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Variation in composition of macro-benthic invertebrates as an indication of water quality status in three bays in Lake Victoria

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Abstract

Knowledge of how biota can be used to monitor ecosystem health and assess impacts by human alterations such as land use and management measures taken at different spatial scales is critical for improving the ecological quality of aquatic ecosystems. This knowledge in Uganda is very limited or unavailable yet it is needed to better understand the relationship between environmental factors at different spatial scales, assemblage structure and taxon richness of aquatic ecosystems. In this study, benthic invertebrate community patterns were sampled between June 2001 and April 2002 and analysed in relation to water quality and catchment land use patterns from three shallow near-shore bays characterized by three major land uses patterns: urban (Murchison Bay); semi-urban (Fielding Bay); rural (Hannington Bay). Variations in density and guild composition of benthic macro-invertebrates communities were evaluated using GIS techniques along an urban-rural gradient of land use and differences in community composition were related to dissolved oxygen and conductivity variation. Based on numerical abundance and tolerance values, Hilsenhoff's Biotic Index of the invertebrates was determined in order to evaluate the relative importance of water quality in the three bays. Murchison Bay supported a relatively taxa-poor invertebrate assemblage mainly comprising stenotopic and eurytopic populations of pollution-tolerant groups such as worms and *Chironomus sp.* with an overall depression in species diversity. On the contrary, the communities in Fielding and Hannington bays were quite similar and supported distinct and diverse assemblages including pollution-intolerant forms such as Ephemeroptera (mayflies), Odonata (dragonflies). The Hilsenhoff Biotic Index in Murchison Bay was 6.53. (indicating poor water quality) compared to 6.34 for Fielding Bay and 5.78 for Hannington Bay (both indicating fair water quality). The characterization of maximum taxa richness balanced among taxa groups with good representation of intolerant individuals in Hannington Bay relative to Fielding and Murchison bays, concludes that the bay is the cleanest in terms of water quality. Contrary, the dominance of few taxa with many tolerant individuals present in Murchison Bay indicates that the bay is degraded in terms of water quality. These result are of importance when planning conservation and management measures, implementing large-scale biomonitoring programs, and predicting how human alterations (e.g nutrient loading) affect water ecosystems. Therefore, analysis of water quality in relation to macro-invertebrate community composition patterns as bio-indicators can lead to further understanding of their responses to environmental manipulations and perturbations.

Key words: Benthic macro-invertebrates, Bio-indicators, biotic index community composition, water quality

Introduction

Macro-invertebrates are larger-than-microscopic, primarily benthic (bottom-dwelling) fauna and are generally ubiquitous in freshwater environments, and play an integral role in the aquatic food web. Many studies on macro-invertebrates in Lake Victoria (e.g. Corbet 1961, Mavuti and Litterick1991, Mbahinzireki 1992 and 1993, Lehman *et al.*, 1994, Mwebaza-Ndawula *et al.*, 2001) have investigated them in the context of understanding their ecological role in the production dynamics of the lake. Few studies in East Africa however, have considered macro-inveretebrates as bio-indicators of water quality changes (e.g. Moog and Graf 1994, Matagi, 1996). Despite the paltry attention macro-invertebrates have received in this region as bioindicators, measurements of change in their communities have been widely used in identifying and monitoring man-made impacts on surface water quality especially in nearshore areas of lakes and rivers (Sládecék, 1973, Persoone and De Pauw, 1979, Rosenberg and Resh, 1992). Invertebrates that occur in polluted water are different from those that occur in less polluted water (Chandler, 1970, DePauw and Van Hooren, 1983, Merrit and Cummins, 1984; Hilsenhoff, 1988), which makes their direct monitoring an unequivocal way and cost-efficient means of assessing ecosystem health. Composition and abundance of benthic macrofauna has been noted to depend on substratum type and depth (Mothersill *et al.*, 1980, Okedi, 1990), vegetation, distance from the shore, season (Balirwa, 1998) trophic status of the lake (Mavuti and Litterick ,1991; Mbahinzireki, 1992; 1993;1994, Matagi, 1996; Mwebaza-Ndawula *et al.*, 2001).

In this study, three bays: Murchison, Fielding and Hannington located in urban, semi-urban and rural catchments respectively were studied for variation in benthic invertebrate community composition patterns as a gauge of water quality conditions. The assumptions in the study were; first, the nearshore locations in the bays are more prone to human alterations and exhibit a stronger dependence on local conditions than offshore places. Secondly, the water quality characteristics in the bays are or have been altered by the passage of water through different catchment land uses. As benthic macro-invertebrates are sedentary, their representative assemblages in the bays integrate effects of environmental conditions and therefore are indicative of the prevailing water quality conditions thereof.

Sampling was conducted at three sites in each bay at the shore edge and 60 m from shore edge. The main goal of the study was to assess composition and abundance of benthic macro-invertebrate communities and use them to gauge conditions of water quality. A secondary goal was to characterize the benthic communities into categories such as those associated with clean water conditions (i.e. significant for fragile ecosystems conditions) and those associated with degraded conditions (i.e. median-affected communities and resilient communities).

This paper reports on composition patterns, abundance and occurrence of macro-invertebrate communities in nearshore areas of the three bays adjoined respectively by urban, semi-urban and rural catchments and their use as indicators of water quality.

Materials and Methods

Study areas

Macrobenthos were collected from 3 stations along the lakeshore edge and 60 m offshore transects respectively on a presumed pollution gradient from Murchison Bay in an urban catchment through Fielding Bay in a semi-urban catchment to Hannington Bay in a rural catchment (Figure. 1). Three grabs were taken using a 15.24 cm X 15.24 cm Ponar grab at each station eight times between June 2001 and April 2002. The sediments were rinsed with a jet of water through a series of graded sieves (mesh sizes, 0.5, 0.216, and 0.125 mm). Material retained on each sieve was washed into the sample bottles and 5 % alcohol buffered with $CaCo_{3.}$ Later samples were sorted into taxa, enumerated and the faunal composition was determined.

Overall, Hilsenhoff (Family) Biotic Index was used for bio-assessment ratings for each bay as the basis for evaluating the degree of water/ habitat quality within the bays. It was computed by dividing the total Tolerance values (Hilsenhoff 1988) by sum of the numbers of the entire benthic macro-invertebrate community found for each bay. Hilsenhoff (Family) Biotic Index- tolerance values of 0 - 10 assigned to individual families increase as water quality decreases; summarizes the overall pollution tolerance of the entire benthic macroinvertebrate community with a single value (Table 1). The overall changes or differences in community structure thus were holistically reflective of conditions of ambient water and habitat quality. For any given bay, however, the actual *in-situ* conditions may vary due to unknown differences in habitat or sources of degradation. Biological impairment, as determined through Hilsenhoff (Family) Biotic Index analysis, is manifested by alterations or differences in macroinvertebrate community structure, compared to a reference or "ideal" condition, assumed to be Hannington Bay located in a rural watershed.

Results

Composition and occurrence of Ephemeroptera community (Mayflies)

In Murchison Bay, mayflies or nymphs were absent at the sampled sites (Figure 2). *Povilla adusta* and *Caenis sp. were* the most common mayflies encountered but occurred more in Hannington Bay than in Fielding Bay (Figure 2). *Caenis sp.* occurred at a mean density between 7 and 38 ind. m^{-2} in Fielding Bay and 4 to 483 ind. m^{-2} in Hannington Bay (Figure. 2). As a whole, mean total of mayfly nymph density was 15 and 135 ind. m^{-2} in Fielding and Hannington bays respectively (Figure.2). While not encountered Murchison and Fielding bays, *Cleon sp.* was found at mean density of 4 ind. m^{-2} in Hannington (Figure 2). *Ephemerella sp.* occurred once in Fielding Bay at a mean density of 7 ind. m^{-2} and twice in Hannington Bay at mean density of 4 ind. m^{-2} (Figure 2). Composition and occurrence of Pelecypoda community (Bivalves)

Of the bivalve community, *Corbicular sp.* occurred most abundantly and dominantly at all sites in the three bays at mean density ranging from 7 to 677 ind. m^{-2} in Murchison Bay, 95 to 296 ind. m^{-2} in Hannington Bay and 27 to 225 ind. m^{-2} in Fielding Bay (Figure 3). Simularly, *Byssanodonta sp*. occurred in all the bays but far less often and abundantly with mean density ranging between 7 and 16 ind. m^{-2} in Fielding Bay, 2 and 27 ind. m^{-2} in Hannington bay and 7 and 38 ind. m^{-2} in Murchison Bay (Figure 3). *Sphaerium sp.* was encountered at a low density mean of 4 ind. m^{-2} in Hannington and 2 ind. m^{-2} in Murchison Bay (Figure 3). *Cealatura sp*. also occurred at a low mean density ranging between 2 and 4 ind. m^{-2} . *Mutera sp.* was encountered only in Hannington Bay at mean density of 4 ind. m^{-2} (Figure 3). Overall bivalve mean total density was 149 ind. m^{-2} in Fielding Bay, 193 ind. m^{-2} in Hannington Bay and 435 ind. m^{-2} in Murchison Bay (Figure 3).

Composition and occurrence of Gastropoda (snails) community

Melanoides sp,, *Bellamya sp.* and *Gabbia sp.* were the most common gastropods in all the three bays (Figure 4). *Bellamya sp*. was ubiquitously the most abundant gastropod at a mean density varying from 41 to 146 ind. m^{-2} in Hannington Bay, 102 to 493 ind. m^{-2} in Fielding Bay and 157 to 633 ind. m^{-2}in Murchison Bay (Figure 4). *Melanoides sp* was most numerous in Fielding Bay at mean density varying from 44 to 248 ind. m^{-2} and averaged 10 to 99 ind. m^{-2} and 7 to 120 ind. m^{-2} in Murchison and Hannington bays respectively (Figure 4). *Gabbia sp* was also most abundant in Fielding Bay with a mean density that varied between 23 and 224 ind. m^{-2} while in Hannington Bay, mean density varied from 5 to 211 ind. m^{-2} and from 4 to 41 ind. m^{-2} in Murchison Bay (Figure 4). *Bulinus sp* and *Biomphalaria*

sp., both bilharzia vectors were encountered in all bays albeit at very low mean densities (Figure 4). *Bulinus sp* mean densities varied from 7 to 41 ind. m^{-2} in Fielding Bay, 2 to 34 ind. m^{-2} in Hannington Bay and 4 to 17 ind. m^{-2} in Murchison Bay (Figure 4). *Biomphalaria sp* mean densities varied from 2 to 11 in Fielding Bay, 2 to 55 in Hannington Bay and 4 to 32 in Murchison Bay (Figure 4). *Lymneae sp* occurred in Murchison Bay at Nakivubo channel mouth site (Figure 4) and *Pilla sp* was encountered only once in Hannington Bay. The mean total density of gastropods was highest (579 ind. m^{-2}) in Fielding Bay, followed by Murchison Bay (407 ind. m^{-2}) and least (225 ind. m^{-2}) in Hannington Bay (Figure 4)
10 to 99 ind. m^{-2} and 7 to 120 ind. m^{-2}.

Composition and occurrence of Community of dipteran larva (chironomids and chaoborids)

Hannington Bay exhibited the most speciose community of chironomids), registering 12 taxa while only six taxa were encountered in both Fielding and Murchison bays respectively (Figure 5). Three chironomid taxa; *Ablebesmyia sp*, *Chironomus sp*, *Clinotanypus sp.* and a chaoborid, *Chaobrus sp.* were found in all the three bays (Figure 5). C*hironomus sp* was most numerous with a mean density varying from 89 to 286 ind. m^{-2} in Hannington bay, 136 to 2261 ind. m^{-2} in Fielding Bay and 72 to 1629 ind. m^{-2} in Murchison Bay (Figure 5). *Ablebesmyia sp.* was encountered at low mean density range between 10 and 55 ind. m^{-2} in Hannington, 2 and 44 ind. m^{-2} in Fielding Bay and 2 and 7 ind. m^{-2} in Murchison Bay (Figure 5). *Clinotanypus sp* was encountered in Hannington Bay at mean densities varying from 4 to 11 ind. m^{-2} and in Fielding and Murchison bays at mean densities fluctuating from 14 to 82 ind. m^{-2} and 4 to 23 ind. m^{-2} respectively (Figure 5). *Chaoborus sp.* was come upon in Hannington Bay at mean densities varying from 10 to 146 ind. m^{-2} and at relatively low mean densities in Fielding Bay (4 ind. m^{-2}) and Murchison Bay (2-7 ind. m^{-2}) (Figure 5). While absent in Fielding Bay, *Tanypus sp.* was come upon at low mean densities respectively in Hannington Bay (7 to 58 ind. m^{-2}) and Murchison Bay (4 to 19 ind. m^{-2}) (Figure 5). *Tanytarsus sp.* was encountered in only Hannington Bay at mean density of 99 ind. m^{-2} (Figure 5). Mean densities of *Coleotanypus sp* . were in Hannington Bay (7 ind. m^{-2}) and in Murchison bay (2- 7 ind. m^{-2}) and absent in Fielding Bay (Fig .5). Absent in Murchison Bay, *Palpomyia sp.* mean density was low in Fielding Bay (10 ind. m^{-2}) in Hannington Bay (4 to 28 ind. m^{-2}) (Figure 5). *Crynonuera sp*, and *Harnischia sp.* and *Probazzia sp.* were found exclusively in Hannington Bay at low mean densities of 14 ind. m^{-2}, 7 ind. m^{-2} and from 2 to 4 ind. m^{-2} respectively (Figure 5). *Procladius sp.* was come upon at low mean densities in Hannington Bay (14 to 16 ind. m^{-2}) and in Fielding Bay (2 ind. m^{-2}) and was absent in Murchison Bay (Figure 5). Mean total density of these dipteran larvae varied from 1104 ind. m^{-2} in Fielding Bay to 459 ind. m^{-2} in Murchison Bay to 276 ind. m^{-2} in Hannington Bay (Figure 5).

Composition and occurrence of Odonata (Dragonflies and Damselflies) Community

Dragonflies (Anisoptera) represented by families of Gomphidea and Lubelludea were encountered in Hannington Bay at mean densities fluctuating from 4 to 7 ind. m^{-2} and 7 to 24 ind. m^{-2} , in Murchison Bay at 7 ind. m^{-2} and from 4 to 11 ind. m^{-2} and in Fielding Bay at mean density from 7 to 11 ind. m^{-2} and 4 to 62 ind. m^{-2} respectively (Figure 6). A damselfly (Zygoptera) genus of *Coenagrion* was exclusively found in Hannington bay at mean densities between 4 and 28 ind. m^{-2} (Figure 6). At Nakivubo channel mouth, no Odonanta taxa were found (Figure 6). On the whole, mean total density of Odonata was 24 ind. m^{-2} in Fielding Bay, 19 ind. m^{-2} in Hannington Bay and 5 ind. m^{-2} in Murchison Bay (Figure 6).

Community of worms: Hirudinea (leeches) and Lumbruculoidea (aquatic worms) communities

The leeches were encountered at mean densities from 4 ti 14 ind. m^{-2} in Hannington Bay, 4 to 9 ind. m^{-2} in Murchison Bay and 2 to 11 ind. m^{-2} in Fielding Bay (Figure 7). Worms of Family Naididae were found in Hannington bay at a mean density of 5 ind. $m^{-2,}$, from 5 to 38 in Murchison Bay and from 5 to 27 ind. m^{-2} in Fielding Bay while those the Family Lumbruculoidae were registered at mean densities in Fielding (7-68 ind. m^{-2}) and Murchison bays (7- 68 ind. m^{-2}) and from and n Hannington Bay (4 -16 ind. m^{-2}) (Figure 7). Combined mean density of these taxa were 42 ind. m^{-2} in Fielding Bay, 7 ind. m^{-2} in Hannington Bay and 36 ind. m^{-2} in Murchison Bay (Figure 7).

Other benthic macroinvertebrate communities

Though absent in Murchison Bay, corixids, a family of Hemiptera were recorded at low mean densities in Hannington Bay (4 ind. m^{-2}) and Fielding Bay (2-4 ind. m^{-2}) (Figure 8). *Hydracarina* (Water mites) were exclusively encountered in Hannington Bay at a mean density between 2 and 24 ind. m^{-2} (Figure 8). *Caridina nilotica*, a decopod was encountered in all the three bays, albeit at low mean densities, in Hannington Bay (4- 34 ind. m^{-2}), in Fielding Bay (4 - 37 ind. m^{-2}) and in Murchison Bay (4 ind. m^{-2}) (Figure 8). Tricoptera (Caddisflies) were recovered exclusively in Fielding Bay at 24 ind. m^{-2} (Figure 8). Both Ostracoda and Conchostraca were absent in Murchison Bay but occurred at very low mean densities from 17 to 347 ind. m^{-2} and 4 to 17 ind. m^{-2} in Hannington Bay, 4 to 337 ind. m^{-2} and 51 ind. m^{-2} in Fielding Bay respectively (Figure 8).

In Murchison Bay, species of pollution-tolerant groups (such as Leeches, chironomids, and worms) tended to dominate over pollution-intolerant forms (e.g. mayflies, stoneflies, dragonfliesetc.), with an overall depression in species diversity (Table 2). Such manifestations are typically due to degraded in-bay environmental conditions, which may be caused by various human activities or land-uses and marked by a biotic index of 6.53 (Table 1). On the contrary, in Hannington bay, benthic community was characterized by a maximum taxa richness, balanced taxa groups and good representation of intolerant individuals (such as mayflies and dragonflies) (Table 2). Such a manifestation is typical of good water quality conditions represented by biotic index of 5.78 (Table 3). Fielding Bay fell moderately in between Murchison and Hannington bays in terms of macro-invertebrate richness (Table 2) but the biotic index was closer to that of Murchison Bay than that Hannington Bay. (Table 3).

Discussion

Lake-inshore are similar to stream habitats in as far as regards allochthonous detrital carbon driving food webs in the two habitats (Lang *et al.*, 1989). Therefore, similarities in the factors regulating community composition of benthic invertebrates between inshore lake sites and streams can be similar. However, many studies that have used macro-benthic invertebrates as bio-indicators are mainly from stream ecosystems (DePauw and Van Hooren, 1983). Findings of this study suggest that taxonomic and structural composition of macro-benthic invertebrates are good predictors of water quality status in the inshore areas of the bays of lake depending on the level of land use in adjoining catchment.

Temporal and spatial dimensions incorporation into experimental designs that take into account the environmental factors (as dissolved oxygen, turbidity, and presence of toxicants and eutrophication) that adversely affect biota in the lake, can enable the detection of impacts caused by humans (Underwood, 1989; 1995). However, unknown differences in habitat or sources of degradation or even intrinsic factors such as habitat choice and life history phenologies compound the variations in invertebrate community structure and composition in the bays that could be explained by environmental or natural factors. Notwithstanding, changes caused by humans are only significant and important if they cause a fluctuation that is greater than the average fluctuation that occurs naturally within the population (Chandler, 1970). In this study, benthic invertebrate communities in Murchison Bay relative to Fielding and Hannington bays showed that sites in the former support relatively taxa- poor invertebrate assemblages compared to the latter which support fairly distinct assemblages, with communities apparently quite similar to each other. However apart from notable communities of Chironomids, mayflies, snails and bivalves, Hannington Bay supported chironomid taxa such *Procladius* sp. *Probazzia* sp , *Coeloetanypus* sp which were neither found in Murchison nor Fielding bays. In Murchison Bay particularly at Nakivubo channel mouth, the invertebrate assemblages were typified by low abundance and diversity of mainly low oxygen tolerant forms including *Chironomus sp*, Oligochaeta , Hirudinea, *Caridina nilotica and Biomphalaria sp*. The more diverse the community is, the better, the water quality conditions as the Hilsenhoff's biotic index reflects.

Comparing previous macro-benthic invertebrates' studies in the lake and what was observed in this study, trends in some taxa point to ecological transformation of the lake. For instance, three decades ago, *Corbicular* was the most common bivalve (Mothersill *et al*. 1980) in the northwestern part of Lake Victoria. Generally in this study too, it was the most numerically preponderant taxon at most sites in all the bays except at Nakivubo channel mouth site in Murchison Bay (Figure 3). At this site, only *Lymnae sp*. and *Biomphalaria sp.* were encountered. In the late 1980s, *Pisidium sp, was* one of the important small bivalve in Murchison Bay (Okedi, 1990). In the present study, it was neither found in Murchison Bay nor the other the two bays. Though it was absent in all bays, its absence in Murchison Bay where it had been noted in earlier studies could be attributed to bay-wide environmental degradation as a result of increased urbanization from the 1980's to present. Still during the late 1980s, Okedi (1990) found *Caelatura sp* and *Mutera sp* as important of the big bivalves in Murchison Bay especially over mud and sand bottoms respectively. In this study, though found, their numerical abundance was very insignificant (Figure 3).

A historical perspective of gastropod community, Corbet (1961), Mbahinzireki (1994), Mwebaza-Ndawula (1994) and Witte *et al.* (1992) on a lakewide scale indicated a preponderance and ubiquity of *Melanoides* and *Bellamya* genera. As observed in this study in all bays, these are still numerically prevalent taxa at most sites (Figure 3). In northwestern Lake Victoria (Mothersill *et al.* 1980) as well as in sublittoral and littoral areas of Mwanza Gulf (Hoogerhoud 1986), *Melanoides* were far more common than *Bellamya*. In this study, a similar pattern was observed in Fielding and Hannington bays and viceversa in Murchison Bay (Figure 4). Okedi (1990) likewise found *Bellamya* as the predominant gastropod in Murchinson Bay during his 1987/88 study. Variations in environmental condition in the three bays do not seem to explain the prevalence of gastropod and bivalve communities. However, Ndawula (1994) and Witte *et al*, (1992), have advanced that *t*he resilience of these communities is probably due to reduced intensity of the grazing food chain principally via haplochromines. Additionally,, McMahon *et al.* (1974) and Branstrator *et al.* (1996) related the mollusk densities to infestation by water hyacinth and other weeds. However, the occurrence and abundance of left-handed snails (*Biomphalaria* and *Bulinus*) have been shown to indicate degraded or poor water quality (Merrit and Cummins 1984). Biomphalaria, one of left-handed snails occurred at the Nakivubo channel mouth in Murchison Bay.

When it comes to benthic insects, mean densities of *Chaoborus larva* in this study were very low varying from 10 to 146 indiv.m^{-2} in Hannington Bay and from 2-7 indiv.m^{-2} in Murchison and Fielding bays respectively (Figure 5).

Table 1. Hilsenhoff Biotic Index as a determinant of water quality and degree of organic pollution

Biotic index	Water quality	Degree of organic pollution
<3.75	Excellent	Organic pollution unlikely
3.76-5.0	Good	Some organic pollution
5.1-6.5	Fair	Substantial organic pollution likely
6.6-10.0	Poor	Severe organic pollution likely

source :Hilsenhoff 1988

Table 2. Tolerance values based on a scale of 0 to 10 (Hilsenhoff, 1988) used for estimating Total tolerance Values for Murchison Bay (MB), Fielding Bay (FB) and Hannington (HB) (Multiplied A times B to get C Values)

Taxon	Pollution tolerance values (a)	Number found (b)			Total tolerance values (c)		
		MB	FB	HB	MB	FB	HB
Mayflies	3.5	0	15	135	0	52.5	472.5
Dragonflies	4.0	5	24	19	20	96	52
Water Beetles	4.3	0	3	0	0	12.9	0
Chironomids (Midges)	6.0	459	1104	276	2754	6624	1656
Earthworms	8.0	36	42	7	288	336	56
Leeches	10.0	3	6	4	30	60	40
Snails	7.0	407	579	225	2849	4053	1575
Total		910	1773	666	5941	11234.4	3851.2

Table 3. Hilsenhof Biotic Index computed (divided total of C by total of B from table 2) for Murchison, Fielding and Hannington bays and implications for water quality based on Table 1

Bays	biotic index	Water quality	Degree of organic pollution
Murchison	6.53	Poor	Substantial pollution likely
Fielding	6.34	Fair	Some organic pollution
Hannington	5.78	Fair	Some organic pollution

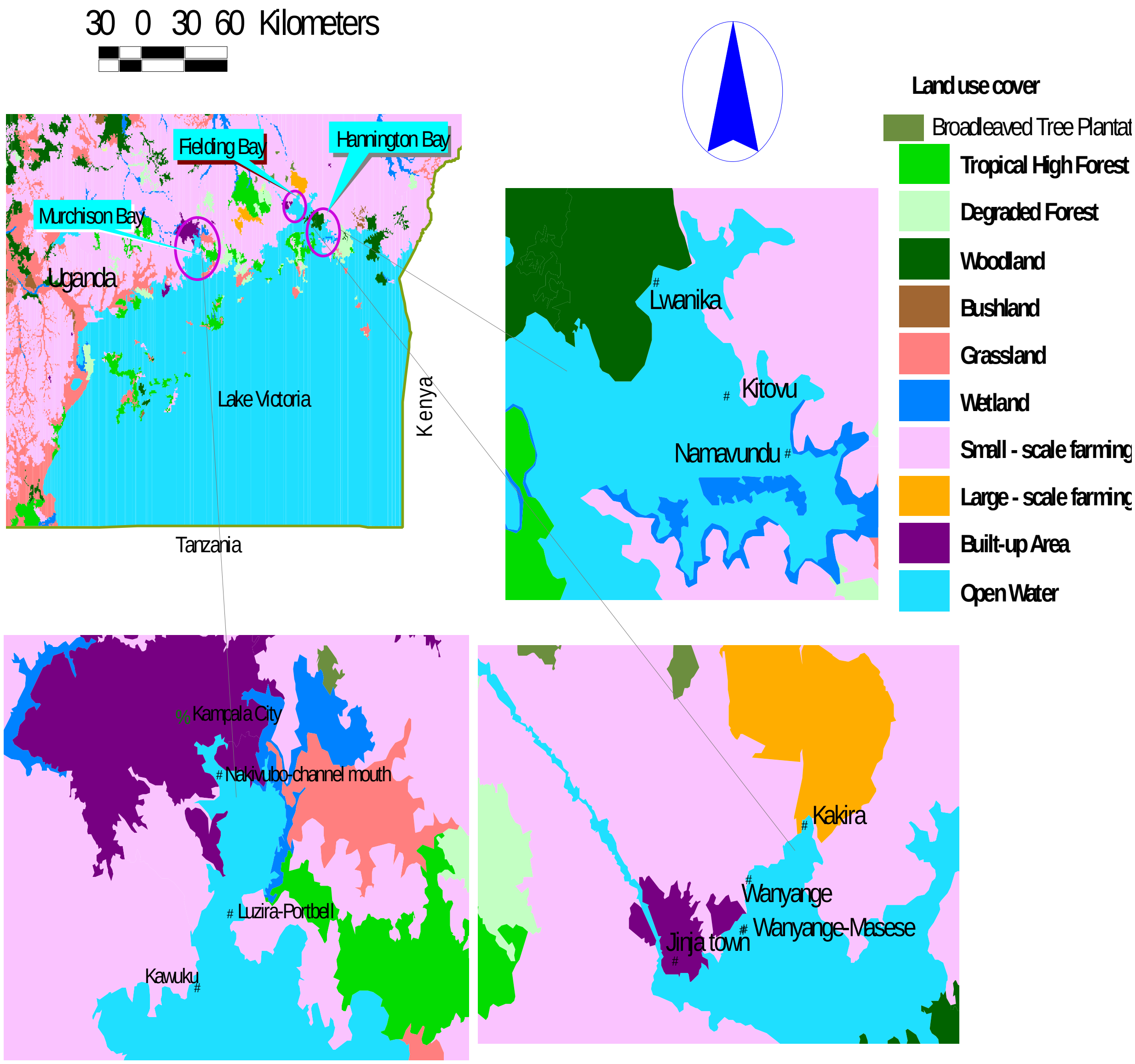

Figure. 1. Study bays, sites and surrounding land use cover

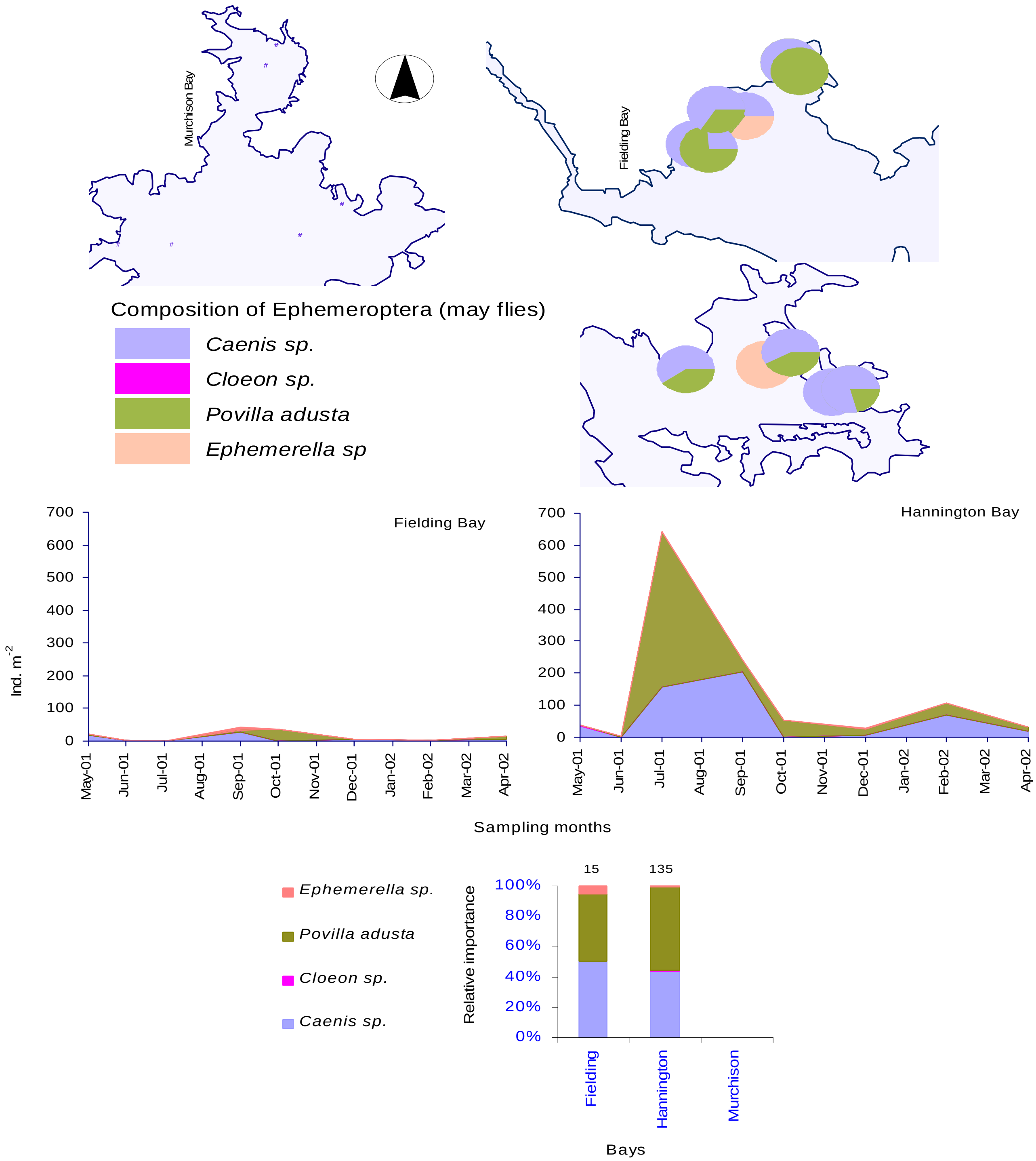

Figure 2. Maps showing overall occurrence and composition of Ephemeroptera taxa (may flies) at the sampled sites and graphs showing composition and variation of mean density (monthly and composite) of may flies in Murchison, Fielding and Hannington bays of Lake Victoria

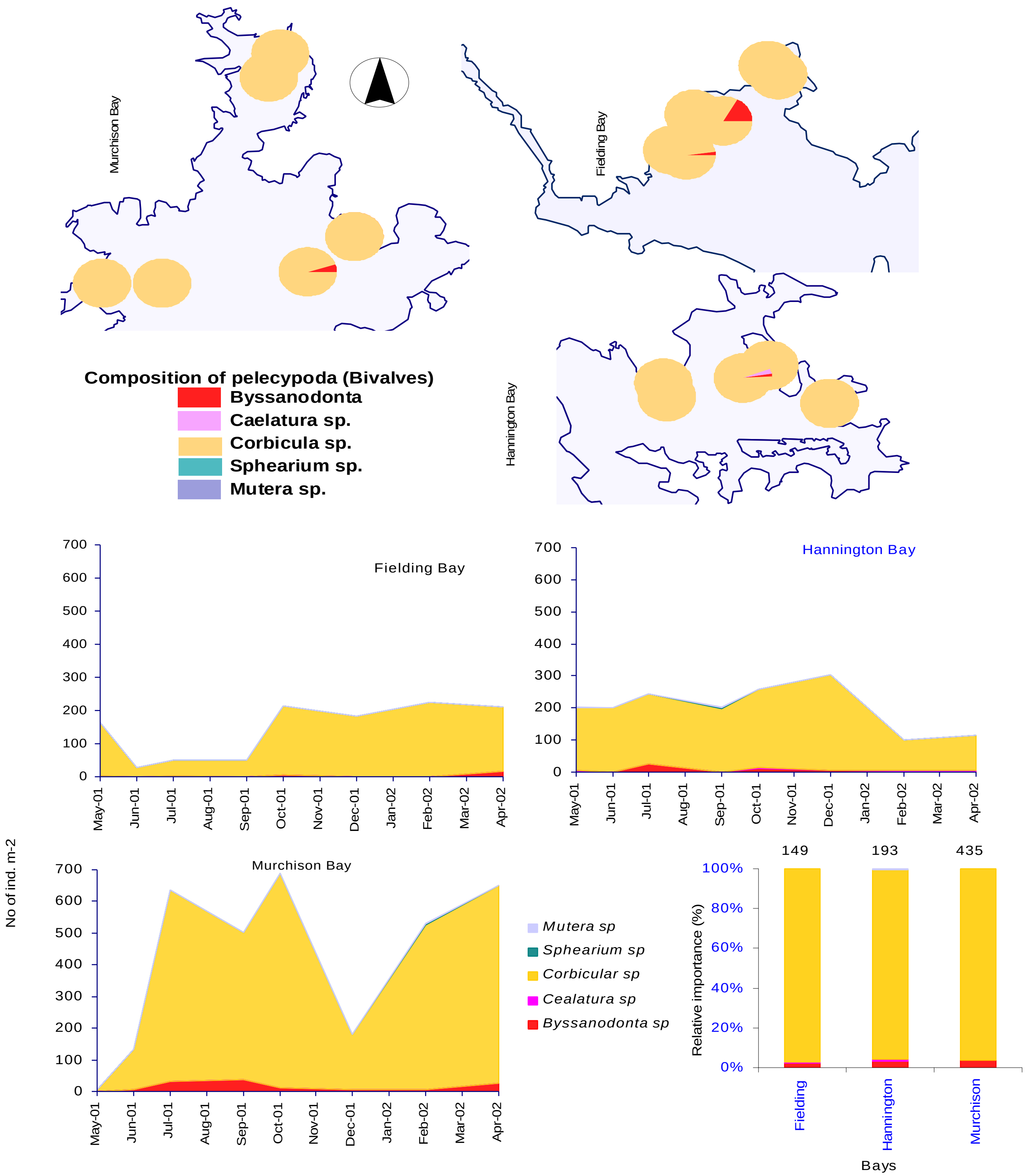

Figure 3. Maps showing overall occurrence and composition of pelecypoda taxa at the sampled sites and graphs showing monthly composition and variation of mean density of pelecypoda taxa (bivalves) in Murchison, Fielding and Hannington bays of Lake Victoria

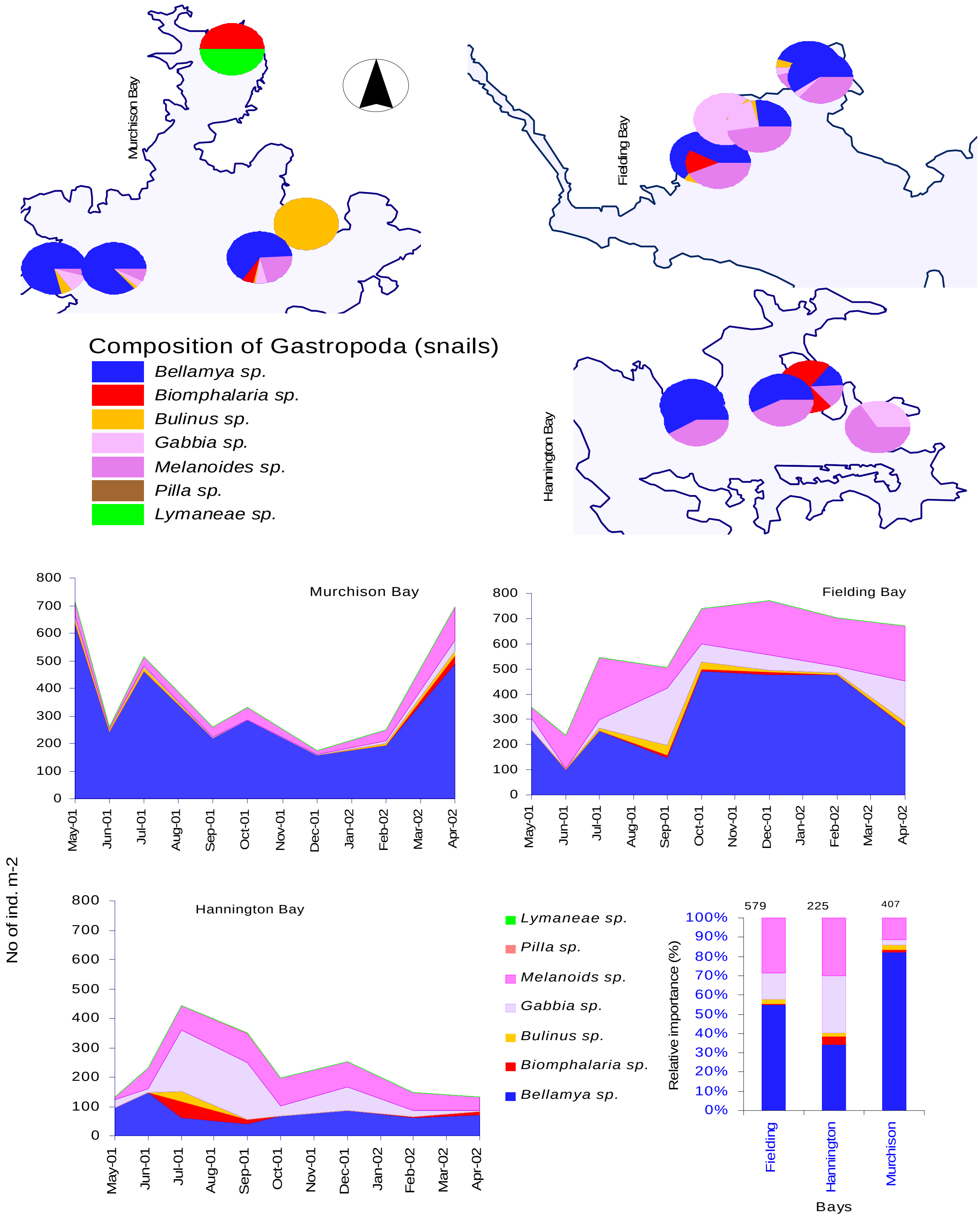

Figure 4. Maps showing overall occurrence and composition of pelecypoda taxa (snails) at the sampled sites and graphs showing monthly and composite composition and variation of mean density of snails in Murchison, Fielding and Hannington bays of Lake Victoria

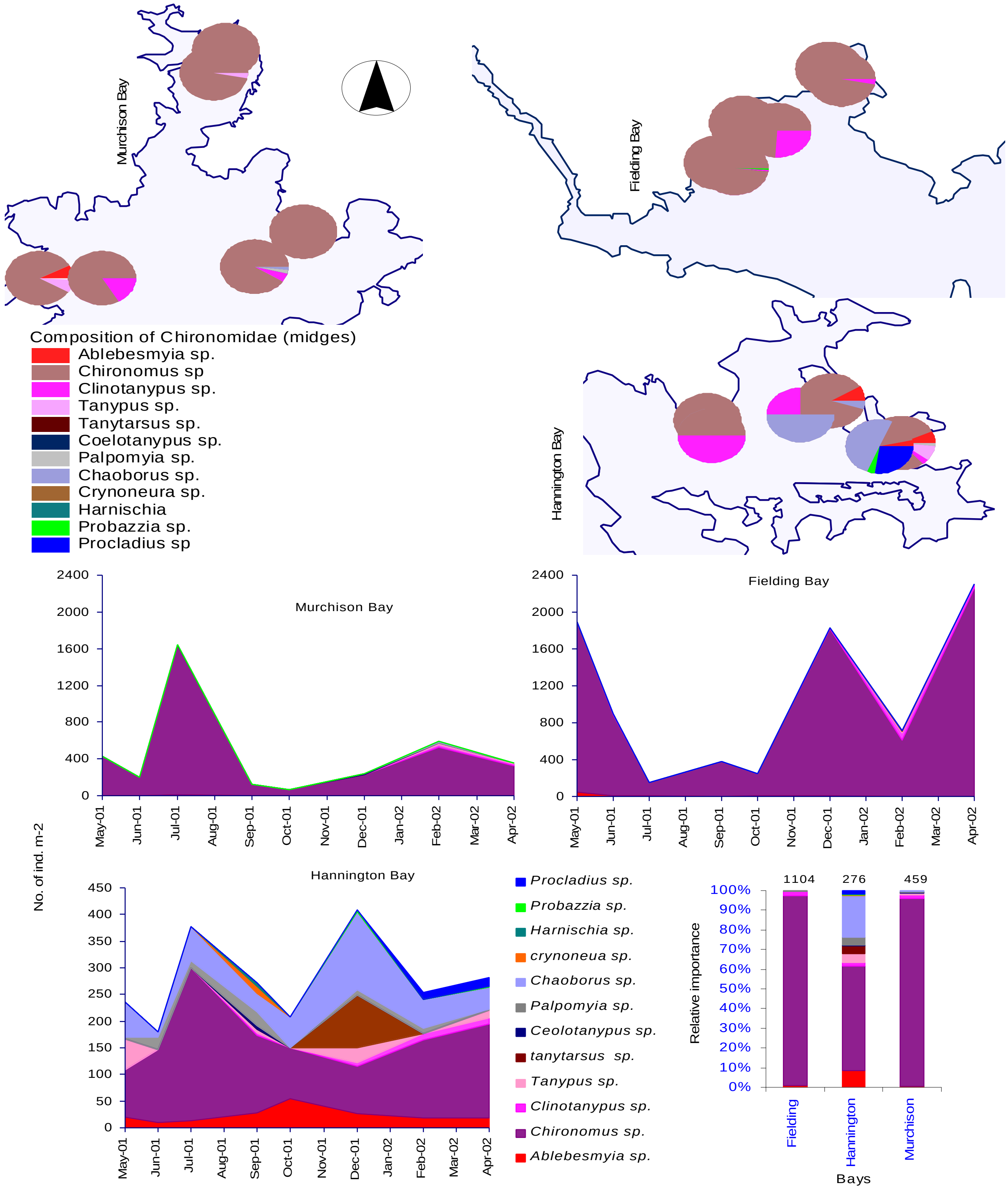

Figure 5. Maps showing overall occurrence and composition of Chironomidae taxa at the sampled sites and graphs showing monthly and composite composition and variation of mean density of Chironomidae taxa (midges) in Murchison, Fielding and Hannington bays of Lake Victoria

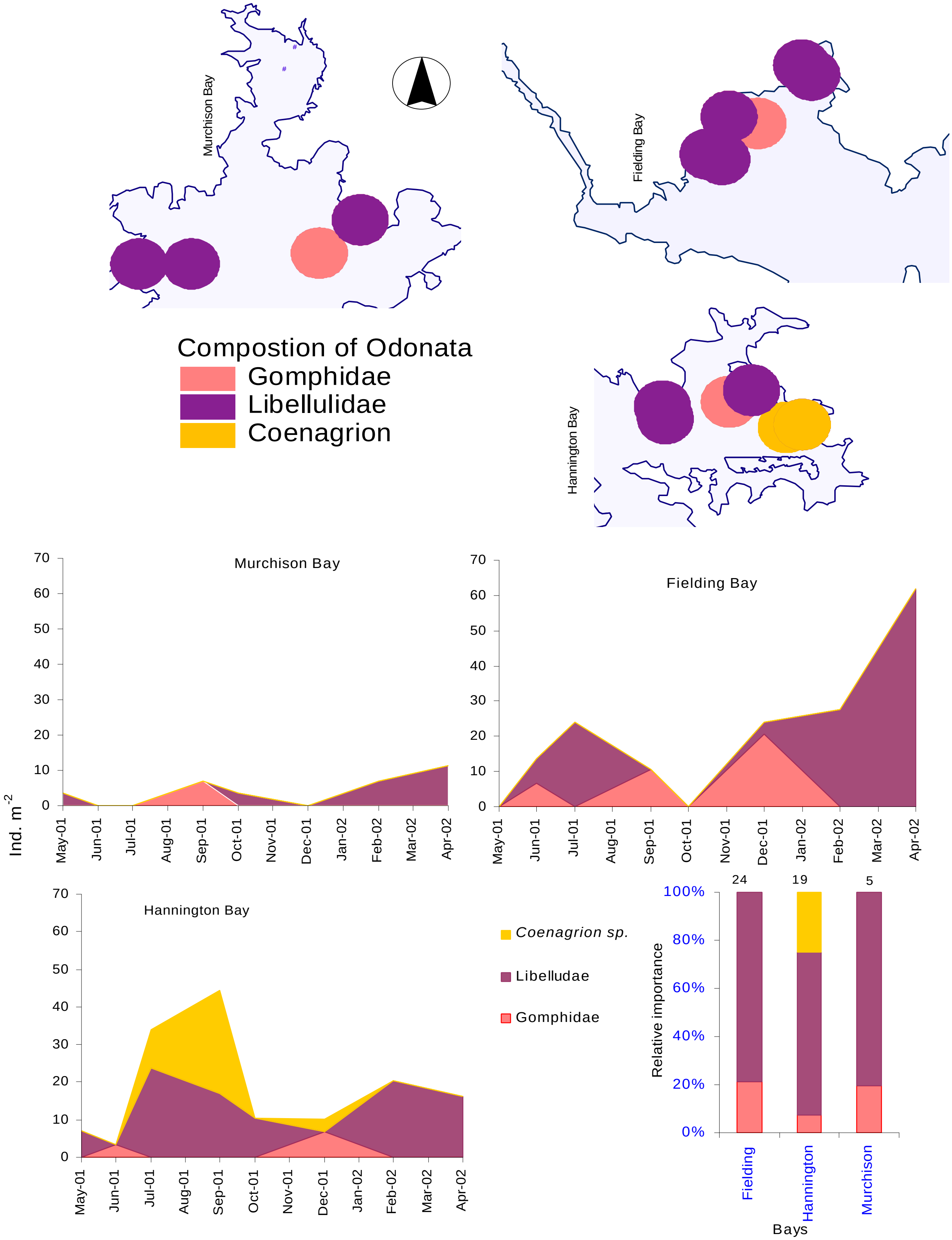

Fig. 6 Maps showing overall occurrence and composition of Odonata taxa (dragon and damsel flies) at the sampled sites and graphs showing monthly and composite composition and variation of mean density of dragon and damsel flies in Murchison, Fielding and Hannington bays of Lake Victoria

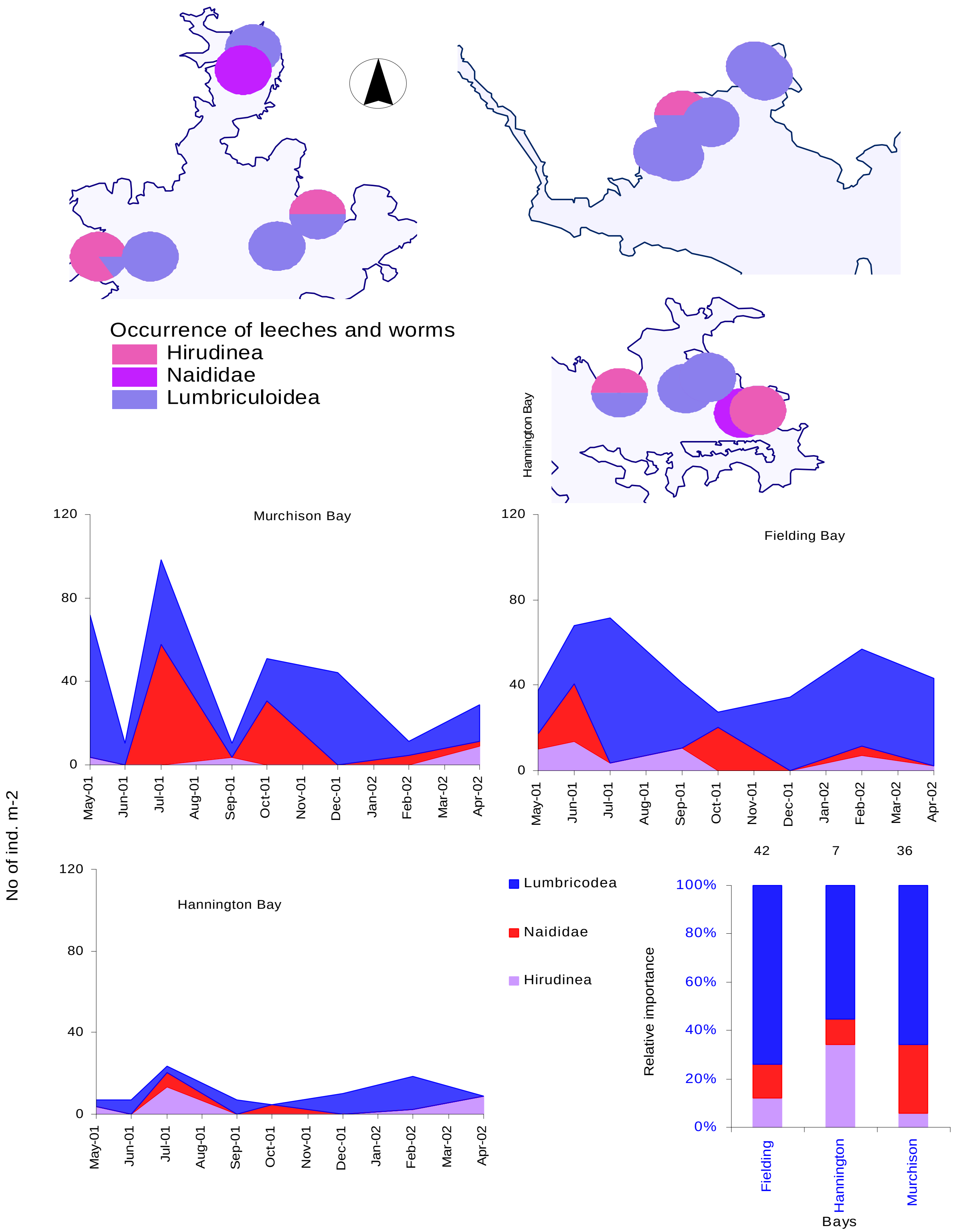

Figure 7. Maps showing overall occurrence and composition of Hirudinea,Lumbriculidea and Naididea at the sampled sites and graphs showing monthly and composite composition and variation of mean density of Hirudinea,Lumbriculidea and Naididea in Murchison, Fielding and Hannington bays of Lake Victoria

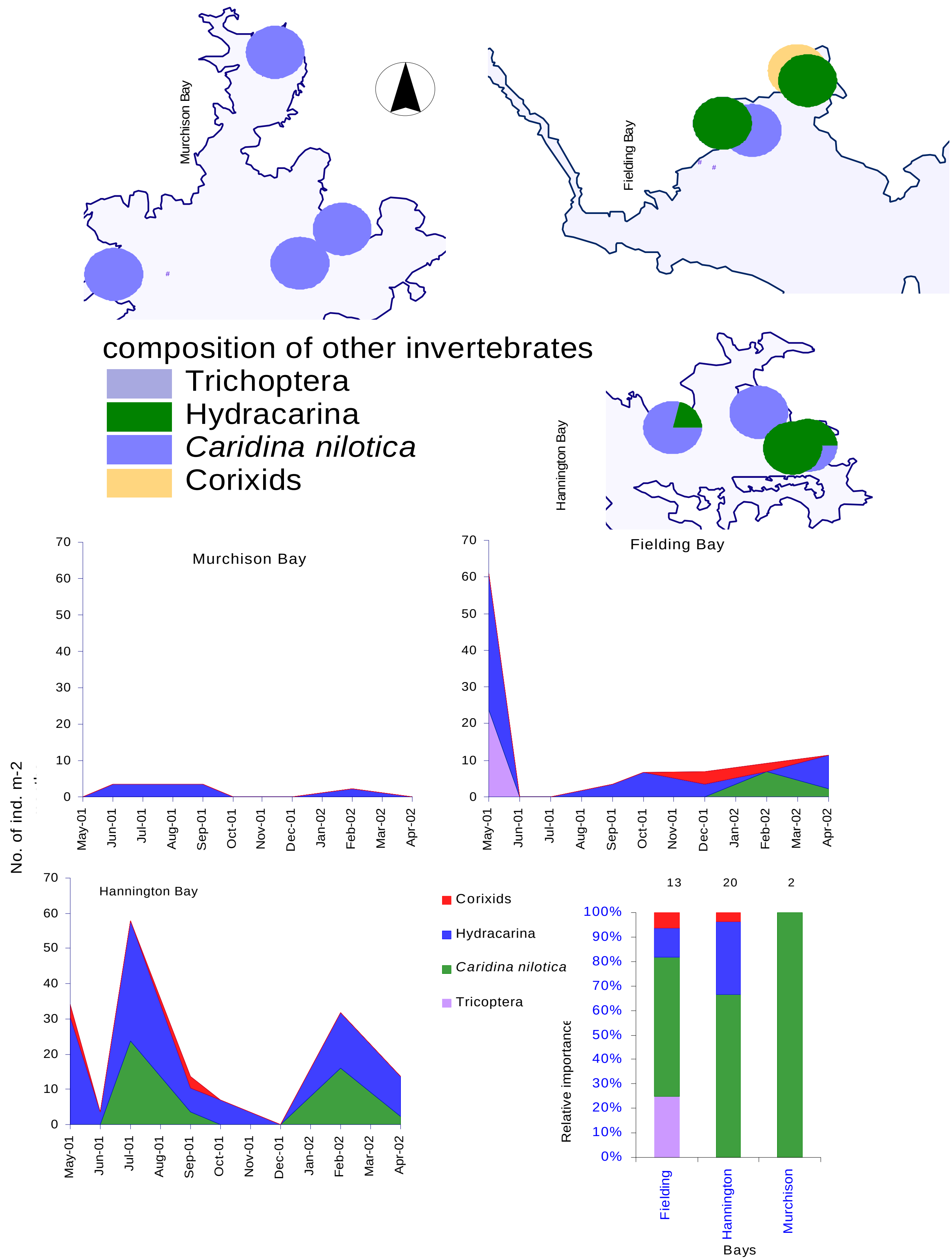

Figure 8. Maps showing overall occurrence and composition of other macroinvertebrates at the sampled sites and graphs showing monthly and composite composition and variation of mean density of other macroinvertebrates in Murchison, Fielding and Hannington bays of Lake Victoria

Similarly, in Murchison Bay during 1987/88, Okedi (1990) found low densities at 12-38 m^{-2}, less than 2% of the benthic insects. Contrary to this pattern however, MacDonald (1956) noted from a small Ekunu Bay in the northern part of the lake, *Chaoborus anomalus* was the most abundant of insect fauna at 2000-2500 indiv.m^{-2}, making 70 % of total insect fauna at depths of 5-15 metres and rare in deeper waters. Bearing in mind that chaoborid larvae and pupae exhibit a diel vertical migration, their abundance densities at night and during day vary. Lehman *et al.* (1994) vertical net collections gave daytime mean densities of *Chaoborus* larvae from 5 $\pm$ 3 to 757 $\pm$ 94 indiv.m^{-2} and nighttime mean densities from 242 $\pm$ 72 to 978 $\pm$ 17 indiv. m^{-2} . Still daytime densities are not comparable to those obtained in this study where sampling was done during day. The red type-chironomids (*Chironomus* sp) were of common occurrence in sediments of the three bays, highest density of up to 2333 indiv.m^{-}2 of *Chironomus* sp was found in Fielding Bay in this study (Fig. 5). C*hironomus sp* is tolerant to low dissolved oxygen and thus its exclusive abundance indicate conditions of degraded water quality (Merrit and Cummins 1988) as was the case in Murchison Bay (Figure 7), particularly at Nakivubo channel mouth where dissolved oxygen hardly exceeded 2.5 mg l^{-1}. On the whole lake basis, the midge has been observed to predominate in the benthos during periods of thermal stratification (October-March) when anoxic conditions prevail in the hypolimonia (Mwebaza-Ndawula *et al*., 2001). Mothersill *et al.* (1980) recognized chironomid larva as the most dominant form of benthic insects in the northwestern Lake Victoria. Okedi (1990) found densities ranging from 265-968 m^{-2} in Murchison bay, comprising 63% of all benthic insects. Macdonald (1956) found 1000 indiv.m^{-2} of chironomid larva in Ekunu Bay. Presence of Tanypodinidea chironomids indicates conditions of good water quality (Merrit and Cummins 1984) as was the case in Hannington Bay. These were infrequent in Fielding Bay and absent in Murchison Bay.

Further, insect forms distinct from the dipteran larva (Chaoborids and chrionomids) were more common in Hannington Bay than in either Fielding or Murchison Bay. *Povilla adusta* was the most common species of mayfly but richer in Hannington Bay than Fielding Bay, and absent in Murchison Bay (Figure 6). It was mainly recovered as a nymph. *Povilla adusta* used to be the most common insect form in L. Victoria (Corbet, 1957) and was common in Murchison Bay twenty years ago as the second most important benthic insects after the chironomid larvae (Okedi 1990). Mayflies are good indicators of good water quality (Merrit and Cummins 1984) and therefore their absence in Murchison Bay indicates poor water quality and presence in both Fielding and Hannington bays reflects good water quality. Like mayflies, some dragonflies are indicators of good water quality conditions. They encountered in Hannington and Fielding bays and were absent in Murchison Bay. Okedi (1990) found 3-21 Odonata m^{-2} in Murchison Bay. Their absence in Murchison in this study is probably related to in-bay environmental degradation resulting from increased urbanization.

Finally in this study, analogous to Chaoborids, *Caridina nilotica* occurred at very low densities in the bays. This may be so because *C. nilotica* are epibenthic, vertically migrating members of the offshore community (Fryer, 1960; Lehman *et al.*, 1994) and yet sampling in this study was conducted in inshore areas. However, they have been reported to occur in littoral regions especially in weedbeds of submerged vegetation. Immense increase in their abundance in the vicinity of the lake noted by Lehman *et al.,* 1994 in recent decades is attributed to their endurance to low oxygen conditions (Branstrator and Mwebaza-Ndawula 1998) which characterizes the hypolimnion for most of the year. In this study they were found at a site in Murchison bay where dissolved oxygen content was less than 2.5 mg l^{-1}. Ostracods and *Hydracarina* exhibited rare occurrence in the bays in only Hannington and Fielding bays. As explained earlier, life history phenologies could be a factor determining their occurrence as for instance Mavuti and Litterick (1991) noted them mostly as zooplankton in Kenyan waters.

Conclusions

The benthic invertebrate community was most speciose in Hannington Bay implying good habitat (water) quality condition, followed by Fielding Bay indicating moderate habitat conditions and lowest in Murchison Bay indicating poor habitat conditions. Notable populations of *Chironomus s;p*; two snails *Melanoides* and *Bellamya* snails and a bivalve, *Corbicular* sp., among other taxa were observed in the three bays. Hannington Bay supported intolerant taxa such as *Povilla adusta*, *Hydracarina* and chironomids like *Procladius* sp. *Probazzia* sp , *Coeloetanypus* sp. In Murchison Bay particularly at Nakivubo channel mouth, the invertebrate assemblages were typified by low abundance and diversity of mainly low oxygen tolerant forms including *Chironomus sp*, Oligochaeta , Hirudinea and *C. nilotica*. Given that the more diverse the community is, the better the water quality conditions, Hannington Bay has fair water quality, than Fielding Bay and Murchison Bay the worst.

The most notable change in the benthos seen between previous studies and the present one is the decline in the abundance of *C. nilotica* across the bays studied and disappearance of nymphs of *P. adusta* and bivalve *Pisidium* in Murchison Bay.

Macroinvertebrates are useful indicators of ecosystem health of lakes, however, they have not been used widely in African Great Lakes as have been for Laurentian and European Lakes. It is hoped that as more data accumulate through continued monitoring of the benthic fauna in Lake Victoria and other water bodies in the region, a broader understanding of these important communities, and how they respond to changing conditions within the lake will develop and form prototypes for gauging water quality and trophic state changes.

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