FIRRI

NARO

Challenges for Management of the Fisheries Resources, Biodiversity and Environment of Lake Victoria

Editors:
J. S. Balirwa,
R. Mugidde,
R. Ogutu-Ohwayo.

Fisheries Resources Research Institute

Technical Document No. 2 First Edition - 2004

IDRC CANADA

UGANDA KENYA TANZANIA

LAKE VICTORIA ENVIRONMENT MANAGEMENT PROJECT LAVEMP FOR MAXIMUM SUSTAINABLE BENEFITS

Challenges for Management of the Fisheries Resources, Biodiversity and Environment of Lake Victoria

Edited by: J.S. Balirwa, R. Mugidde and
R. Ogutu-Ohwayo.

Fisheries Resources Research Institute

Technical Document No. 2

First Edition 2004
FIRRI, Jinja Uganda.

6.3. The status and significance *of invertebrate* communities

L. Mwebaza-Ndawula, V. Kiggundu and W. Pabire Gandhi

Introduction

Invertebrates constitute a major link in energy flow culminating into fish production in aquatic ecosystems. In tropical water bodies relatively little research has been done on invertebrate ecology especially their role in fishery production.

European scientists through periodic expeditions to Africa in the last quarter of the 20th century carried out the earliest research on zooplankton. Rzoska (1957) listed these early workers including Stuhlmann (1888), Weltner (1897) and Mrazek (1897-1898). Daday (1907), Verestchagin (1915) and Delachaux (1917) undertook further work during the early twentieth century. These early works provide a useful basis for tracking community changes by comparison with modem investigations. Worthington (1931) provided the first quantitative account of the zooplankton of Lake Victoria along with information on diurnal vertical migrations, compared to a temperate lake. The establishment of the East African Freshwater Fisheries Research Organisation (EAFFRO) at Jinja in 1947 enabled investigations on the fisheries, algae, invertebrates and water quality aspects of the lake (EAFFRO Annual Reports 1947-1977) to be regularly carried out. Macdonald (1956) made the first detailed observations on the biology of chaoborids and chironomids (lakeflies) in relation to the feeding of the elephant snout fish, *Mormyrus kannume*. A detailed study of the biology of the mayfly, *Povilla adusta* Navas with special reference to the diurnal rhythms of activity was carried out by Hartland-Rowe (1957).

The search to unravel the ecological role of aquatic invertebrates in the production dynamics of the lake has taken invertebrate research to greater heights through recent investigations including Okedi (1990), Mavuti & Litterick (1991), Mbahinzireki (1992, 1993), Branstrator *et al.*, (1996), Mwebaza-Ndawula (1994, 1998), Mwebaza-Ndawula *et al.*, (2000). Modern motorised water transport, sampling equipment and laboratory analytical instrumentation have all enabled twentieth century researchers to traverse the lake and sample different habitats, carry out taxonomic identification and produce vital quantitative data for better understanding of the invertebrate communities.

Aquatic invertebrates constitute important food resources for many fishes and are therefore key elements in the flow of energy in the ecosystem and contribute directly to fish production. Relatively few studies (Corbet 1961; Greenwood 1966; Mwebaza-Ndawula1998; Mwebaza-Ndawula *et al.*, 2000), however have addressed in detail aspects of fish-invertebrate trophic interactions in Lake Victoria.

In this chapter, we review current knowledge on aspects of the taxonomic composition, distribution, abundance and community structure patterns in time and space and define the ecological importance of aquatic invertebrates in Lake Victoria.

Zooplankton Community

Composition, distribution and abundance

The zooplankton community of Lake Victoria is composed of largely crustaceans, which include copepods, and cladocerans (water fleas). Non-crustacean elements comprise rotifers, aquatic insect larvae/pupae and water mites (Table 6.3.1). Copepods consist of two orders: Cyclopoida and Calanoida, although Harpacticoid copepods are also occasionally encountered. Cyclopoid copepods are made up of three genera: *Thermocyclops*, *Mesocyclops* and *Tropocyclops* while calanoids comprise two genera: *Thermodiaptomus* and *Tropodiaptomus*. Cladocera comprise seven genera: *Diaphanosoma*, *Daphnia*, *Ceriodaphnia*, *Bosmina*, *Moina*, *Chydorus* and *Alona*. Rotifera, is the most diverse non-crustacean group especially around shallow nearshore areas and consist of several genera and species (see Table 6.3.1).

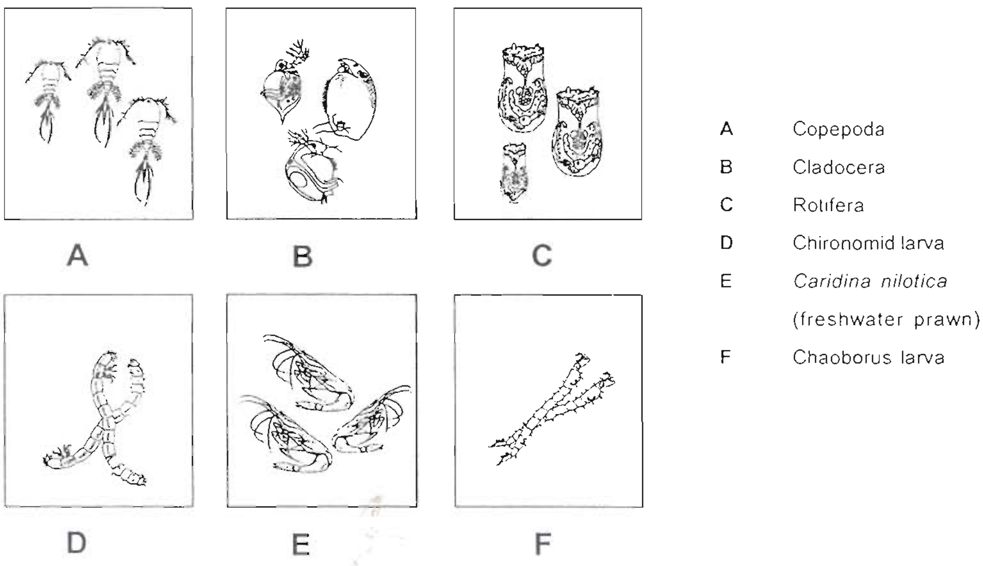

Plate 6.3.1: Examples of common invertebrates in Lake Victoria

The cyclopoid genus *Thermocyclops* contains four species: *T. neglectus, T. emini, T. incisus* and T. *oblogatus; Mesocyclops* contains a single species: *M. aequatorialis* while the genus *Tropocyclops* contains *T. confinnis* and *T. tenellus*. The two calanoid genera contain one species each: *Thermodiaptomus galeboides* and *Tropodiatomus stuhlmanni.*

Table 6.3.1. Occurrence of zooplankton taxa from inshore (Napoleon Gulf), offshore (Bugaia) and historical (off Dagusi Is.) samples, Lake Victoria

		Occurrence		
Taxa	Number of species	Inshore(1995)	Offshore(1995)	Historical(1961)
Rotifera:				
Brachionus	7	P	P	
Filinia	2	P	A	
Keratella	2	P	P	
Polyarthra	1	P	A	
*Lecane**	++	P	A	
Asplanchna	1	P	P	
Trichocerca	1	P	A	
Aneuropsis	1	P	A	
Euclanis	1	P	A	
Hexathra	1	P	A	
Pompholyx	1	P	A	
Cyclopoida:				
Thermocyclops	4	P	P	P
Mesocyclops	2	P	P	P
Tropocyclops	2	P	P	P
Calanoida:				
Thermodiaptomus	1	P	P	P
Tropodiaptomus	1	P	P	P
Cladocera:				
Daphnia	2	P	P	P
Ceriodaphnia	1	P	P	P
Diaphanosoma	1	P	P	P
Bosmina	1	P	P	P
Chydorus	1	P	A	P
Alona	1	P	A	P
Moina	1	P	A	P
Decapoda:				
Caridina	1	P	P	
Insecta:				
Chaoborus larvae/pupae	1	P	P	
Arachnida:				
Acarid mites	1	P	A	A

*Several unidentified *Lecane* species

Most cladoceran genera contain one species each i.e. *Diaphanosoma excisum, Moina micrura, Ceriodaphnia cornuta, Bosmina longirostris, Chydorus sphaericus* and *Alona sp*. The exception to this general situation is in a single genus *Daphnia* in which various authors (Rzoska, 1957; Mavuti & Litterick ,1991; Green 1971; Branstrator *et al.*, 1996) have reported the occurrence of two daphnid species: *D. longispina* and *D. lumholtzi* in the lake. A recent revelation by Jonnah and Lehman (2002) is the occurrence of a *Ctenodaphnia species* that is morphologically similar to *Daphnia lumholtzi var. monacha* but conforms more closely to the large-bodied *Daphnia magna,* a common species in freshwater temperate zooplankton communities. It is argued that food web alterations in Lake Victoria may have created conditions of relaxed planktivory by fish leading to the establishment of a prey organism of unusually large size such as *D. magna.*

Rotifers comprise the genera: *Brachionus, Ascomorpha, Asplanchna, Euclanis, Filinia, Hexathra. Keratella, Lecane, Polyarthra, Synchaeta* and *Trichocerca*. Brachionus and Lecane are the most diverse while most others have a few species each. *Keratella tropica* is the most widely distributed species occurring in both nearshore and offshore habitats, albeit in relatively small proportions.

Variations in zooplankton species composition are apparent from reports of different authors working at different times and places on the lake. As an example, Mavuti and Litterick (1991) reported the occurrence of *Thermocyclops hyalinus, Microcyclops sp., Tropodiaptomus neumanii* and *T. banforanus* in the Winam Gulf, which have not been reported elsewhere in the lake. Such variations may reflect restricted distribution of particular species or lack of standard taxonomic keys for different invertebrate of the lake. Other groups of zooplankton reported in the northeastern part of the lake (Kenyan waters) include *Microturbellaria, Hydracarina and ostracods* (Mavuti & Litterick, 1991).

The species composition of the zooplankton community of Lake Victoria for the 1990s (modern) and 1960s (historical) (Table 6.3.1) indicate no significant differences. This is the case despite the fact that over the same time period, Lake Victoria has undergone drastic changes in its physical-chemical character, trophic status (Hecky, 1993), algal composition (Mugidde, 1993) and fish fauna (Kaufman 1992; Witte *et al.*, 1992) since the 1960s.

Most of the zooplankton taxa exhibit lakewide distribution, occurring in the littoral/sub-littoral, shallow nearshore zones as well as the deep offshore parts of the lake. An interesting distribution pattern is shown by one cladoceran species, *Daphnia lumholtzi,* a small-bodied, helmeted form occurring around nearshore areas and a large-bodied, round-headed "monacha" form only recovered in the deep open water (65m) off Bugaia island in the northern part of the lake (Branstrator *et al.*, 1996). Similar spatially segregated forms of *Daphnia* have been reported in the Lake Albert where (Green, 1967) has linked this distribution pattern to differential fish predation pressure. Rotifers also, present an exception to the lakewide distribution trend, being common and diverse (< 20 species) around the shallow nearshore areas and becoming rare and much less diverse in the deep open waters (Table 6.3.1).

Comparison of taxa in the shallow nearshore areas (including bays and gulfs) with open offshore waters (Fig. 6.3.1a & b) shows dominance of cyclopoid copepods both in terms of numbers and biomass compared to calanoid copepods and Cladocera. Rotifers occur with much higher densities in inshore relative to offshore waters. No clearly defined nearshore-offshore trends in abundance have been observed with respect to dipteran larvae in the lake. Relative proportions of major crustacean taxa remain generally constant throughout the year and in terms of mean water column abundance and rank as follows: Cyclopoida > Calanoida > Cladocera (Branstrator *et al.* 1996). Akiyama *et al.*, (1976) also observed high abundance of Copepoda compared to other taxa in the Mwanza Gulf in the southern part of the lake. He also reported Cladocera, which occurred in small proportions in the plankton but were found in large amounts in the gut contents of small catfishes such as *Schilbe mystus* and *Synodontis afrofischeri,* suggesting possible predatory regulation of populations of preferred zooplankton prey species.

An increasing gradient of areal zooplankton densities occurs from the shallow nearshore areas to the deeper open waters of the lake over a range of < 0.1 to > 4 million ind.m^{-2} (Mwebaza-Ndawula *et al.*, 2000). This trend represents an inverse relationship with the distribution of fish stocks in general as reported by Kudhongania & Cordone (1974) and Okaronon *et al.*, (1999). Pelagic densities of zooplanktivorous fishes including *Rastrineobola argentea*, some haplochromines and fish larvae are also reported to follow a similar trend (Mwebaza-Ndawula, 1998). Based on estimates made by Mwebaza-Ndawula (1998) the high densities of zooplankton observed in the deep open waters do not seem to be efficiently utilised for fishery production as the pelagic fish stock densities offshore are evidently very low. There are, however, indications of gradual recovery of pelagic haplochromines (Tumwebaze 1997) which may help channel more of the offshore zooplankton resource into fish production.

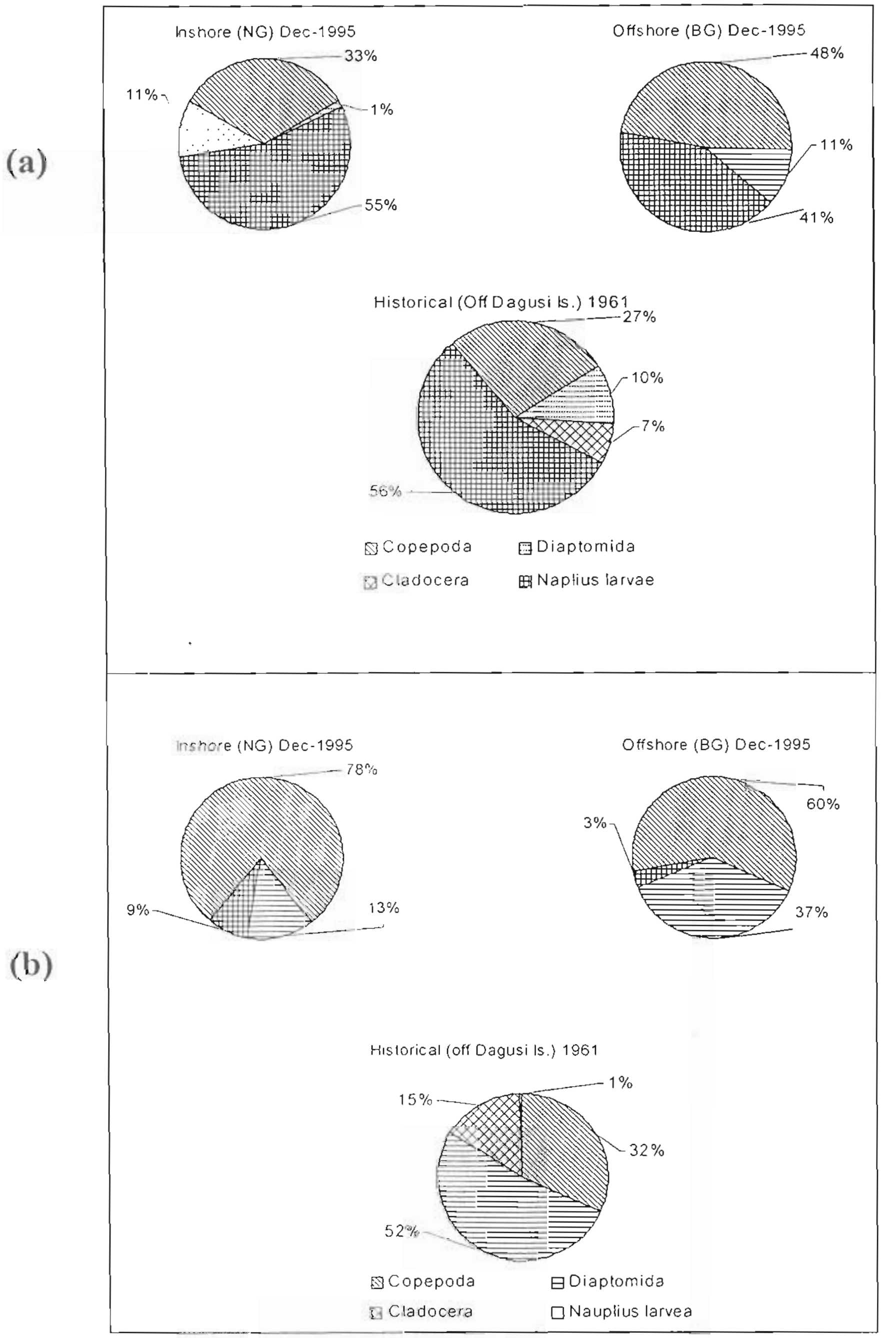

Fig. 6.3.1. (a) Zooplankton Relative abundance. (b) Biomass: modern (inshore, offshore) and historical. NG = Napoleon Gulf: BG = Bugaia.

Seasonal variation of zooplankton abundance at Bugaia, a deep, open water station in northern part of the lake shows a build-up of populations from January from about 1 million ind.m^{-2} through February, March and April culminating into a peak abundance of up to 6 million ind.m^{-2} in May (Fig. 6.3.2). Thereafter, a gradual decline occurs until December. Branstrator *et al.*, (1996) reported peak abundance occurring between April and August in the northern part of the lake. Akiyama *et al.*, (1976) made comparable temporal trends with respect to copepods in Mwanza Gulf in the southern part of the lake suggesting that the more abundant copepoda drive the observed seasonal variation in abundance. This seasonal regime is generally similar among the different crustacean taxa and the peak abundance coincides with the annual turnover of the lake and increased primary productivity (Branstrator *et al.*, 1996). However, year-to-year variation in the timing of on-set, build-up and attainment of peak concentrations of populations may be expected due to variations in local environmental conditions. It is not certain to what extent planktivorous fish species and carnivorous invertebrates (i.e. *Chaoborus, Mesocyclops* spp.) in the lake play in influencing the annual fluctuations in zooplankton abundance through predation impacts. Nonetheless, Mwebaza-Ndawula (1998) found low zooplankton densities in the Napoleon Gulf to coincide with high pelagic densities of larval *R. argentea* during the month of July while at the deep offshore waters where very low pelagic fish densities occurred, high zooplankton abundance was common.

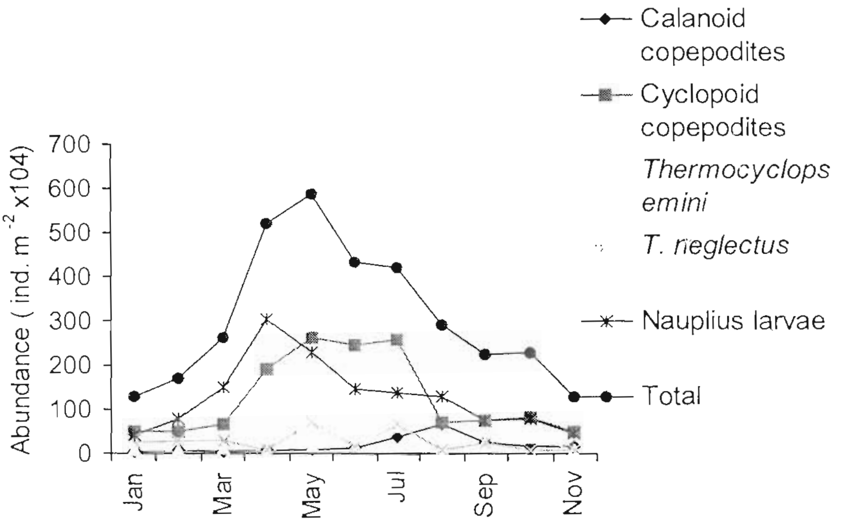

Fig. 6.3.2. Seasonal variation in abundancy(no/m2) of Zooplankton taxa at Bugaia offshore station, Lake Victoria.

Historical changes in zooplankton relative abundance

Relative abundance and biomass of different taxa from two inshore areas i.e. the Napoleon Gulf (NG) in 1995 and off Dagusi island in 1961 indicate remarkable changes between the communities of the 1960s and those of the 1990s (Fig. 6.3.3A & B). Substantial increase in the proportion of cyclopoid copepods from ca. 54% in the 1960s, to ca.82% of the total zooplankton in the 1990s is indicated. Over the same period, Cladocera and calanoid copepods show a drastic decline from ca. 30% and 13% during the 1960s to ca. 2% and 3% respectively in the 1990s (Fig. 6.3.3A). Corresponding dry weight data (Fig. 6.3.3B) show similar changes. Such shifts in abundance are probably associated with eutrophication processes as observed elsewhere by Green (1976) resulting from, among others, changes in algal faunal composition and abundance (quality and quantity) reported by Mugidde (1993). The current algal community dominated by cyanobacteria species including *Anabaena, Cylindrospermopsis, Planktolyngbya* and *Microcystis* is largely of poor nutritive value to most grazers in the lake. Decline in abundance of commonly favourite fish prey organisms such as Cladocera suggests either alterations in predation pressure probably related to drastic changes in fish species composition or food supply over the past four decades. Low pelagic (planktivorous) fish densities have been observed at Bugaia (Mwebaza-Ndawula, 1998), a deep offshore water station where the large-bodied, *Daphnia lumholtzi 'monacha'* is confined (Branstator *et al.*,1996).

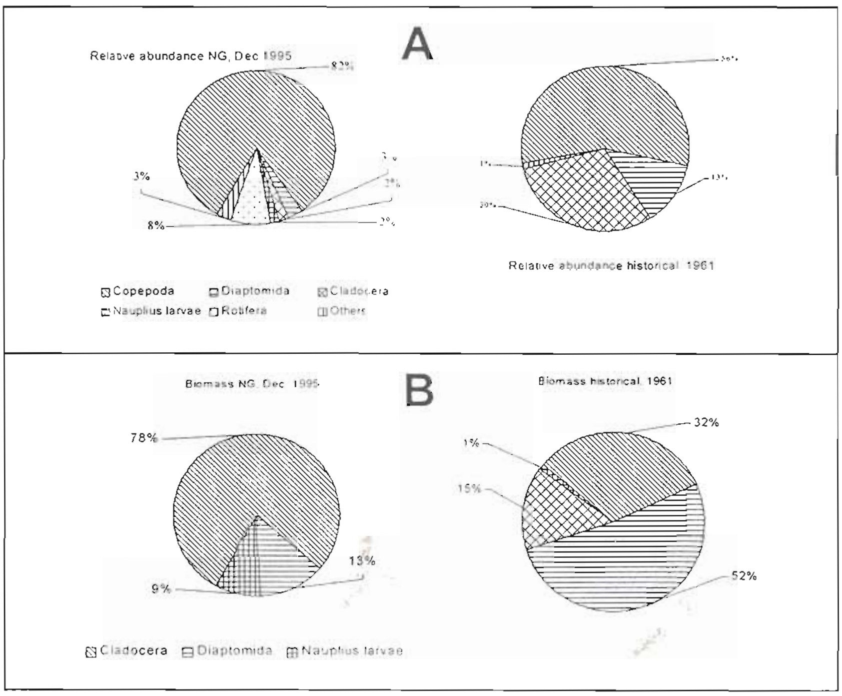

Fig. 6.3.3. Relative abundance and dry weight of different Zooplankton taxa in samples from inshore (Napoleon) Gulf, 1995 and historical (off Dagusi Island, 1961) samples from Lake Victoria.

Size structure and biomass of historical and modern communities

The size structure of the zooplankton community in the nearshore zone of Napoleon Gulf (NG, December 1995 and July 1996) and offshore zone of Bugaia (BG, December 1995) compared with a historical community (off Dagusi Island, 1961) (Fig. 6.3.4) shows interesting contrasts and similarities. Naupiius larvae and rotifers dominate the lower size range between 100 and 200µM while calanoid copepods dominate the upper size range between 1000 and 1500µM. Cyclopoid copepods and to a less extent cladocerans occur between the two size ranges . In all four data sets there is remarkable domination of the communities by cyclopoid copepods (copepodites, adults and nauplius larvae), while proportions of calanoid copepods and cladocerans are generally low across all size classes (Fig. 6.3.4). Comparison of the December 1995 nearshore and offshore size distributions shows the occurrence of low proportions of large-bodied calanoid copepods (> 900µM) in the nearshore area. In contrast, mean numbers of rotifers and naupliar larvae indicate high abundance nearshore compared to offshore. Cyclopoid copepods over the size range 500-700µM were found to be less abundant in nearshore compared to offshore plankton. Cladocerans show very low occurrence (hardly detectable in Fig. 6.3.4) in both nearshore and offshore plankton communities which probably manifests a historical change as noted above.

Nearshore zooplankton size structure during July 1996, though basically similar to the December 1995 pattern, shows striking differences as well. Some Cladocera, (namely *D. excisum. Ceriodaphnia cornuta, Daphnia longispina, D. lumholtzi, Chydorus sphaericus* and *Moina micrura*) and large-bodied cyclopoid copepods (900-1400µM) were observed in the plankton at this time of the year. This period (Juiy) coincided with low pelagic fish density (Mwebaza-Ndawula, 1998). Such reciprocal relationships between abundance of predator and prey commonly indicate cause-and-effect trophic interactions. Cladocerans in the historical community occurred over a wide size range (200-1400µM) compared to that of the 1990s. The occurrence of large-bodied cyclopoids copepods such as *M. aequatorialis*) in the 900-1400µMsize range is also worthy of special mention because such big-bodied cyclopoids are not common in the modern zooplankton community.

[1] This size structure excludes the largest and mostly meroplanktonic elements such as the atyid prawns, *Caridina nilotica* and Chaoborus larvae.

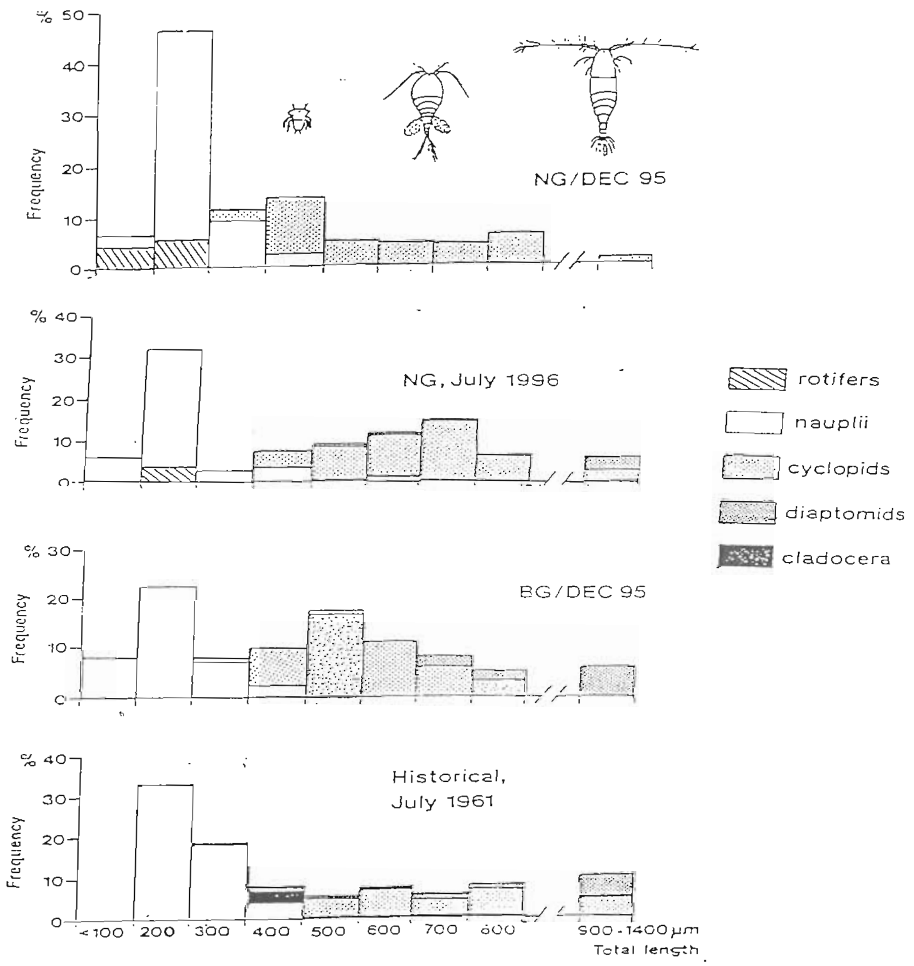

Fig. 6.3.4. **Zooplankton size structure in northern Lake Victoria: modern (1995) vs historical (1961) communities.**

Biomass distribution of different size categories of zooplankton confirms the dominance of cyclopoid copepods in time and space (Fig. 6.3.5). Cyclopoids contributed 68-75% and ca. 50% of the total zooplankton biomass in December 1995 and July 1996 respectively. Corresponding calanoid contributions were between 12 and 46%. In general, the percentage of cyclopoid biomass was higher in nearshore compared to offshore waters while the reverse was true for calanoid biomass. A small difference in cyclopoid biomass occurred between the December 1995 and July 1996 inshore samples (68.6 - 75.2%), while the July 1996 calanoid biomass (26.6%) for the same area was nearly double the December 1995 value (12.9%).

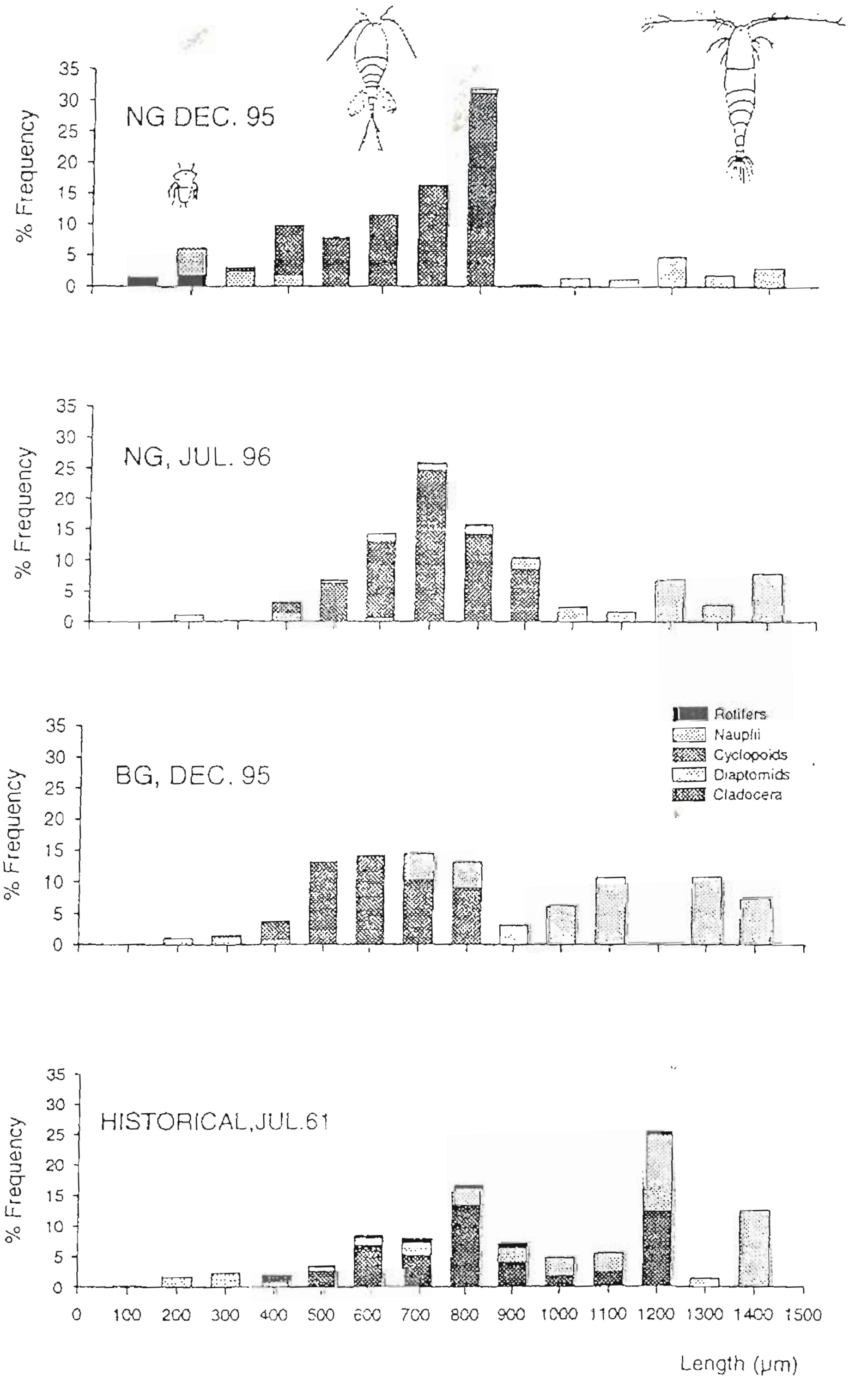

Fig. 6.3.5. Zooplankton size - biomass structure in nothern Lake victoria: modern (1995) vs historica communities

Comparison of cyclopoid and calanoid biomass between historical and modern zooplankton indicate an increase of cyclopoid biomass from 50.7% to 68.6 - 75.2% while calanoids show a decline from 39.9% to 12.9-26.6%. These patterns of biomass confirm earlier records on historical changes in relative abundance (Mwebaza-Ndawula 1994). It should be noted that biomass of the numerous but small-bodied nauplii and rotifers and the rare cladocerans is negligible in all communities, although the latter are detectable (up to 1%) in the historical and July 1996 data.

Apparent differences between nearshore and offshore of zooplankton composition, size and biomass may be linked to possible horizontal gradients in distribution and abundance of both fish (Green 1967) and invertebrate (i.e. *Mesocyclops* spp., Chaoborus larvae, acarid mites and planktonic flatworms) predators. On the other hand, difference in the cladoceran content and biomass between the December 1995 and July 1996 nearshore communities at Napoleon Gulf seem to imply a seasonal response to changes in planktivorous fish abundance. Relative similarity in size structure, biomass and cladoceran content between the historical and the July 1996 nearshore communities may be associated with both seasonal and long-term changes in levels of planktivory and food supply. Shifts in planktivory may have occurred due to changes in fish species composition following establishment of the introduced Nile perch in the lake (Ogutu-Ohwayo 1990). Changes in quality and quantity of algal food for invertebrates have been observed in association with development of eutrophication in the lake (Mugidde 1993).

Macro-invertebrate community

Composition, distribution and abundance

Macro-benthic organisms comprise both crustaceans and non-crustaceans. Crustaceans are represented by the atyid prawns *Caridina nilotica* while non-crustaceans are a diverse group comprising larvae of lakeflies (chaoborids and chironomids), molluscs, nymphs of mayflies (Ephemeroptera), caddisflies (Trichoptera), dragonflies (Odonata), oligochaetaes and nematodes (Table 6.3.2).

Table 6.3.2. Occurrence of macro-invertebrate taxa from inshore and offshore samples, Lake Victoria, 1998-2001.

		Occurrence	
Taxa	Family/Species	Inshore	Offshore
Odonata	Libellulids	P	A
Gastropoda	*Bellamya* spp.	P	P
	Bulinus spp.	P	P
	Gabbia spp.	P	A
	Melanoides spp.	P	P
Pelecypoda	*Byssanodonta* spp.	P	P
	Caelatura spp.	P	A
	Corbicula spp.	P	P
	Sphaerium spp.	P	P
Ephemeroptera	*Caenis* sp.	A	P
	Povilla adusta	P	P
Decapoda	*Caridina nilotica*	P	P
Diptera	Ceratopogonids	P	P
	Chaoborids	P	P
	Chironomids	P	P
Conchostraca		P	A
Hirudinea		P	A
Nematodes		P	P
Oligochaetes		P	P
Ostracods		P	A
Tricoptera		P	P
No of taxa		20	15

Most macro-invertebrates exhibit wide distribution in the lake. Dipteran larvae (i.e. chaoborids and chironomids) are clearly the most abundant organisms especially around nearshore waters where mean densities of up to 1000 ind. m^{-2} and above are common followed by gastropods (ca.100 ind.m^{-2}) (Fig. 6.3.6a). Most other taxa occur at low abundance (< 100 ind.m^{-2}). The chironomid, chaoborid larvae and gastropods exhibit high frequency of occurrence compared to oligochaetes (Fig. 6.3.6b). In general, the near-shore areas support higher abundance of macro-invertebrates than the offshore areas although variations to this trend may arise due to sediment type and texture (Mwebaza-Ndawula *et al.*, 2001). An additional factor that has recently affected distribution and abundance patterns of macro-invertebrates is the water hyacinth, *Eichhornia crassipes*, which invaded the lake in the late 1980s. The floating mat of the weed provided new habitats for colonization by aquatic macro-invertebrates (Wanda *et al.*, 2001). The well-oxygenated outer fringes of the hyacinth mats at the interface with open water supported diverse and abundant invertebrate communities. However, deeper into the weedbed, the oxygen concentration in the water column below the mat declined. The low oxygen zone thus created was associated with decline in abundance and diversity of invertebrates typified by low oxygen-tolerant forms such as chironomid larvae, oligochaetes, Hirudinea and Coleoptera.

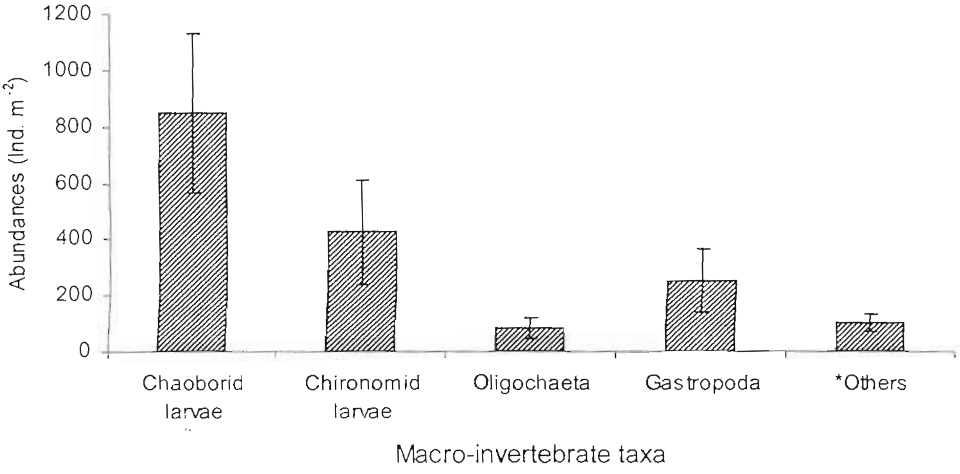

Fig. 6.3.6 (a) Adundance of major macro-invertebrate taxa in nothern Lake Victoria, 1995-1997

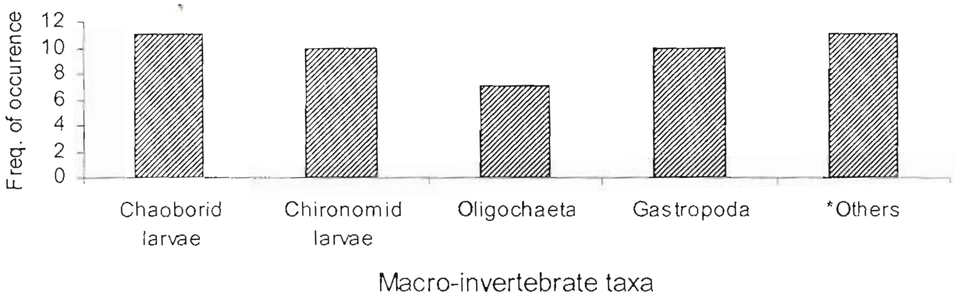

Fig. 6.3.6 (b) Frequency of occurrence of major macro-invertebrates taxa in northern Lake Victoria, 1995-1997.

Two macro-invertebrate taxa, *Caridina nilotica* and the dipteran (chironomid and chaoborid) larvae constitute key forage items for the commercially important Nile perch (Ogutu-Ohwayo, 1990) and a host of other native fish species (Greenwood, 1966; Corbet,1961). These ecologically more important macro-invertebrate taxa in the lake deserve special mention.

Dipteran larvae (lakeflies)

The dipteran larvae in Lake Victoria need detailed taxonomic description. However, based on features of the antenna and mouthparts it has been possible to separate two groups: *Chaoborus anomalus* Edw. and *C. pallidipes* Theo. Also two chironomid groups: Tanypus guttatipennis Goetgh. and Procladius umbrosus (Goetgh.) have been described. Historical records of Macdonald (1956) working in Ekunu bay in the north-eastern part of the lake indicate *Chaoborus anomalus* as most abundant at depths of 5-15 metres and rare in deeper waters. Macdonald (1956) recorded chaoborid areal densities of up to 2000-2500 indiv.m^{-2} representing 70% of total insect fauna. Corresponding abundance of chironomid larvae was 1000 indiv.m^{-2}. Periodic swarms of lakeflies extending several hundred metres above the water surface are a common phenomenon on Lake Victoria. The occurrence of the swarms appears to be sychronised with phases of the moon, with peak concentrations around the new moon. A recent study of secondary production of *Chaoborus* in Lake Victoria shows that average production amounts to ca. 6 mg C m^{-2} d^{-1} (Lehman *et al.*, 1998). This production amounts to about 1000-fold less than primary production and about one half that of the freshwater prawn, *Caridina nilotica*. The animals consume as much as 80% of their body weight daily, a consumption rate, which makes *Chaoborus* major agents of mortality on zooplankton prey especially in offshore areas of the lake.

Caridina nilotica (freshwater prawns)

The first record on *Caridina nilotica* in the lake is in the report by Worthington (1931) who captured a few organisms during a study of diel vertical migration of zooplankton. Fryer (1960) suggested the occurrence of two species of the genus *Caridina* with *C. nilotica* as an important member of the littoral fauna and the benthos of the lake. Little or no investigation of *C. nilotica* was done since these early records until the 1990s when Mbahinzireki (1992) undertook surveys on distribution and abundance in the northern part of the lake. Estimates by field net collections (Lehman *et al.*, 1996) and direct observation by underwater video at several offshore locations around Bugaia island, northern Lake Victoria indicated that *C. nilotica* can survive in low-oxygen zones (O_2 < 2.0 mg l^{-1}). These observations are largely born out by laboratory experiments which showed that survivorship and body growth are not significantly different between Caridina reared under low-oxygen conditions and those reared in well-oxygenated waters (Branstrator & Mwebaza-Ndawula, 1998). Occupation of low-oxygen areas by *Caridina* is likely to reduce predation pressure by the Nile perch although it inevitably affects the Nile perch production potential.

[2] Timing, frequency of sampling operations and type of gear used can influence population estimates of the prawns, which are known to engage in diurnal vertical migrations.

[3] ROV:remote operated vehicle

C. nilotica abundance has increased tremendously in recent decades following the collapse of haplochromine cichlids (Branstrator & Mwebaza-Ndawula, 1998) although low densities are shown in Table 6.3.2 . Witte *et al.*, 1992) reported that prawns became common in the catches of bottom trawl surveys in the Mwanza Gulf during the 1980s. In 1992, a trawl codend of 5mm-mesh size operated for 10 minutes harvested 100,000 individuals of *C. nilotica* in the same area (Budeba, 1999). Tweddle & Bassa (1999) recorded 40 kg of *C. nilotica* in a 30-minute frame trawl while Othina and Osewe-Odera (Unpublished report) reported 3180 tones of *Caridina* landed in Kenya waters during 1995. Densities of 2004, 1295 and 714 ind. m^{-2} were recorded from 6.5, 19.8 and 22m depths respectively in Mwanza Gulf in Tanzania waters during 1999 (Budeba, op.cit.).

Caridina nilotica attain a maximum adult body size of 2.5 cm and are common in littoral regions especially in weedbeds of submerged vegetation (Fryer,1960) but also occur as epibenthic, vertically migrating members of the offshore community. A study of abundance of *C. nilotica* in Lake Victoria using ROV midwater video transects (Lehman *et al.*, 1996) showed the prawns follow a Poisson distribution pattern. Daytime distribution showed concentration of the prawns at depth with ca. 200 ind.m^{-3} at 60m and less than 2 ind. m^{-3} at shallower depths. On the other hand, nightime distribution showed more or less homogeneous dispersion through the water column with maximum concentration of ca. 20 ind. m^{-3} at 20m depth. Derived areal density estimates of 1055 ind.m^{-2} (daytime) and 790 ind. m^{-2} (nightime) were given. Corresponding ROV data from bottom video transects gave estimates of 166 and 81 *Caridina* per square metre for day and night times respectively. In addition, *Caridina* were found to be significantly more abundant on the lake bottom during daytime than at night. Nonetheless, only 14% of the total estimated number of *Caridina* occurred on the lake bottom during daytime compared to 9% during nighttime. Mean abundances of *C. nilotica* based on 4 replicates of vertical net collections in offshore Lake Victoria showed consistently higher nighttime densities (125±11SE -1186±70SE ind. m^{-2}) compared to daytime densities (3±3SE - 909±41SE ind. m^{-2}) (Lehman *et al.*, 1996). From the same vertical net collections mean Chaoborus larvae (phantom midge) followed a similar day-night abundance pattern with 242±72SE - 978±17SE ind. m^{-2} for nighttime and 5±3SE -757±94SE ind.m^{-2} for daytime densities. These observations provide support for diel vertical migration behaviour exhibited by the two macro-invertebrates.

With the use of a model for secondary production in conjunction with abundance and size frequency data from an offshore station in Uganda waters, Ignatow *et al.*, (1996) estimated average net production for *C. nilotica* to be 11.4 mg cm^{-2} d^{-1}. This estimate is an order of magnitude greater than the fishery yield. On the other hand, Hart (2001) used molting intervals (MI) and per molt increments to estimate in situ growth rate and concluded that *C. nilotica* in Lake Victoria grows much faster (by ca. 20%) than previously estimated by Ignatow *et al.*, (1996). Notwithstanding the differences by the two workers, both growth rate estimates make the prawns a quantitatively significant forage item for fishes in Lake Victoria.

Ecological value of invertebrates

Aquatic invertebrates are important in the trophic dynamics of Lake Victoria as grazers on phytoplankton and as agents of nutrient recycling (Mavuti & Litterick, 1991) for organic production. The benthic invertebrates play a major role in activating the release of nutrients from the lake bottom back into limnetic waters (Okedi, 1990). One of the key and primary functions of aquatic invertebrates is the provision of food for different fish species, thereby contributing directly to fishery production. All fish larvae including those of commercially important species in the lake i.e. the Nile perch, *Lates niloticus*, *Rastrineobola argentea* and the Nile tilapia, *Oreochromis niloticus* feed on zooplankton as the first external food. Prawns currently constitute a major forage item to juveniles and sub-adults of *Lates niloticus* (Nile perch) in the lake (Ogutu-Ohwayo, 1990). They also occur in significant proportions in diets of the perch up to 80cm body length (Hughes, 1992).

Nile perch with gut engorged with *Caridina nilotica*

Nile perch gut slit open to show *Caridina nilotica*

***Caridina nilotica* out of a Nile perch gut**

Plate 6.3.2. The Kabaka's lake, a small water body in the Victoria basin area, lacking key invertebrate taxa such as *Caridina nilotica*, Odonata etc. supports an impoverished Nile perch fishery (FIRRI workshop report 2001).

On account of their feeding on detritus and numerical abundance *C. nilotica* are important as a means of keeping nutrients in solution and possibly as consolidators of bottom sediments Fryer (1960). By feeding on energy-rich detrital material that accumulates in large amounts at the bottom of the lake, *C. nilotica* plays a vital function of mobilising enormous amounts of energy from the hypoxic hypolimnion, bringing it back into the food chains for fishery production. This function is accomplished by the high tolerance of low oxygen conditions (Branstrator & Mwebaza-Ndawula, 1998) in the hypolimnion especially during annual spells of thermal stratification.

In Lake Victoria, the pelagic cyprinid, *Rastrineobola argentea* thrives entirely on a diet of zooplankton with copepods as the major food item (Mwebaza-Ndawula & Schiemer 1997; Mwebaza-Ndawula, 1998). As a valuable source of proteins, amino acids, lipids, minerals and enzymes (Kibria *et al.*, 1997) zooplankton are extensively used to add value to fishmeal in aquaculture practices (Watanabe *et al.*, 1983; Millamena *et al.*, 1990).

Some invertebrates such as rotifers, cladocerans, chironomid (midge) larvae, aquatic worms, leeches, left-handed snails etc can be used as bio-indicators of environmental degradation. This is an important function especially in view of the current high rate of municipal, agrochemical and industrial wastewater discharges into the lake (Calamari *et al.*,1995). Zooplankton respond quickly to environment change and are considered effective indicators of subtle alterations in water quality (Gannon & Stemberg, 1978). A commonly used example is the ratio of calanoid copepods to other major groups of zooplankton, which appear to have value in identifying relative differences in trophic conditions. Saether (1979) has elaborated on the use of ratios of chironomids to oligochaetes and distribution patterns of single species in pin-pointing localised areas of pollution. In Lake Victoria today, the red type of chironomids or "blood worms" are now of common occurrence in bottom sediments in areas where anoxic conditions prevail especially during periods of thermal stratification (October-March).

In a recent biodiversity survey of water bodies in the Victoria basin, the small-bodied and ecologically less valuable rotifers have been found to be more diverse and abundant in the shallow nearshore waters of Lake Victoria compared to the less eutrophic offshore waters of the lake (Mwebaza-Ndawula *et al.*, 2001). From the same survey, eutrophic small water bodies in the Victoria basin area including lakes Wamala, Mburo, Kachera and the Kabaka's lake have been found to support higher diversity and abundance of rotifers compared to other basin water bodies (Mwebaza-Ndawula *et al.*, op.cit.). Reduced species diversity of Cladocera and increased diversity of rotifers reported by Mavuti and Litterick (1991) in the more eutrophic Winam Gulf is consistent with observations in the Ugandan part of the Victoria basin area.

Long-term changes in relative abundance of key fish food items such as calanoid and cyclopoid copepods, Cladocera, rotifers and *C. nilotica* and the occurrence of low-oxygen tolerant forms indicate deterioration of the water quality and changes in food-web dynamics. Such changes in the zooplankton communities of Mutanda and Mulehe lakes in western Uganda were attributed to, among other things, the development of eutrophication (i.e. over-fertilization of the water through excessive nutrient loading) (Green, 1976). In Lake Victoria eutrophication and pollution (water contamination) have developed simultaneously over the past four decades and are correlated with increase in human and livestock populations, urbanization and industrialization in the lake basin. These events have coincided with shifts in relative abundance of some elements of the invertebrate communities as noted in the fore-going sections. The resulting increased abundance of important forage items such as cyclopoid copepods and *C. nilotica* is vital for sustenance of commercially important fish species, such as *Lates niloticus* and *Rastrineobola argentea*. On the other hand, the development and dominance of zooplankton communities by small-bodied rotifers in small, eutrophic water bodies (Mwebaza-Ndawula *et al.*, 2001) in the Victoria basin does not augur well with increased fishery production. In absence of specific legislation for protection of aquatic invertebrate communities, steps need to be taken to enforce existing regulations on pollution, eutrophication and protection of riparian wetland zones which function as natural filters of in-coming materials from the catchment. The relevant regulations are embedded in the Public Health Act 1935, the Public Land Act 1998, the Water Statute of 1995 and the Wetland Policy. Upholding of the provisions in these legal instruments constitutes a key step towards protection of the environment of ecologically and economically valuable invertebrate and fishery resources.