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Summary

There is paucity of data on benthic organisms in Lake Victoria, as in many other African lakes. A study to ascertain the biomass, standing crop and spatial distribution of benthic organisms in the northern shores of Lake Victoria indicated a rich benthic fauna composed mainly of insects, molluscs and oligochaetes. Total biomass for the 200 km^2 Murchison Bay was 146,000 tonnes. The lamellibranchs formed the highest biomass (68,940 t) followed by gastropods (30,840 t), insects (25,760 t) and annelids (20,460 t). Mean standing crop biomass values for genera in the various taxa were determined from their spatial distribution patterns (mean numbers per unit area) and mean individual weights. The high benthic biomass is currently under-utilized by benthic organisms at higher trophic levels and consequently represents utilizable organic matter directly or indirectly for man's benefit. Hence, a lakewide study is recommended.

Key words: benthos, Lake Victoria, East Africa, biomass.

Résumé

On possède peu de données sur les organismes benthiques du lac Victoria comme de beaucoup d'autres lacs africains. Menée dans le but de connaître la biomasse, l'inventaire et la distribution spatiale des organismes benthiques sur les bords nord du lac Victoria, une étude a révélé une faune benthique riche, composée principalement d'insectes, de mollusques et d'oligochètes. La biomasse totale pour les 200 km^2 de la Murchison Bay était de 146,000 tonnes. Les lamellibranches en composaient la plus grande part (68,940 t), suivis par les gastéropodes (30,840 t), les insectes (25,760 t) et les annélides (20,460 t). Les valeurs moyennes de biomasse par genre des différents taxons ont été déterminées à partir du schéma de leur distribution spatiale (nombres moyens par unité de surface) et du poids individuel moyen. La biomasse benthique élevée est actuellement sous-utilisée par les organismes benthiques des ordres trophiques supérieurs et représente par conséquent une matière organique directement ou indirectement utilisable au profit de l'homme. On recommande donc une étude à l'échelle du lac entier.

Introduction

Lake Victoria has a total area of 66,500 km^2 with mean depth of 40 m and maximum depth of 79 m. It lies between longitude 30°30′E and 34°31′E and

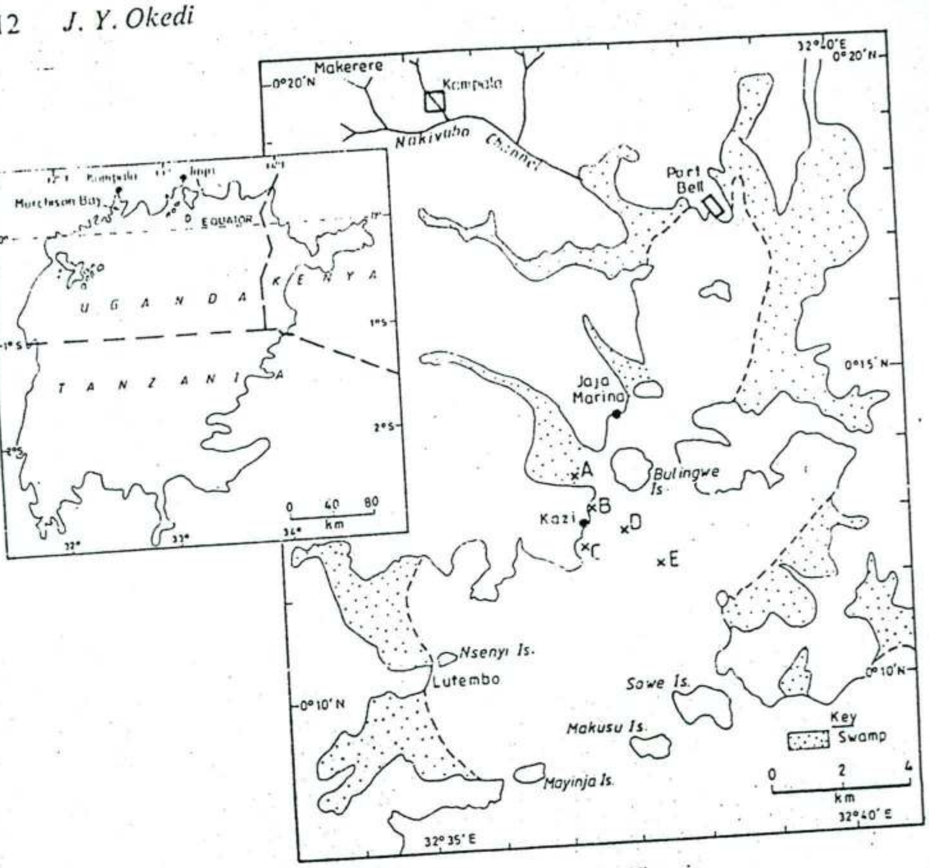


Fig. 1. Map of Murchison Bay, Lake Victoria.

latitude 00°30'N and 02°31'S. It is the second largest lake in the world and is shared between Kenya, Uganda and Tanzania (Fig. 1).

Murchison Bay is located in the northwestern part of the lake in Uganda, some 14 km from Kampala City. The Bay has an area of about 200 km^2 with a shoreline length of 124 km and a mean depth of 8 m. It lies between longitude 32°33' and 32°41' East and latitude 00°05' and 00°18' North at an altitude of 1154 m. The Bay has several small islands including Bulinguge, Nsenyi, Mayinja, Makusu and Sowe. The bottom is predominantly sandy with mud near fringing vegetation and rock near rocky shores. Although the bottom of Murchison Bay is mainly sandy, a thick layer of debris is found in areas adjacent to papyrus and this was the main area of sampling as it consisted of muddy material derived from vegetable decomposition. Here the papyrus swamps are surrounded by forests but within the swamp water lilies float in open water spaces. The predominant fringing vegetation type is *Cyperus papyrus*, *C. rotundus* and *Phragmites communis*. Further inland are forested areas composed of *Maesopsis emini*, *Lovoa brownii* and *Ficus mucuso*.

Past workers in Lake Victoria concentrated on ichthyological studies (Corbet, 1961; Greenwood, 1960). Hartland-Rowe, 1955; Macdonald, 1956, Corbet *et al.*, 1955; and Corbet, 1958 studied lakeflies (Chironomidae, Chaoboridae and *Povilla adusta*, Ephemeroptera) and showed lunar periodicity in their patterns of emergence in Lake Victoria. Phytoplankton has been extensively studied (Talling, 1965, 1966; Beedle, 1974; and Visser, 1974) and Ochumba & Kibaara (1989), amongst others, have revealed tendencies towards algal blooms in the lake. Yet these are important trophic segments in the trophic relations of the lake, playing a major role in feeding ecology and nutrient recycling between autotrophs and heterotrophs. This study is one of the first attempts to quantify benthic organisms in Lake Victoria. The biomass and patterns of distribution of benthic invertebrates (Insecta, Mollusca and Annelida) were studied in a shallow bay in the northern portion of the lake.

Materials and methods

Five sampling stations were established along the Kaazi area of Murchison Bay and were sampled regularly twice-monthly from November 1987 for six months. Station A was near the shore, fringed by *Cyperus papyrus* in water about 1·5 m deep. Station B (1·5 m water depth) was fringed by *Cyperus rotundus*. Station C (1·5 m water depth) was fringed by *Phragmites communis*. The water column here was dominated by dead fibrous vegetable matter and the bottom was composed of rotting macrophytic material in varying stages of decomposition. Station D was an offshore station 500 m from the shore in clear open water about 8 m deep but with muddy bottom. The substratum here was composed of flocculent dark grey mud with little or no vegetable matter. Station E, also offshore and 500 m from Station D, had a sandy bottom at a depth of 8 m. The sand was mainly fine-grained and brown in colour mixed with some fine greyish silt.

Pieces of fresh rotting vegetation types were cut out from the fringing vegetation and kept in separate buckets before being weighed and carefully split open. The insect larvae boring into the plant material were identified with the aid of a binocular microscope, weighed and preserved in 5% formaldehyde solution.

Bottom samples from Station A, D and E were collected using an Eckman dredge with an opening of 225 cm^2. Two dredges from each station were usually taken as standard, and their contents, often mud, sand or debris, were emptied into separate numbered buckets. In the laboratory the samples were sieved several times through progressively finer meshed sieves (0·6, 0·5, 0·2 and 0·075 mm) to reduce bulk. The invertebrates retained in the sieves were sorted, identified and counted at species level and weighed with a Mettler balance after partial drying on filter paper.

Observations

Povilla adusta

Povilla nymphs were collected from three main host plants, *Cyperus papyrus*, *C. rotundus* and *Phragmites communis* in Stations A, B and C. The numbers and weight of *Povilla* caught per sampling day are given in Table 1 for each host plant. The largest number of nymphs caught was 49 in *C. papyrus* and the fewest was 3 in *Phragmites*. The largest number of *Povilla* caught were found in *Cyperus papyrus* (226) but the lowest number (41) in *Phragmites*. This may perhaps indicate a habitat preference of *Povilla* over *Cyperus papyrus*, moderate attraction for *C. rotundus* and least preference for *Phragmites*. However, a piece of dried submerged wood carried 729 nymphs (Table 1) giving the highest density of nymphs collected during this study.

Table 1. Numbers of *Povilla* caught per kg host plant material with their biomass (g) in parentheses

Plant host	Number per kg		Percentage %
Cyperus papyrus	32	(4·992)	4·1
C. rotundus	16	(2·486)	2·0
Phragmites communis .	6	(0·936)	0·8
Dried plank	729	(113·724)	93·1

It is interesting to note that calculated as a percentage of host material, 11% of the weight of the plant material was made up of *Povilla* nymphs, whereas they formed only 0·5% of submerged *C. papyrus*, 0·25% of *C. rotundus* and only 0·1% of submerged *Phragmites*. These figures can be used as a guide to estimate *Povilla* biomass in certain submerged woody materials. However, *Povilla* biomass in submerged logs is related to the state of decomposition of the host material.

Povilla was also collected with the Eckman dredge, from the muddy bottom of Station A and D (Table 2) and a few from the sandy bottom of Station E. In the Bay as a whole the *Povilla* formed 30% of all the benthic insects as shown in Fig. 2 with 15% occurring in Station A, 14% in Station D and 1·3% in Station E. This indicates that *Povilla* nymphs are found also in the benthos away from the fringing vegetated zone of the Bay. Their biomass has been calculated based on a mean fresh weight of 0·15 per individual (Table 3), as 40 g m^{-2} (Table 4). Their total biomass for the Bay is shown in Fig. 3 as 7920 t. This composition, however, does account for *Povilla* boring into plant material both along the shore and submerged in the Bay.

Chironomidae

Chironomids were the most abundant insect larvae in both inshore and offshore station. The mean number was 978 m^{-2} in Station A, 765 m^{-2} in Station D and 265 m^{-2} in Station E (Table 2). Chironomids made up 63% of all the benthic insects in the Bay (Fig. 2). However, 30% occurred in Station A, 24% in Station D and 8·5% in Station E. It becomes apparent at this stage that the chironomids prefer a mud bottom.

With a mean weight of 0·12 g (Table 3) the mean standing crop biomass of the Chironomidae was calculated as g 80/m^2 (Table 4). However, Station A had a biomass of 117 gm^{-2}, Station D 92 gm^{-2} and Station E 32 g m^{-2}. For the whole Bay, the chironomid biomass was estimated at 16,060 t constituting 11% of all the organisms in the Bay (Fig. 3).

Chaoborus *larvae*

The mean numbers of *Chaoborus* per square metre are given in Table 2 as 25 for Station A, 38 for Station D and 12 for Station E. The mean weight of an individual was 0·13 g (Table 3). Its standing crop in g m^{-2} was 3 for Station A, 5 for Station D and 1·6 for Station E (Table 4). The chaoborids made up less than 2% of the benthic insects, 1·2% of which occurred in Station D. Both Station A and E made up less than 1% of all the organisms shown in Fig. 3.

Table 2. Mean numbers of organisms caught per m² in three stations in Murchison Bay

Class	Station A	Station D	Station E
Lamellibranchs	(103)	(219)	(130)
Mutela	2	2	23
Pisidium	59	175	105
Caelatura	42	42	2
Gastropoda	(205)	(291)	(36)
Bellamya	108	206	28
Mellanoides	17	76	8
Biomphalaria	70	3	0
Bulinus	10	6	0
Insecta	(1412)	(1186)	(317)
Povilla	382	377	32
Chironomidae	978	765	265
Chaoborus	25	38	12
Odonata	21	3	8
Belastome	6	3	0
Annelida	(301)	(41)	(624)
Oligochaeta	288	41	624
Hirudinea	13	0	0
	2021	1737	1107

Odonata nymphs

The distribution of the Odonata is mainly inshore (Table 2), with 21 km^{-2} being caught in Station A, 3 in Station D and 8 in Station E. In all the three stations they composed 1% of all the organisms. Amongst the insects, the Odonata were less than 3%, 2% of which occurred in Station A. Sixty-five percent of all the specimens were found in the shallow inshore station. However, Odonata nymphs are heavy, with a mean weight of 0·35 g (Table 3). Their standing crop (g m^{-2}) was 3·7 (Table 4) but total biomass was calculated at 740 t or 0·5% of all the organisms in the Bay (Fig. 3).

Belostome larvae

The composition of *Belostome* larvae was low, 6 in Station A, 3 in Station D and none in Station E. Table 2 shows this genus as predominantly prefering a mud bottom; 66% in Station A alone and 34% in Station D. The mean biomass was almost 2 g m^{-2} (Table 4) giving a biomass of 380 t for Murchison Bay as a whole (Fig. 3).

Thus benthic insects made up 18% of the total biomass of benthic invertebrates in the Bay (Fig. 4). However, Station A contained their largest biomass, 33%, with Station D at 26% and Station E just 4·2%.

The Lamellibranchs

Lamellibranch molluscs occurred in three stations; 103 m^{-2} in Station A, 219 m^{-2} in Station D and 130 m^{-2} in Station E (Table 2). However, they tended to prefer the muddy offshore Station D where 48% of them occurred. Only 22% were found in

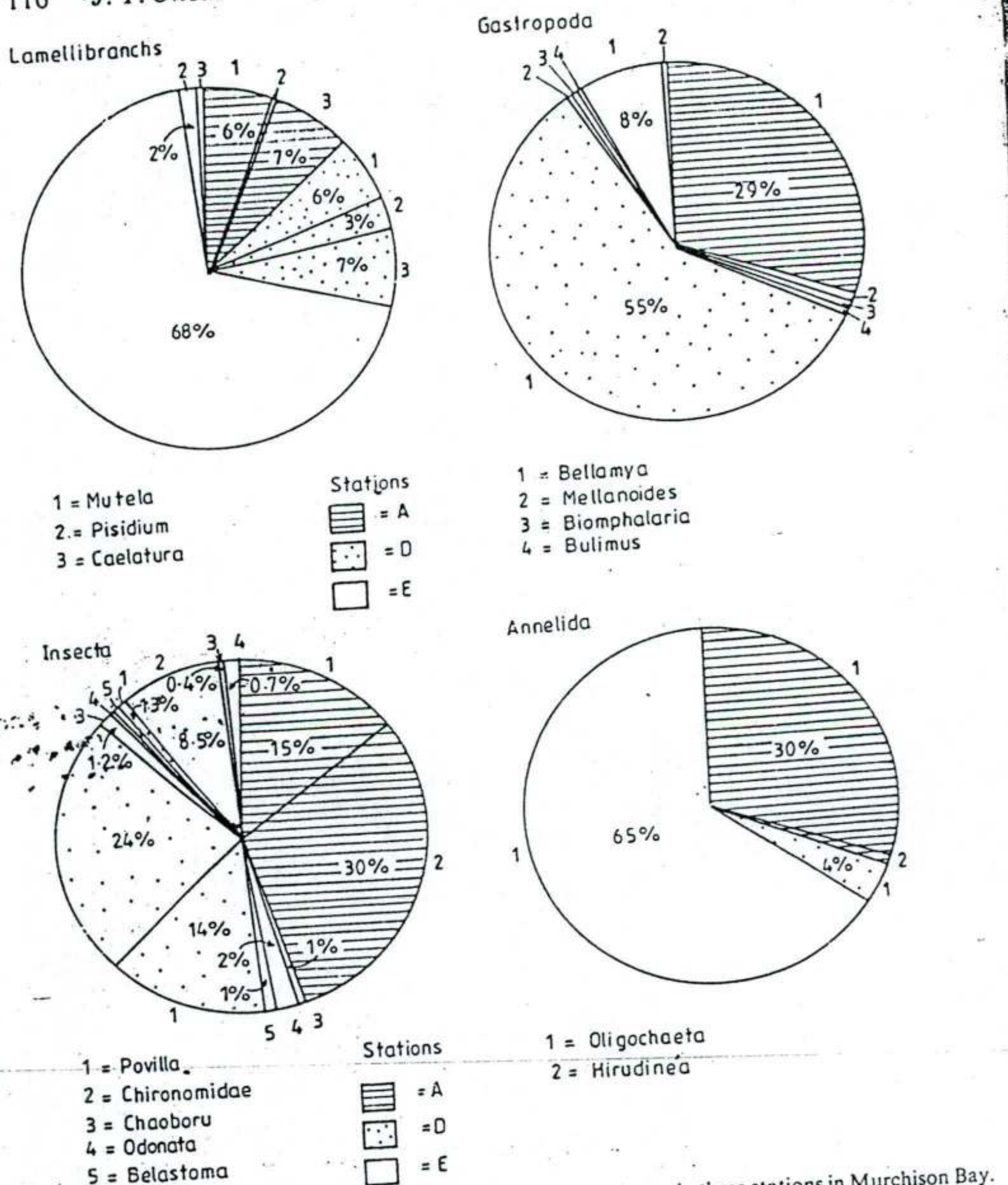


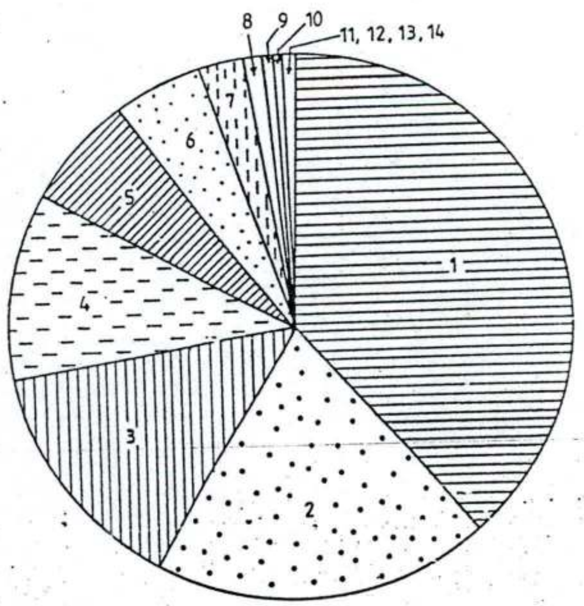
Fig. 2. Percentage composition of four major invertebrate classes in three stations in Murchison Bay.

the inshore station and 29% occurred in the sandy bottom offshore station. Their biomass formed 47% of the biomass of all the organisms in the Bay (Fig. 4).

In Station A the main component of the lamellibranchs was the genus *Pisidium* ($59\ m^{-2}$—Table 2), but Station D was their favoured habitat ($175\ m^{-2}$). *Pisidium* was also heavily present in the sandy bottom station ($105\ m^{-2}$). *Pisidium* is a small lamellibranch with a mean weight of 0·16 g. Its standing crop (Table 4) was $18\ m^{-2}$ (28 g in Station D, 17 g in Station E and 9 g in Station A) with a total biomass for the Bay of 3620 t.

Table 3. Mean fresh weights per individual of various benthic organisms in Murchison Bay

Organism	Number weighed	Mean weight (g)
Mutela	3	31·03
Pisidium	60	0·16
Bellamya	20	1·25
Mellanoides	30	0·25
Biomphalaria	12	0·12
Oligochaeta	50	0·32
Odonata	20	0·35
Povilla	30	0·15
Chironomidae	40	0·12
Chaoborus	30	0·13
Belostoma	3	0·62
Hirudina	10	0·15
Caelatura	10	1·65
Bulinus	40	0·07



1. Mutela	= 558060 m.t	8. Mellanoides	= 1680 m.t
2. Bellamya	= 28500 "	9. Odonata	= 740 "
3. Oligochaeta	= 20320 "	10. Chaoborus	= 660 "
4. Chironomidae	= 16060 "	11. Biomphalaria	= 580 "
5. Caelatura	= 9460 "	12. Belastome	= 380 "
6. Povilla	= 7920 "	13. Hirudinea	= 140 "
7. Pisidium	= 3620 "	14. Bulinus	= 80 "

Fig. 3. Biomass (t) of the major taxa of benthic communities in Murchison Bay.

Table 4. Mean standing crop biomass (g m^{-2}) from three stations in Murchison Bay. T = total biomass across the three stations

	Stations A	D	E	Mean biomass
Lamellibranchs				
Mutela	62·1	62·1	713·7	279·3
Pisidium	9·4	28·0	16·8	18·1
Caelatura	69·3	69·3	3·3	47·3
	140·8	159·4	733·8	(T = 1034)
(%)	(13·6)	(15·41)	(70·1)	
Gastropoda				
Bellamya	135·0	257·5	35·0	142·5
Mellanoides	4·3	19·0	2·0	8·4
Biomphalaria	8·4	0·4	0	2·9
Bulinus	0·7	0·4	0	0·4
	148·4	277·3	37·0	(T = 462)
(%)	(32·1)	(60·0)	(8·0)	
Annelida				
Oligochaeta	92·2	13·1	199·7	101·6
Hirudinea	2·0	0	0	0·7
	94·2	13·1	199·7	(T = 307)
(%)	(30·6)	(4·3)	(65·1)	
Insecta				
Povilla	57·3	56·6	4·8	39·6
Chironomidae	117·4	91·8	31·8	80·3
Chaoborus	3·2	4·9	1·6	3·3
Odonata	7·4	1·1	2·8	3·7
Belastome	3·7	1·9	0	1·9
	189·0	156·3	41·0	(T = 386)
(%)	(49·0)	(40·5)	(10·6)	

Similarly *Mutela* was well represented in the sandy offshore Station E (23 m^{-2}—Table 2); both the shallow muddy Station A and offshore Station D had very few *Mutela* (2 m^{-2}). However, *Mutela* is a very heavy Lamellibranch with a mean weight of 31 g. Therefore, its mean standing crop (Table 4) was 279 g m^{-2}, although Station E contained its highest standing crop (713 g m^{-2}) with only 62 g m^{-2} in the other station. *Mutela* had therefore a total biomass of 55,860 in the Bay (Fig. 3) and this was 38% of the biomass of all the invertebrates.

Caelatura, on the other hand, showed marked preference for the muddy bottom, 42 m^{-2} in both Station A and Station D, but only 2 m^{-2} in Station E (Table 2). However, *Caelatura* is a light lamellibranch with a mean weight of 1·65 g, giving a standing crop per m^2 (Table 4) of 47 g. *Caelatura* has therefore a moderate biomass of 9460 t in the Bay (Fig. 3) which was 6·5% of the total biomass of all the organisms in the Bay.

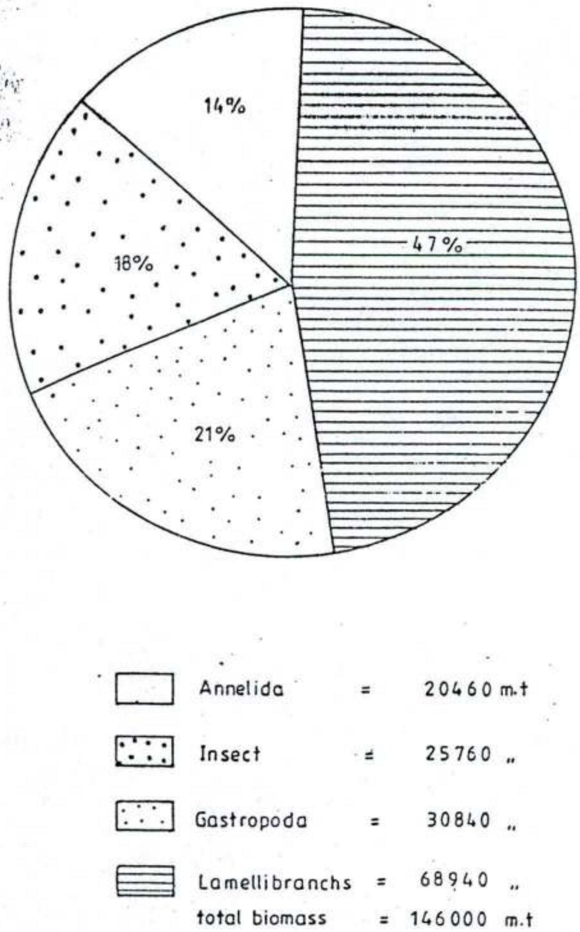


Fig. 4. Biomass of the major benthic invertebrates in Murchison Bay.

The lamellibranchs are therefore very important in Murchison Bay; their biomass is the highest of all the major taxa forming 47% of all encountered benthic organisms in the Bay.

The Gastropoda

The gastropod molluscs were equally important in the Bay with 205 m^{-2} in Station A and, 291 m^{-2} in Station D (Table 2). Their number dropped significantly to only 36 m^{-2} at Station E.

Bellamya was the most prevalent genus in all the three stations. Its highest occurrence was in Station D (206 m^{-2}). In the inshore mud bottom Station A, there were 108 m^{-2}, while fewer *Bellamya* occurred in Station E (28 m^{-2}). Hence, *Bellamya* was the most common gastropod in the Bay, but it tended to prefer muddy bottoms. This gastropod is medium-sized (1·25 g mean weight). As expected its heaviest standing crop occurred in Station D at 257 g m^{-2}. Table 4 further shows a standing crop of 135 g m^{-2} in Station A but only 35 g m^{-2} in Station E. Its mean standing crop for the Bay was therefore 142 g m^{-2} giving a total estimated biomass of 28,500 t for *Bellamya* in the Bay as a whole (Fig. 3).

Three other gastropods occurred in the Bay, namely *Mellanoides*, *Biomphalaria* and *Bulinus*. The last two genera are important secondary hosts of *Schistosoma mansoni* and *S. haematobium* (Beadle, 1974). Schistosomea are important vectors of bilharzia, which is a common human disease along the northern shores of Lake Victoria. Observations made here, however, reveal that both bilharzia-carrying snails are largely restricted to the shallow inshore waters (Table 2) and that *Biomphalaria* is more common than *Bulinus*—hence the prevalence of intestinal Schistosomiasis (carried by *Biomphalaria*) as opposed to the urinary type bilharzia which is carried by *Bulinus*.

Table 2 shows that 70 *Biomphalaria* per m^2 were found in Station A but only 3 m^{-2} were found in Station D. No *Biomphalaria* were found in the offshore sandy bottom Station E. *Biomphalaria* is a lightly built snail, mean weight 0·12 g (Table 3). *Biomphalaria* has a standing crop of 8 g m^{-2} in Station D (Table 4). Thus, its mean standing crop for the Bay is 2·9 g m^{-2} but total biomass was 380 t (Fig. 3).

The concentration of *Bulinus* was much lower (10 m^{-2}) in Station A and Station D (6 m^{-2}). No *Bulinus* occurred in the deeper offshore sandy bottom—Station E. *Bulinus* is a very light snail (mean weight 0·07 g) giving a standing crop of just 0·7 m^{-2} (in Station A) and 0·4 g m^{-2} in Station D (Table 4). Its total biomass for the Bay was therefore only 80 t (Fig. 3).

The other gastropod encountered was *Mellanoides* occurring at levels of 17 m^{-2} (Station A), 76 m^{-2} (Station D) and only 8 m^{-2} (Station E). At a mean weight of 0·25 g (Table 3) this genus gave a standing crop of 8·4 g m^{-2} and a total biomass of 1680 t for the whole Bay (Fig. 3). However, 75% of this biomass occurred in the mud bottom offshore Station D.

Annelida.

Two groups of annelids were encountered in Murchison Bay. The blood-sucking Hirudinea worms occurred at a very low level of 13 m^{-2} (Table 2) in the shallow inshore Station A only; none was found offshore. However, the annelids as a whole made up 16% of the biomass of the invertebrates in Station A, 20% in Station E and only 2% in Station D. However, in total, the annelids formed 14% of the biomass of all the benthic invertebrates in the Bay (Fig. 4).

The major annelid found was the oligochaete blood worm which occurred in all the three stations. The offshore sandy bottom Station E carried the highest density (624 m^{-2}), but blood worms were also common in the shallow inshore Station A (301 m^{-2}) (the offshore mud bottom Station D had only 41 m^{-2}). The oligochaete worms had a mean weight of 0·32 g and they had a standing crop of 102 g m^{-2} (Table 4) with total biomass estimated at 20,320 t (Fig. 3) for the whole Bay.

Discussion

In several studies of African lakes emphasis has been on the study of fish and limnological conditions. What little has been studied on benthos has included works related to biology, emergence and colonization of artificial substrata (e.g. Hartland-Rowe, 1955; Corbet & Tjonneland, 1955; McDonald, 1956; Corbet, 1958; Burgis *et al.*, 1973; Hare & Olisedu, 1987). The limnology of Lake Victoria has been well documented with the foundation works of Talling (1965, 1966), Beadle (1974) and Visser (1974).

The paucity of data on the benthos and substratum is therefore evident. Yet in lake ecosystems limnetic waters and the profundal zone are in constant interchange with the lake bottom, both in terms of chemical or ionic exchange of nutrients as well as constant biotal interaction. There are many benthic organisms which specialize in utilizing and exploiting the benthic zone for food, breeding and shelter. These bottom organisms play a major role in activating the release of nutrients from the lake bottom back into limnetic waters. Each unit or trophic level of the ecosystem is vital for the sustenance of the others. The benthos therefore plays a major role but its significance has been overshadowed by difficulties in the methodology of its sampling and assessment.

Lake Victoria is an interesting example that typifies many African lakes. There has been a tendency toward diminishing fish catches marking the virtual extinction of certain endemic haplochromiine (Wanik *et al.*, 1988) and tilapiine species. The introduction of the voracious predator *Lates niloticus* in the 1960s (Ligtvoet, 1988) had a detrimental effect on the fish biota. Lake conditions have deteriorated due to pollution (Awiti, 1984) in certain bays. There is therefore an urgent need to understand what changes are taking place in the lake and how lake flora and fauna are reacting to those changes. For example is Lake Victoria increasingly becoming eutrophic? At what rate and what are the factors causing eutrophication? Is the biota consequently changing rapidly in favour of euryhaline and more tolerant species? Evidently further studies are needed.

Some organisms inhabiting the benthic zone of Lake Victoria are very abundant but have hitherto not been directly utilized for man's benefit. The lakefly swarm in great numbers. The molluscs are there in great quantities. The oligochaete worms are plentiful. The data given here are positive and give an idea of what is available for human exploitation given the glum picture of diminishing fish stocks and fall in available protein. Furthermore, the oligochaete worms are abundant and widespread but appear to form an under-utilized trophic level. Previous studies on feeding habits of fish show that only the mormyridae feed on these worms (Corbet, 1961). The worms are primarily benthic and mud-dwelling thus restricting their capture by fish. A study to identify and encourage other fish species capable of utilizing oligochaete worms for food should therefore be mounted.

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