of *Rastrineobola argentea* (Mukene) and larval *Lates niloticus* (Mputa) while larval cichlids consumed a proportional mix of copepods, Cladocera and aquatic insect larvae. Lakes with high abundance of relatively large-bodied copepods, Cladocerans and aquatic insect larvae are rated high in fishery production than those dominated by small-bodied rotifers. The latter lakes are generally eutrophic (over-fertilised) water bodies, where the invertebrates' fish food environment is no longer favourable for fishery production. There is need to put in place measures to mitigate increasing eutrophication of water bodies within the Victoria basin area in order to ensure stable food environment for sustained fishery production.

Introduction

Aquatic invertebrates include all organisms without a backbone. On the basis of size, these organisms are classified as micro-invertebrates or zooplankton (generally < 2mm body length and can not be seen with a naked eye) and macro-invertebrates or macro-benthos (generally > 2mm body length and can be seen with a naked eye). Zooplankton are minute insect-like organisms living in the water column and are composed of mostly crustaceans in which the key groups are copepods and cladocerans (water fleas). Non-crustacean zooplankton includes rotifers and larvae of chironomids and chaoborids (lakeflies). Macro-invertebrates are generally sediment-dwelling while others live among roots of aquatic macrophytes. They can be categorised

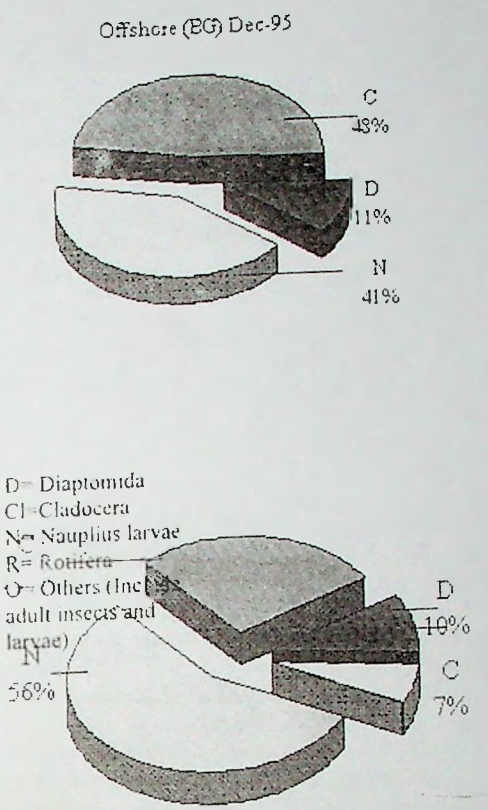
as semi-aquatic (e.g. dragonflies and lakeflies), having aquatic developmental stages, but living as terrestrial organisms as adults. Others like gastropods (snails & limpets), pelecypods (bivalves) i.e. clams & mussels, Oligochaetae (earth worms), Hirudinae (leeches) and ostracods (seed shrimps) are exclusively aquatic.

Aquatic invertebrates are of economic and biological importance. They, in general, occupy an important position in aquatic food chains, linking algal primary production to higher trophic levels culminating into fish production. All fish larvae, regardless of species must feed on invertebrates particularly zooplankton as the first external food following hatching from eggs. Zooplankton therefore provide high nutrition food supply to fishes at a most critical time in their life history to enhance rapid growth and development prior to switching to other food resources. A number of fishes such as the pelagic cyprinid, *Rastrineobola argentea* (Mukene) and several species of Haplochromines (Nkejje), which support important fisheries, rely entirely on a diet of zooplankton throughout their life histories. The freshwater prawn, widely occurring in lakes Victoria and Kyoga are an important food source for the juveniles and sub-adults of commercially important Nile perch, *Lates niloticus*. Some invertebrates including Chironomids rotifers, oligochaetes etc are useful as bio-indicators of water quality. In Lake Victoria, *Caridina nilotica* and molluscs are commercially harvested, processed and incorporated into domestic animal feeds. Others such as leeches and Argulids are parasitic on fish and other aquatic organisms. The gastropods *Bulinus* spp. and *Biomphalaria* spp are vectors of Schistosoma, which cause bilharzia in man. Other types are scavengers on dead organisms e.g. fish and even vegetation thus helping in cleaning of the water bodies.

Past research has shown that invertebrate diversity and abundance is threatened by changes in water quality including eutrophication (over-fertilisation) and pollution (contamination). In Lake Victoria, increasing eutrophication over most of the last quarter of the twentieth century has coincided with drastic changes in relative abundance of key zooplankton taxa. The proportions of calanoid copepods and Cladocera have decreased relative to that of cyclopoid copepods (Mwebaza-Ndawula 1994).

In the past, only limited investigations linking aquatic invertebrates to the fisheries have been done in the Victoria basin area. Corbet (1961) provided concise documentation of the food of non-cichlid fishes in lake Victoria including *Engraulicypris (= Rastrineobola)* argentea, Mormyrids, Barbus species, some haplochromines etc either specialising in consumption of invertebrate or incorporating substantial proportions of invertebrates in their diets. Greenwood (1966) has provided notes on the food of most fishes of Uganda. In a recent study, Mwebaza-Ndawula (1998) gives a detailed description of the diet of and prey selectivity by *R. argentea* in Lake Victoria.

Fig. 1. Zooplankton relative abundance: modern (inshore, offshore) and historical.



As many invertebrate-eating fishes are commercially important species, it is important to study the dynamics of these organisms and in particular to understand their contribution to fishery production. This paper presents results of a study on the diversity and abundance of aquatic invertebrates in various water bodies in the Victoria lake basin and attempts to elaborate the relationship between invertebrate communities, ecosystem functioning and fish production.

Study Area

The study area covered selected water bodies within the Victoria lake basin namely, lakes Victoria, Mburo, Kachera, Wamala, Kayanja, Kayugi, Nabugabo and the Victoria Nile (Figure 1)

Materials and methods

Zooplankton were sampled at selected inshore and offshore sites with plankton nets of 50 - 100um mesh and 0.25 m mouth diameter. Three vertical hauls were taken to make a composite sample, which was preserved

Table 1. Occurrence of zooplankton species in the Victoria basin lakes

Species	Kayanja	Kayugi	Nabugabo	Kachera	Mburo	Victoria	Wamala	Kabaka's Lake	Freq. Of occurence
Harpacticoida			P			P			2
Total (Spp)	**0**	**0**	**1**	**0**	**0**	**1**	**0**		
Cyclopoida									
Eucyclops spp.			p	p		p			3
Mesocyclops spp.	p		p	p	p	p	p		5
Thermocyclops emini				p	p	p			3
Thermocyclops incisus	p			p		p	p	p	5
Thermocyclops neglectus	p	p	p	p		p	p	p	7
Thermocyclops decipiens							p		1
Thermocyclops incisus						p			
Thermocyclops oblongatus						p			
Tropocyclops confinnis						p			1
Tropocyclops tenellus			p			p			2
Total (spp)	**3**	**1**	**4**	**4**	**2**	**9**	**5**		**2**
Calanoida									
Thermodiaptomus galeboides						p			1
Tropodiaptomus stuhlamanni						p			
Total (spp)	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	
Cladocera									
Alona bukobensis						p			1
Bosmina longirostris		p				p	p		3
Ceriodaphnia cornuta		p	p			p	p		4
Chydorid spp.						p	p		2
Daphnia longispina						p			1
Daphnia lumholtzi						p			1
Daphnia lumholtzi 'monacha'						p			1

Diaphanosoma excisum		p	p			p	p	p	5
Moina micrura	p	p	p	p	p	p	p	p	8
Macrothrix sp.	p		p			p	p		4
Total (spp)	**2**	**2**	**5**	**2**	**1**	**10**	6	**2**	
Others									
Caridina					p				1
Chaobrid pupae			p	p	p	p			3
Chironomid larvae		p			p	p			2
Ostracods		p			p				2
Total (spp)	**0**	**2**	**1**	**1**	4	**2**	**0**		
Rotifera									
Anureupsis fissa						p			
Ascomorpha sp.						p	p		2
Asplanchna brightwelli	p	p	p	p		p	p	p	7
Brachionus angularis	p	p	p	p	p	p	p	p	8
Brachionus bidentatus		p	p		p	p			4
Brachionus budapestinensis			p	p	p	p	p	p	6
Brachionus quadridentatus					p	p			2
Brachionus calyciflorus	p	p	p	p	p	p	p	p	8
Brachionus caudatus					p				
Brachionus dimidiatus					p				
Brachionus falcatus	p	p	p	p	p	p	p	p	8
Brachionus forficula					p				
Brachionus patulus			p		p				1
Brachionus plicatilis				p	p				2
Collotheca sp.					p				2
Euclanis spp.				p	p	p			3
Filinia longiseta	p	p	p	p	p	p	p	p	8
Filinia opoliensis	p	p	p	p	p	p	p	p	8
Hexathra spp.	p	p	p	p	p	p	p		6
Keratella cochlearis	p	p	p			p	p	p	6
Keratella tropica	p	p	p	p	p	p	p	p	8
Lecane bulla	p	p	p	p	p	p	p		7
Polyarthra spp.	p	p		p	p	p			5
Polyarthra vulgaris.	p	p	p	p	p	p	p	p	8
Synchaeta pectinata		p	p		p	p	p		5
Synchaeta spp.	p	p	p	p	p	p	p	p	8
Trichocerca cylindrica	p	p	p	p	p	p	p	p	8
Trichocerca spp.		p		p		p	p		4
Total (spp)	**13**	**14**	**18**	**16**	**16**	**26**	**21**	14	
Grand total no.of spp.	18	17	30	23	20	48	34		

in 4% sugar-formalin. The samples were taxonomically identified and the different taxa counted under an inverted stereomicroscope at 40X magnification.

Pelagic fishes were sampled (in Lake Victoria) with a small, canoe-towed, mid-water trawl net described by Mwebaza-Ndawula (1998). Samples were preserved in 10% formalin. Each fish was dissected, and the gut contents examined under a compound microscope. Prey organisms were identified to broad taxonomic groups and counted. Zooplankton biomass was computed from available length-weight regressions (Botrell et al. 1976). Historical zooplankton and fish samples were obtained from field collections of Jack Talling and the Fisheries Resources Research Institute (FIRRI) Museum respectively.

Macro-invertebrates were collected at the water edge (from macrophyte roots), inshore and offshore areas (sediments) in each lake. Selected macrophyte area was demarcated with a wooden quadrat of size 0.5 X 0.5 m. Macrophyte roots were dislodged using a machete and placed in labeled polythene bags. A Ponar Grab was used to take three sediment hauls from each sampling point. The sediment was sieved through a 500 µm-mesh-washing bag and the sample placed into a labeled bottle containing 5% formalin or 70% ethanol. Sediment type was determined by visual inspection and described according to texture. In the laboratory, organisms were sorted and taxonomically identified as far as possible.

Results

Zooplankton composition, distribution and abundance

Zooplankton communities of the Victoria basin lakes were composed of cyclopoid and calanoid copepods, cladocerans, rotifers, aquatic insect larvae/pupae and water mites (Table 1).

Copepods were composed of the genera: *Thermocyclops, Mesocyclops and Tropocyclops (Cyclopoids),*

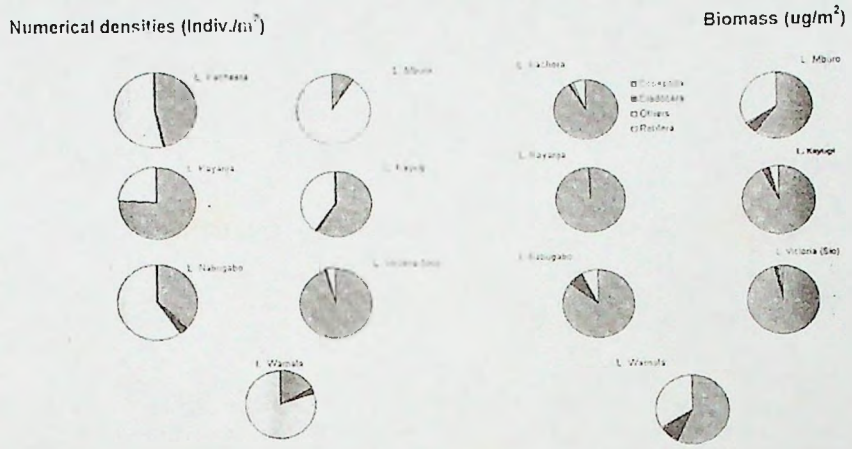


Figure 2. Densities (ind./m²) and Biomass (ug/m²) of zooplankton taxa in the Victoria basin lakes (1997-2000)

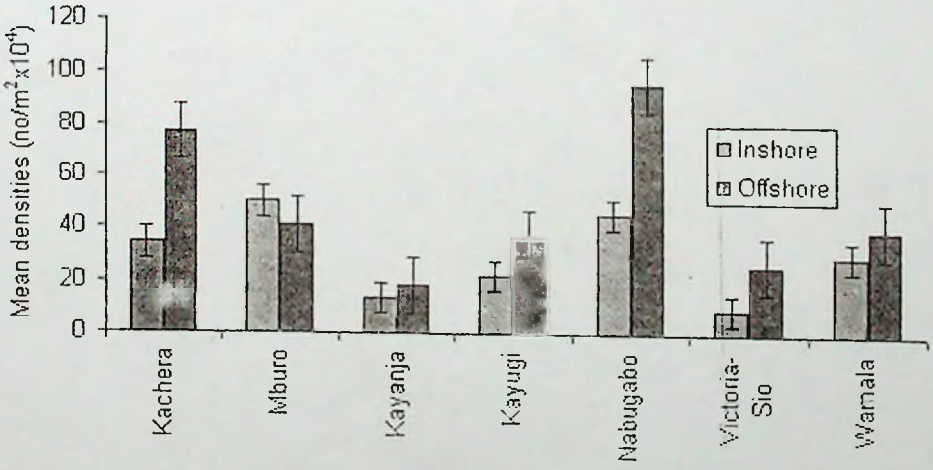


Figure 3. Inshore offshore variation of zooplankton densities (ind./m²) *in Victoria basin lakes*

Thermodiaptomus and Tropodiaptomus (Calanoids). Cladocera comprised eight genera: *Diaphanosoma, Daphnia, Ceriodaphnia, Bosmina, Moina, Macrothrix, Chydorus* and *Alona.* Rotifers comprised the genera: *Ascomorpha, Asplanchna, Brachionus, Euclanis, Filinia, Hexathra, Keratella, Lecane, Polyarthra, Synchaeta* and *Trichocerca.*

The commonest and most widely distributed species were *Mesocyclops* sp., and *Thermocyclops neglectus* among Copepoda; *Diaphanosoma excisum* and *Moina micrura* among Cladocera and several species of the genera *Brachionus, Filinia, Hexathra., Keratella, Lecane, Polyarthra, Synchaeta* and *Trichocerca.* among Rotifera (Table 1). Cyclopoid copepods and rotifers were

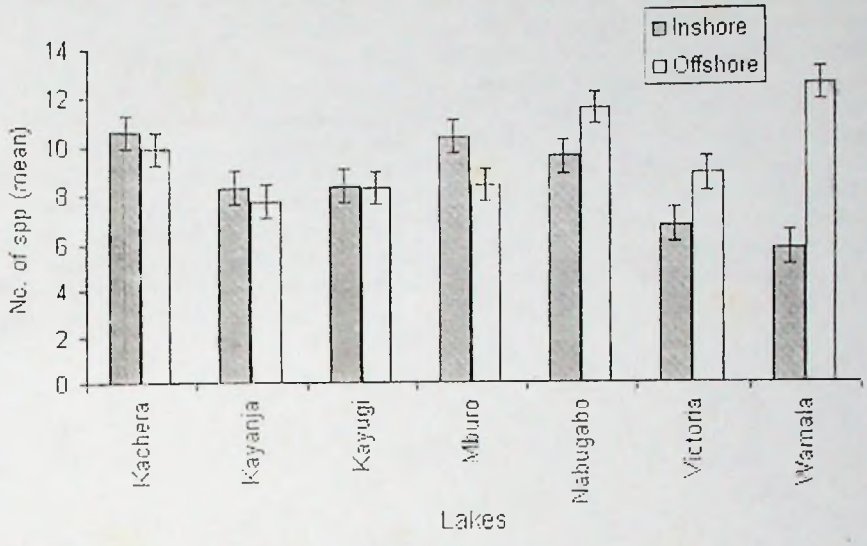


Figure 4. Inshore-Offshore distribution of diversity of zooplankton in the Victoria basin lakes

numerically the most dominant groups. However, in terms of biomass, cyclopoids had the highest relative abundance in all basin lakes (Fig.2). Kachera and Nabugabo had significantly higher mean densities of zooplankton offshore while other lakes showed no clear inshore-offshore trends in abundance (Fig. 3).

Zooplankton diversity

Mean zooplankton species diversity varied between 7 and 13 species. Higher species diversity offshore was recorded in Wamala, Nabugabo and Victoria while the reverse trend occurred in Lake Mburo (Fig. 4). There were no clear inshore-offshore trends in diversity of organisms in Kachera, Kayanja and Kayugi.

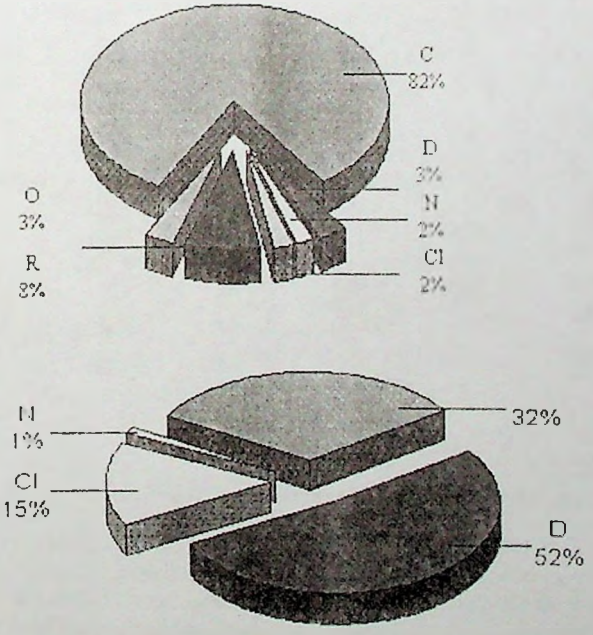


Figure 5A & B. Relative abundance and dry weight of different zooplankton taxa in samples from inshore (NG, 1995) and historical (off Dagusi Island, 1961) samples from Lake Victoria

Historical changes in zooplankton relative abundance in Lake Victoria

Relative abundance and biomass of different taxa from the Napoleon Gulf, (1995) and off Dagusi Island (1961) indicated remarkable changes between the communities of the1960s and 1990s (Fig. 5A and B). Cyclopoid copepods showed a substantial increase from 56% in the 1960s, to 82% in the 1990s. In contrast, Cladocera and calanoids showed a drastic decline from 30% and 13% in the 1960s to 2% and 3% respectively in the 1990s. Corresponding dry weight data (Fig. 5B) showed similar changes.

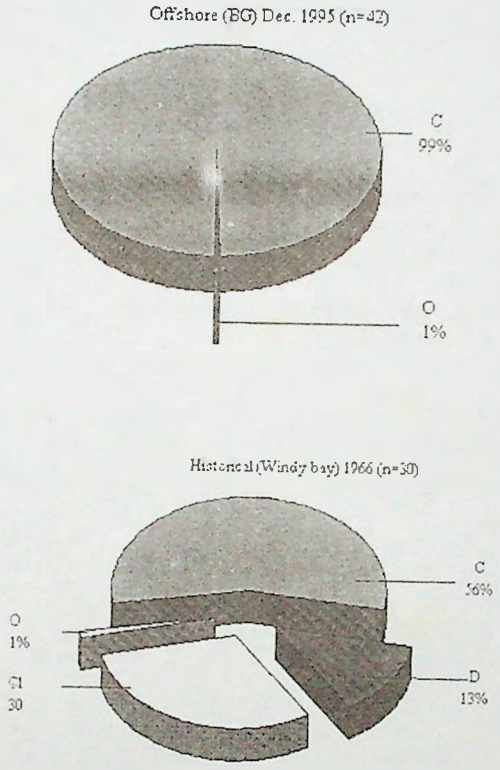


Fig. 6. Contribution of different zooplankton taxa in the diet of R. argentea (Mukene) inshore (NG) and offshore (BG) Lake Victoria (C, D, Cl, N, R. and O as in Figure 1).

Diversity of macro-invertebrates

A horizontal gradient of sediment-dwelling organisms was apparent within the different lakes. Higher diversity occurred inshore compared to offshore areas in the majority of lakes (Fig. 10). Macrophyte roots generally supported higher diversity of macro-invertebrates than

Zooplankton in the diet of Mukene (Rastrineobola argentea) in lake Victoria

The frequency of different zooplankton taxa in the diet of *R. argentea* from inshore and offshore waters and historical sample (Windy Bay.1966) showed cyclopoid copepods as the main prey item (Fig. 6). In the offshore sample, nearly 100% cyclopoid consumption was attained. Greater consumption of Cladocera and calanoid copepods was evident in the historical (1960s) fish diet compared to that of the 1990s, corresponding to their greater abundance in the historical zooplankton community (Fig. 5A and B).

Zooplankton in the diet of other commercial fish species in Lake Victoria

Larval *Lates niloticus* ingested mostly cyclopoids (70%) and Cladocera (17%) compared to larval cichlids in which favourite prey items were nauplius larvae (48%), adult aquatic insects (20%) and cyclopoid copepods (18%) (Fig.7). Supplementary prey for larval *L. niloticus* included calanoid copepods, and other minor items while cyclopoids and cladocerans supplemented the diet of larval cichlids.

Macro-invertebrate composition, distribution and abundance

The macro-invertebrate community of the Victoria basin lakes was composed of the following broad taxonomic groups: Gastropods, Pelecypods, Ephemeroptera, Odonata, Hemiptera, Diptera, Trichoptera, Hirudinae, Oligochaetes, Ostracods, Conchostraca and Caridina nilotica (Table 2). Most of these taxonomic groups contained a number of genera. The most widely occurring taxa were *Chironomus* spp., Tanypodinae, *Chaoborus* sp., Biomphalaria spp., Povilla adusta, Libellulidae, Coleoptera, Hirudinae, Oligochaete and Ostracods.

Within lakes, the densities of sediment organisms were generally higher offshore than inshore although such differences were not always significant (Fig. 8). High densities of sediment organisms (> 1500 ind./m^2) occurred in the lakes Nabugabo and Mburo, while very low densities (< 500 ind./m^2) occurred in Kachera, Kayugi and Kayanja. Roots of aquatic macrophytes generally supported higher densities of organisms than the sediments (Fig. 9) although in some cases these differences were not significantly different. Within macrophytes, densities of organisms were generally higher in papyrus roots than in other vegetation types (Table 3). Among sediments, sandy/gravel sediments supported higher densities of organisms than muddy bottoms (Table 4).

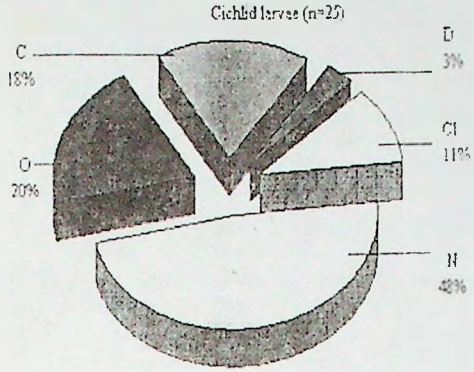


Fig. 7 Contribution of different zooplankton taxa in the diet of larval Lates niloticus and larval Cichlids (Ngenge and Nkejje) from Napoleon Gulf of Lake Victoria (C, D, Cl, N, R. and O as in Figure 1)

Table 2. Summary of the Occurrence of aquatic macro-invertebrates in individual lakes of the Victoria basin

	Lakes						
Taxa	Mro	Kra	Nbo	Kji	Kja	Wla	Vic
Gastropods							
Bellamya sp.							P
Biomphalaria sp.		P			P	P	P
Bulinus sp.	P	P			P	P	P
Gabia sp.							P
Lymnaea sp.		P					
Melanoides sp.							P
Pelecypods							
Byssanodonta sp.							P
Caelatura sp.							P
Corbicula sp.			P				P
Mutera sp.							P
Ephemeroptera							
Caenis sp.	P	P	P		P	P	P
Povilla adusta	P	P	P		P	P	P
Other	P	P	P		P	P	
Odonata							
Gomphidae	P						P
Libellulidae	P	P	P	P	P	P	P
Coenagrionidae	P	P	P		P	P	P
Hemiptera							
Corixids	P		P		P		P
Naucorids	P	P	P		P	P	
Ranatura	P	P			P	P	
Coleoptera	P	P	P		P	P	
Caridina niloticus							P
Deptera							

Chironomus sp.	P	P	P		P	P	P
Tanypodinae	P	P	P		P	P	P
Palpomyia sp.	P	P	P		P		P
Chaoborus sp.	P	P	P		P	P	P
Tabanids		P		P		P	
Syrphids(flower flies)		P		P			
Trichoptera	P	P	P	P	P		P
Hirudinae	P	P	P	P	P	P	P
Oligochaetes	P	P	P		P	P	P
Hydracarina	P	P		P	P	P	P
Ostracods	P	P		P		P	P
Conchostraca			P	P			P
Water spider	P	P					
No of Taxa	**21**	**23**	**17**	**8**	**19**	**18**	**26**

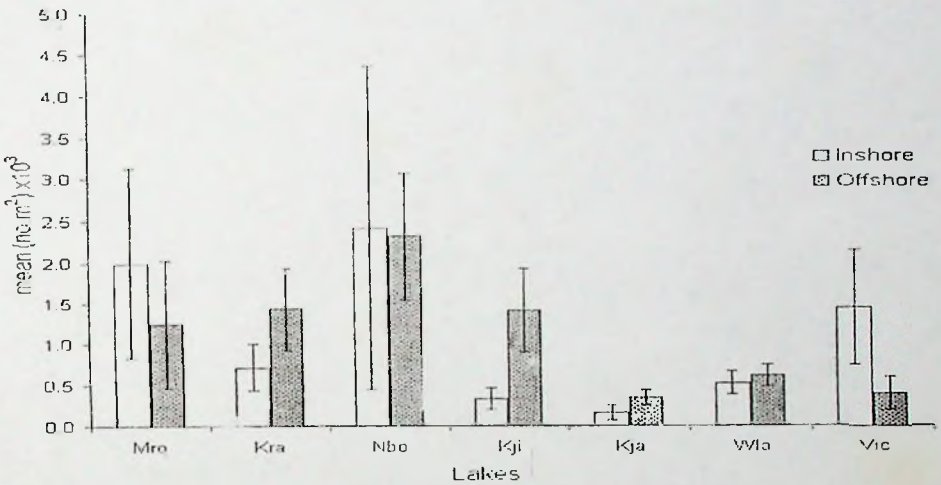


Fig. 8 Inshore-offshore densities (no.m2) of sediment macroinvertebrates in Victoria basin lakes.

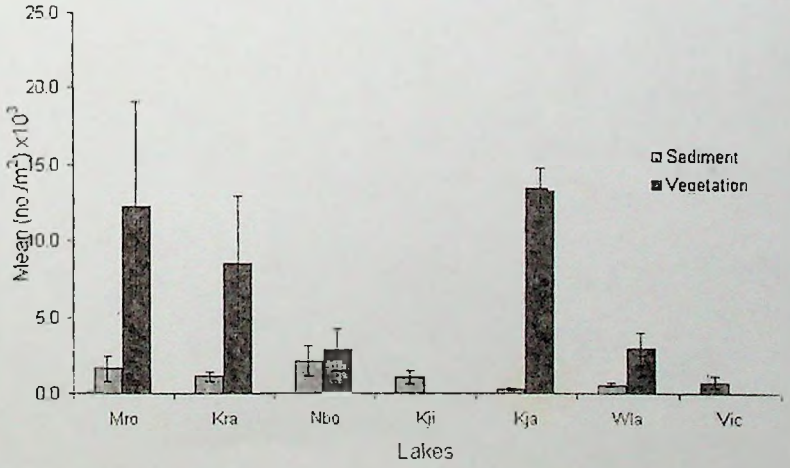


Fig. 9 Mean densities (no.m²) of invertebrates in sediment and roots of aquatic macrophytes macrophytes.

Table 3. Macroinvertebrate diversity and abundance: papyrus Vs other macrophytes

Lakes	Victoria-Nile	Kachera		
Vegetation	Water hyacinth	Papyrus	Nile-cabbage	Papyrus
Total no./m²	2628	4886	4136	11526
No. of taxa	24	16	17	13

Table 4 Macro invertebrate diversity and abundance: sandy Vs muddy bottom

Lake	Bottom type	No. of taxa	Mean density (no./m²)
Mburo	Sandy/gravel with little plant debris	16	1613
Nabugabo	Woody substrate and sand grains	12	2127
Victoria	Soft organic material and sandy	26	910
Kachera	Muddy/ boggy	9	189
Kayugi	Muddy/ boggy	7	144
Kayanja	Muddy/ boggy	8	248
Wamala	Muddy/ boggy	8	558

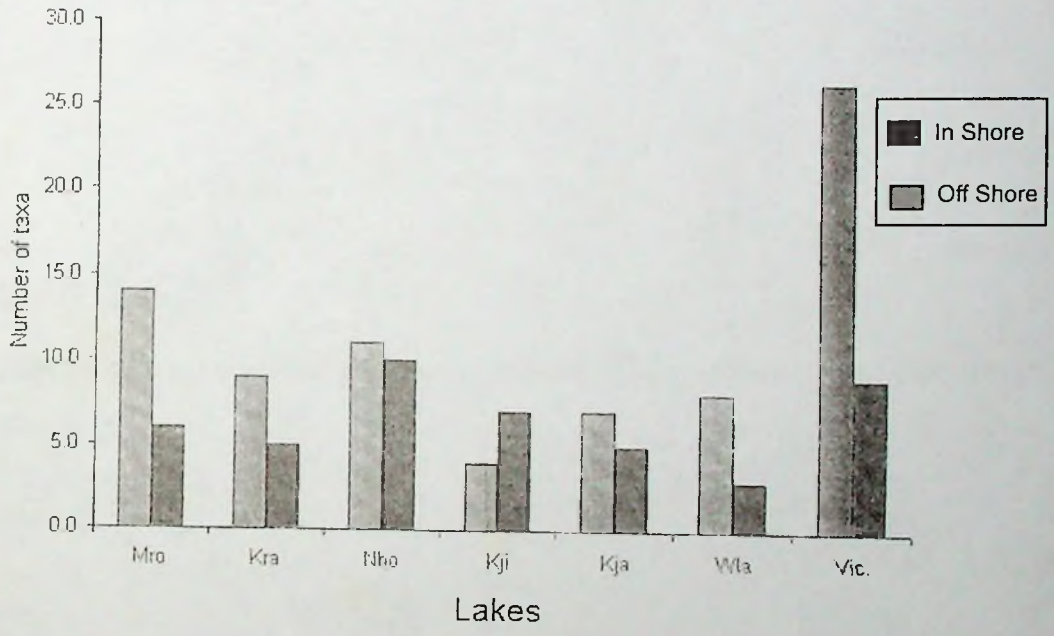


Fig. 10 Inshore-offshore distribution of macrobenthos taxa in the Victoria basin lakes.

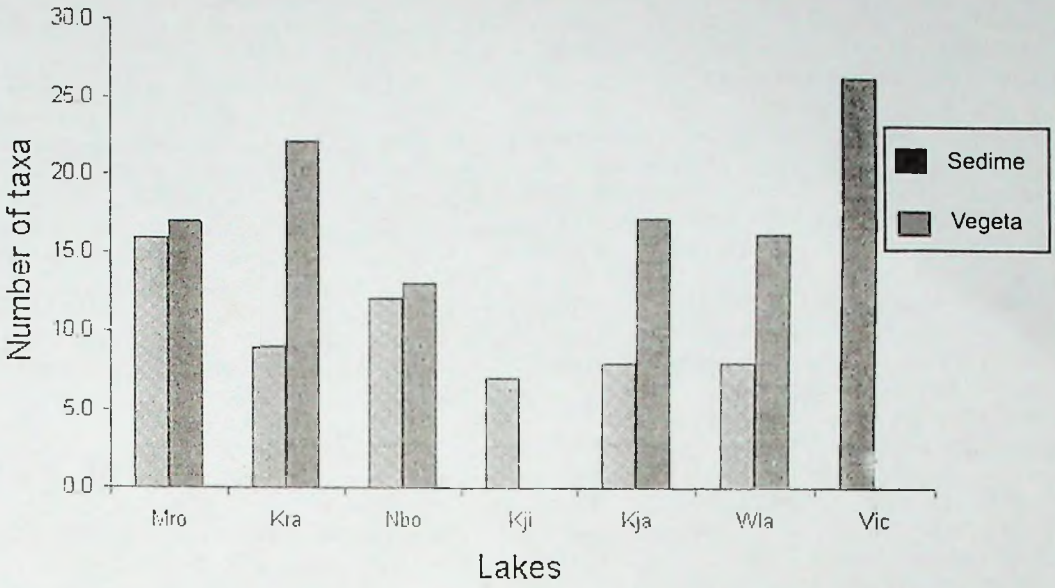


Fig.11 Diversity of aquatic macro invertebrates in sediment and vegetation of the Victoria basin lakes

sediments (Fig. 11). The diversity of organisms also varied with macrophyte types (Table 5).

Discussion

The Victoria basin area has a rich and diverse fauna of invertebrates especially among Copepoda, Cladocera, Rotifera, Diptera, Gastropods and Pelecypods (Table 1&2). Widely distributed and abundant species such as cyclopoid copepods, some species of Cladocera (*D. excisum* and *M. micrura*), chironomid and chaoborid larvae, Odonata and Hirudinae are ecologically important groups, which are considered to be readily available as prey to fish. However, some of the organisms that are abundant and widely distributed such as the small-bodied rotifers do not constitute important fish food resource due to their diminutive size and probably low calorific content. Notably, rotifers have been found to be most abundant in eutrophic lakes such as Mburo, Nabugabo and Wamala (Fig. 2). Lakes rich in such minute organisms and poor in larger-bodied ones such as copepods, Cladocera, lakefly larvae etc may not rate high in terms of fishery production potential, as they are evidently not selected as prey by fishes (figs 6&7).

Inshore-offshore trends in invertebrate diversity and abundance observed in most basin lakes (Figs. 3,4, 8 and 9) can also be related to fish abundance, as fishes would naturally tend to concentrate in areas that provide both shelter, abundance and a variety of prey organisms.

Some of the organisms that are important as fish prey occur only in a few water bodies. These include several species of Cladocera and the freshwater prawn *Caridina nilotica*. Cladocera in general have certain structural and behavioural attributes (large body size, conspicuous eyes and poor escape response) that make them highly vulnerable to fish predation. These organisms are therefore favorable prey items for most fishes and their paucity in most basin lakes is often associated with high planktivory. *Caridina nilotica*, encountered only in Lake Victoria during this study, is a major prey item for the commercially important Nile perch, *Lates niloticus* (Ogutu-Ohwayo 1990). Basin lakes lacking such important prey species or where they occur in low abundance may also lack capacity to sustain related fisheries. One such case is the Kabaka's lake, which has been found to have an impoverished Nile perch fishery (FIRRI Workshop Report 2001).

Observations on the food and feeding habits of key commercial fish species such as *R. argentea, L. niloticus* and cichlid fishes have shown the utilisation of different proportions copepods, cladocerans and aquatic insects (Figs 6 & 7) in apparent strategy to reduce competition while sharing common invertebrate food resource (Mwebaza-Ndawula et al.: In press). Reports by Corbet (1961) and Greenwood (1966) provide valuable information on fish-macro-invertebrate trophic relationships and therefore their contribution to fishery production in Lake Victoria and other water bodies in the basin.

One of the major ecological changes taking place in most Victoria basin lakes today is nutrient enrichment (eutrophication), which can be traced back to human activities (vegetation clearance, bush burning, over-grazing, swamp encroachment, inflows of untreated effluents and pollutants), in the catchment and around the lakes and rivers. The resulting eutrophication leads to changes in algal species composition and increased phytobiomass (Mugidde 1993), which affect both the diversity and abundance of invertebrates and fish that feed on algae. Blue-green algae, which become abundant under eutrophic conditions, are poor food quality for invertebrates and fishes that depend on them while some produce harmful toxins. Excess algal biomass leads to accumulation of the "soft flocculent" mud sediment; a common feature in many Victoria basin lakes. Our results show that these muddy sediments contain less diversity and abundance of macro-invertebrates (Table 4), most of which would form important prey for fish. This is in contrast to sandy/ gravel sediments, which support a variety of macro-invertebrate fauna (Table 4).

Given the role of aquatic invertebrates in fish nutrition and impacts, which may result from environment degradation, management options involving control of nutrients and pollutants influx into water bodies from the catchment need to be examined. This is necessary to slow down water quality deterioration, avert decline in aquatic biodiversity and abundance, restore and sustain fishery production on which poor rural communities depend for income, employment and nutrition.

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