# The Nile Benthos

**Gamal M. El-Shabrawy and Mohamed R. Fishar**

**Abstract** Benthic macro and micro-invertebrates include those biota that spend a significant portion of their life on or in the bottom. Nile benthic macroinvertebrates (molluscs, worms and crustaceans) exhibit a marked variation in composition and abundance, reflecting a range of microhabitats but a comprehensive inventory of the taxa present is still lacking. Meiobenthos (nematodes, flatworms, and micro-crustaceans) has to date remained almost unstudied. Macroinvertebrate species richness in Egypt amounts to about 7–31 species at individual bank-side sites of the river and delta and the macrobenthos of the White Nile and its lakes is represented by about the same number of species. The sandy bed of the White Nile is sparsely populated, with the larvae of small Chironomidae prominent. Information about the Blue Nile is scarce, but its benthos appears to be poor, because of torrential flow and drastic changes in water level. Generally, benthic invertebrates of the Nile lakes have low diversity compared with temperate lakes. Twelve species of molluscs, 14 species of insects and three species of oligochaetes are known from Lake Victoria. The benthic community of Lake Turkana includes a sponge, a bryozoan, 8 gastropods, 3 bivalves, 17 ostracods, 23 insects and several hydracarines and annelids. *Caridina nilotica*, *Potamonautes niloticus* (Crustacea), *Limnodrilus hoffmeisteri*, *Branchiura sowerbyi* (Oligochaeta), *Corbicula fluminalis*, *Cleopatra bulimoides* and *Melanoides tuberculata* (Mollusca) occur Nile-wide.

## 1 Introduction

Benthic invertebrates, usually classified as macro- and meiobenthos, play an important role in the cycling of material and in energy flow. The main distinction between the two groups is size, with a zone of overlap that may cut across taxonomic borders. Large oligochaetes, for examples, are macrobenthic, while small species

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are classified as meiobenthic. Meiobenthos is mainly composed of nematodes and other small worms, and microcrustaceans such as ostracods and copepods. In many areas of the world, meiobenthos has been much less well studied than macrobenthos, and the Nile is no exception to this rule. Limited data are available mainly for some equatorial lakes.

It may be difficult to define what species are benthic, and what species are not. The shrimp *Caridina*, for example, may as well lead a benthic as a planktonic life (for lake Victoria, see Lehman, 2009). The larva of the phantom midge, *Chaoborus,* likewise spends part of its life hidden in the bottom sediment, and part swimming in the plankton (see further). Other species may not be strictly associated with bottom sediments, but live among macrophytes (see Section 4), and are periphytic, or they live on rocky substrates, such as the mussel *Etheria* and the larvae of simuliids (black-flies). Within the context of this articles, we will consider all these as "benthic".

Benthic, especially macrobenthic, production generally exceeds that of zooplankton (Liang & Liu, 1995). It integrates change in physical, chemical and ecological characteristics of its habitat over time and space (Milbrink, 1983) and plays a key role in the accumulation and transfer of contaminants to higher trophic levels (Amyot et al., 1994). Because of this, benthic communities are useful for detecting alterations in aquatic ecosystems (Dickman et al., 1990). Macrobenthos species offer advantages to water quality surveys because (a) they inhabit all kinds of waters, (b) they are sedentary, unable to avoid environmental disturbances, (c) they have long life cycles compared to planktonic groups, (d) their responses to different environmental conditions are known, (e) they are in the middle of the aquatic food web, reflecting the productivity of trophic levels below and above.

In spite of this, ecological formation on invertebrates, large and small, in Egypt is sparse. Most studies are taxonomic (Hussein et al., 1988; Ali, 1989; El-Shimy et al., 1995; Ibrahim et al., 1999) or address small areas (Abdel Aal, 1979; El-Shimy & Obuid-Allah, 1992; Abdel Salam, 1995; Abdel Gawad, 2001; Fishar & Williams, 2006, 2008; Fishar et al., 2006).

## 2 Spatio-Temporal Longitudinal Variation

The macrobenthos of the Nile, mainly composed of Crustacea, Molluscs and Annelida, varies in density, biomass and diversity from the delta to Lake Nasser. Its density increased from 1,400–1,700 ind $m^{-2}$ in the Nile branches and from Cairo to Aswan, to 2,075 ind $m^{-2}$ at Aswan reservoir, followed by a sharp decrease to 95 ind $m^{-2}$ in Lake Nasser (Fig. 1) (Iskaros, 1988; Fishar, 1995; El-Shabrawy, unpublished). Biomass in the Nile and its branches (649 and 142 g fresh wt $m^{-2}$) was also much higher than in Aswan reservoir and Lake Nasser (17 and 3.5 g fresh wt $m^{-2}$, Fig. 2). This mainly reflected the abundance of two large bivalves (*Mutela* and *Caelatura*). Crustacea are common at Aswan reservoir and in lake Nasser, forming 25–35% of total benthos, with *Caridina nilotica* (Decapoda) dominant. Mollusca are even more abundant in the Nile branches and the Cairo-Aswan Nile, forming 20–95% of the

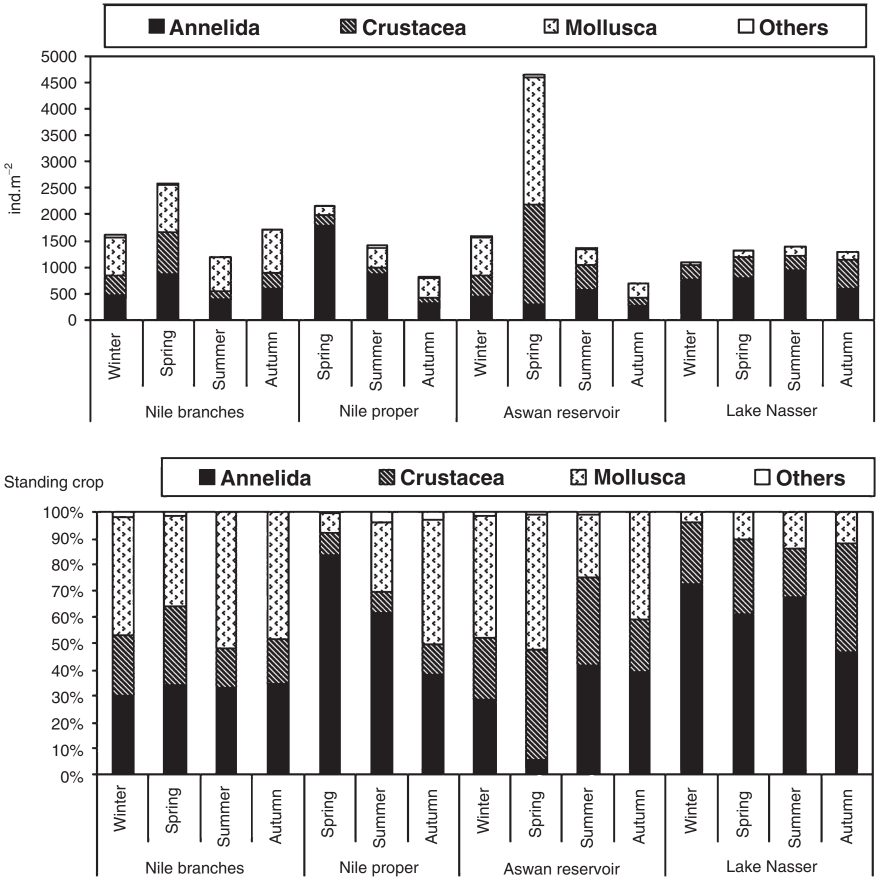


**Fig. 1** Mean abundance and proportion of the three main groups of the macrobenthos by geographic sector and by season in the River Nile (original)

total in 2007 (El-Shabrawy, unpublished). Ramadan et al. (2000) mentioned that the bivalve *Corbicula consobrina* is abundant and peaks during spring and winter in the Nile (Cairo-Aswan). Type of sediment is the main factor affecting mollusc distribution. Sandy-mud bottoms are preferred over sandy or gravely sand bottoms. The widespread *Melanoides tuberculata* reaches up to 240 ind $m^{-2}$ at Aswan reservoir in spring with highest biomass, 25.3 g fresh wt $m^{-2}$, in the delta branches in autumn (Fig. 3) (El-Shabrawy, op. cit.). Annelida are well represented in Lake Nasser and the Egyptian Nile, forming 62% and 68% of total density. Iskaros (1988) found that they made up 50% and 47% of total biomass at Lake Nasser and Aswan Reservoir. *Limnodrilus hoffmeisteri* reached a maximum of 1,500 ind $m^{-2}$ between Cairo and Aswan in spring (Fig. 3). The nearly monogeneric assemblage of tubificid worms, with *L. hoffmeisteri* most abundant, indicates that the river is somewhere between gross organic pollution and simple eutrophication (Brinkhurst, 1974).

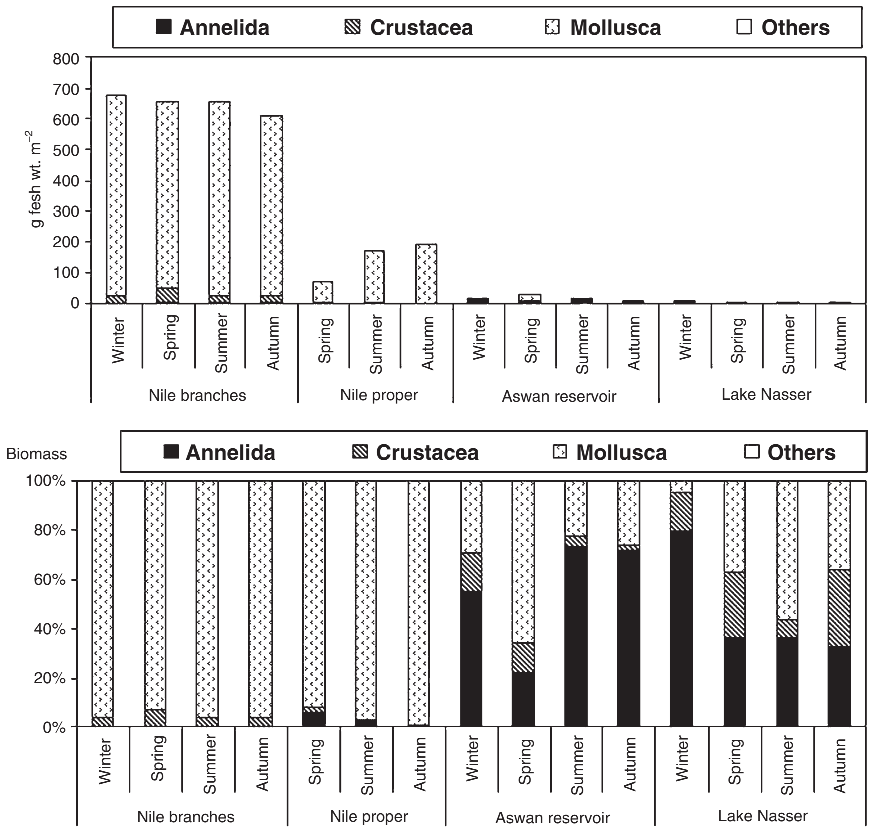


**Fig. 2** Mean biomass and proportion of the three main groups of the macrobenthos by geographic sector and by season in the River Nile (original)

Many authors have noted a longitudinal zonation in rivers although it is recognised (Vannote et al., 1980) that a river is a continuum that changes gradually rather than in a stepwise manner. Illies & Botosaneanu (1963) broadly divided rivers into the eroding rhithron in the upper course, and a depositing potamon in the lowland section. Fishar & Williams (2006) showed that the Nile fauna from Aswan to Cairo can be described as a potamon. The insect fauna contains ubiquitous groups such as chironomids but is dominated by Odonata, Coleoptera and Corixids characteristic of lowland weedy reaches. Plecoptera are absent and Trichoptera limited whilst Ephemeroptera are represented only by *Baetis, Caenis* and Potamanthidae. Thus the EPT (Ephemeroptera/Plecoptera/Trichoptera) of the rhithron are poorly represented. The greatest diversity of insects occurs in macrophyte stands, little represented in the rhithron zone. The mollusc fauna is diverse throughout the river and includes gastropods and bivalves, typical of weedy and mud-depositing habitats. Only *Ferrissia* sp., a river limpet which clings onto solid surfaces, and some bivalves such as *Sphaerium* sp. and *Corbicula* sp. are found in sand. The worms and

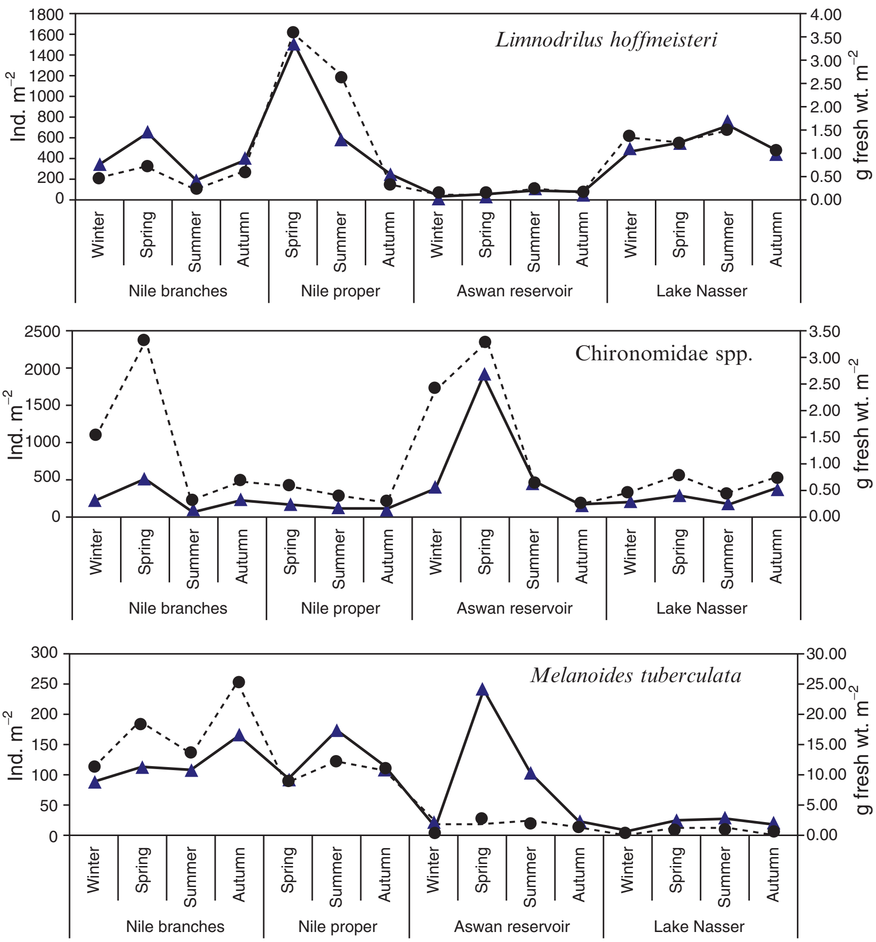


**Fig. 3** Mean abundance of the dominant macrobenthic species by geographic sector and by season in River Nile (original)

leeches present are also typical of lowland reaches. *Caridina nilotica*, *Potamonautes niloticus* (Crustacea), *Limnodrilus hoffmeisteri*, *Branchiura sowerbyi* (Oligochaeta), *Corbicula fluminalis*, *Cleopatra bulimoides* and *Melanoides tuberculata* (Mollusca) are present along the whole Nile system.

## 3 Diversity of the Macrobenthos

Lotic ecosystems show unidirectional water movement, maintaining such processes as organic matter transport, sediment deposition and the formation of longitudinal gradients (Vannote et al., 1980). These factors directly or indirectly influence the resident biological communities (Ward, 1998). Fluvial continuity allows the colonization of river reaches downstream from upstream habitats. Abdel Gawad (2001) listed twenty eight species of annelida, mollusca and arthropoda (60%, 28% and 12% of total macrobenthos density) at Helwan region. Ramadan et al. (2000) recorded twenty species of mollusca (fourteen gastropods, six bivalves) between Esna and El-Kanater El Kharia. (El-Shabrawy, unpublished) listed 46 and 51 benthic species (of them 23 and 29 mollusca) in the Nile (Cairo-Aswan) and its branches, respectively. The documented taxon richness of macroinvertebrates in the Nile currently adds up to 51 taxa with 7–31 spp. at individual bank-side sites (but see further for evidence that this represents either a strong underestimate, or many species have gone extinct in the course of the twentieth century). Mid-stream biodiversity is lower (0–19). Lowest diversity occurs at polluted sites, highest at sites with high levels of sedimentation (Fishar & Williams, 2006). Information on macroinvertebrate diversity in large rivers from the United States and Europe can be used for comparison. Moyle (1940) collected a total of 111 taxa in a survey of the Upper Mississippi basin, whereas Elstad (1986) recorded 144 taxa in 1975 and 131 taxa in 1976–1977. Newell (1998) identified 55 taxa from the Columbia River, USA and Duane et al. (2004) recorded about 260 species in the Missouri River. In comparison, the invertebrate taxon richness of the Nile is low. A comparison between the macroinvertebrate taxon richness of the Nile and that of the Rhine over the past 80 years (CIPR, 1991) (Fig. 4) shows that macroinvertebrates in the Rhine fell from about 120 taxa in the 1920s, with strong insect representation, to about 27 taxa in the 1970s with far fewer insect species present. The current macroinvertebrate diversity

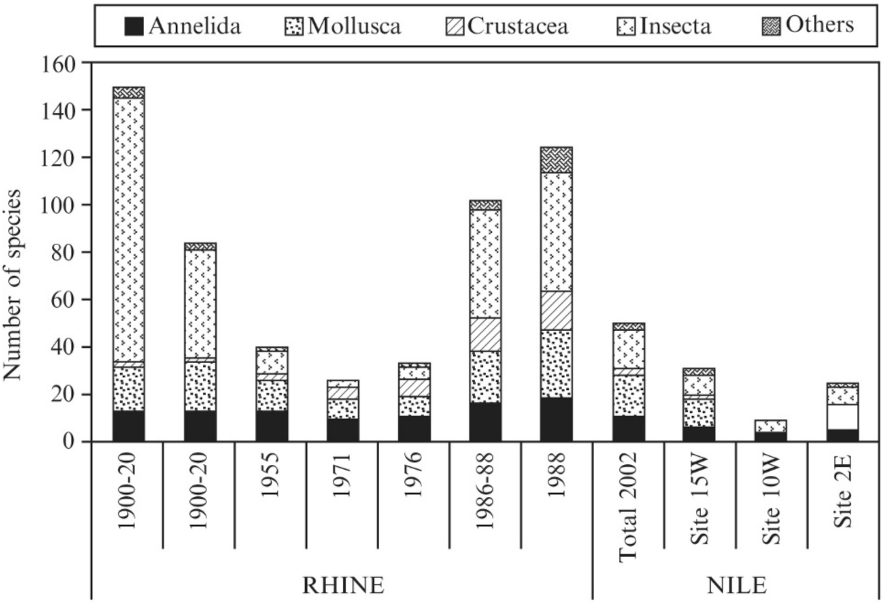


**Fig. 4** Comparison of invertebrate diversity in the Nile and Rhine Rivers (after Fishar et al., 2006)

in the Nile is similar in number and composition to that of the Rhine in the 1950s. Subsequent improvements in the Rhine have been the result of two actions: pollution control and habitat restoration. The diversity of Nile macroinvertebrates is therefore probably lower than before. Flow regulation and pollution as a result of urbanisation and population growth since the nineteenth century may be the main reasons for this. However, in the case of the Nile (and many other rivers of Africa), taxonomy is lagging behind international standards and inventories – especially made in an ecological context – are far from accurate. Thus, in the case of the White Nile – the 50 + species on record are only a fraction of the 300 + that taxonomic surveys of adult Diptera alone have brought to light (see Dumont, 2009, and Green & El-Moghraby, 2009, for further details, mainly taken from the work of D. J. Lewis).

## 4 Macroinvertebrates as Indicators of Pollution

Biological criteria to develop a biotic pollution index can be used in conjunction with physical–chemical data. Many biotic indices are based on the pollution tolerance of macro-invertebrates. Benthic invertebrates are useful because they are long-lived, sessile, and the diversity of species may indicate water quality conditions over a period of months; chemical records are relevant only for the time of their measurement. Intermittent pollution can be easily missed by chemical sampling. Macro-invertebrates are fairly easy to identify, and do not require the skills of highly specialised taxonomists (Hellawell, 1986).

The use of biotic indices for pollution monitoring in rivers was developed in Europe and in the United States (Rosenberg & Resh, 1993). Indices have been developed using Protozoa (Jian & Yun, 2003), diatoms, macrophytes, and fish (Plafkin et al., 1989; Iliopoulou-Georgudaki et al., 2003).

One of the simplest methods using macroinvertebrates was developed in the UK. The first version (ISO-BMWP, 1979) scores each family present from 1–100 and has two scales, one for depositing and one for eroding habitats. Later, the scoring was simplified to 1–10 and the scale for depositing zones was excluded.

The simplicity and reliability of this BMWP score has made it an attractive model for adaptation to countries other than Britain, especially to countries in which taxonomy is not well developed. Fishar and Williams (2008) described a related Nile Biotic Pollution Index (NBPI) for Egypt. Seven chemical variables were used to and Biological data were collected from the same sites using Artificial Substrate Samplers (ASS). A biotic pollution index (NBPI) was based on the presence of invertebrate taxa identified to family level using the BMWP scoring system supplemented by the "Saprobien" System. The Average Score per Taxon (NBPI-APTS) was also calculated. The NBPI-ASPT performed a little better in the river as a whole as a pollution indicator than the NBPI. In clean waters, there was a wide range of NBPI scores, suggesting that the diversity of taxa also depends on other aspects of habitat quality. Conversely, in the polluted delta the scoring of individual taxa is critical, as one high scoring taxon may have a distorting effect.

This is useful information for an overall ecological assessment of the river. The relatively low taxon richness in the Nile and great variability of NBPI score at clean sites is of concern for the future management of the Nile, however.

## 5 Macroinvertebrates Associated with Macrophytes

Sampling large rivers such as the Nile is marred by logistic difficulties. Fishar & Williams (2006) used three sampling methods (Ekman Grab, macrophyte sweep netting and Artificial Substrate Samplers, ASS) for monitoring macroinvertebrate diversity. They found that the average number of taxa collected per sample from the banks by each method indicates that the ASS were by far most efficient with 7.2, followed by macrophytes with 3.4 and only 2.4 for the grab samples. The Nile was characterized by its large number of plant species that forms a mosaic of communities (see also Zahran, 2009). The habitats created by the combination of emergent plants and open water are prolific areas for insect development (Magee et al., 1999) since a part of providing habitat, decaying plant material supplies food for aquatic detritivores (some midges and mayflies), and creates refuges, allowing successful avoidance of predation in vegetated areas (Evans et al., 1999). Macroinvertebrate assemblages appear to be strongly influenced by vegetation (Battle et al., 2001). In Egypt, they are rich in insects such as Ephemeroptera, Odonata, Hemiptera, Coleoptera, Trichoptera, Lepidoptera and Diptera (Agami, 1989). Many ecological and taxonomical studies on Nile insects are available (Ali et al., 1993; Geene, 1994). Mohamed (2007) studied the insect community in the Nile at Cairo: 44 genera belonging to Diptera (85% of total insect density), Ephemeroptera (6%), Odonata (5%), Trichoptera (2%), Hemiptera (2%), Coleoptera (0.3%) and Lepidoptera (0.01%) were found. Diptera comprised 13 genera in 7 families. Ephemeroptera was represented by *Baetis* sp. and *Caenis* sp., and Odonata by at least *Ischnura* sp., *Trithemis* sp., *Orthetrum* sp., and *Sympetrum* sp. Trichoptera, Hemiptera, Coleoptera and Lepidoptera were represented by 3, 4, 12 and 2 genera, respectively. Dumont (1980) stated that 52 + species of Odonata occur in Egypt (and therefore, as stated earlier, the 51 species of the total benthos must be a severe underestimate, even if some species may have gone extinct by river pollution). Chironomid larvae were abundant, reaching 1920 ind $m^{-2}$ at Aswan reservoir in spring (Fig. 3) and represented by 15 and 12 species in Lake Nasser and Aswan reservoir, respectively (Iskaros, 1988). The different macrophyte communities of Lake Nasser (dominated by *Najas* spp.) and the reservoir/river system north of Aswan High Dam (*Potamogeton crispus–Ceratophyllum demersum* association predominant) clearly reflect this (Springuel & Murphy, 1991).

## 6 Invasive Macrobenthic Species in Egypt

Many alien species have been introduced to the Nile in Egypt. The following are examples of Mollusca and Crustacea reported by Ibrahim and Khalil (2004) (see also Dumont, 2009; Van Damme & Van Bocxlaer, 2009). The mollusc *Helisoma* *duryi* is a North American species, first recorded in Egypt in 1980. It had been suggested as a biological control agent of *Biomphalaria* and *Bulinus*, intermediate hosts of schistosomiasis.

The red swamp crayfish, *Procambarus clarkii,* and the White River Crawfish, *Procambarus zonangulus*, indigenous to the United States and Mexico, have been introduced to Egypt in the early 1980s and now coexist in mixed populations throughout the Nile (Ibrahim et al., 1997). They are large and prolific (a female can produce over 600 young), have a burrowing life-style (causing damage to levees, barrages and irrigation systems), and are adapted to areas with seasonal fluctuations in water levels which they survive in burrows. *Procambarus clarkii* is voracious, preying on various crustaceans, molluscs and small fish, as well as on their eggs and fry. It is the most common of the two and is noted for attacking fish in trammel nets, leading to economic losses. But it also feeds on benthic snails, making itself useful as a biological schistosome control agent, and it is readily consumed by the local population. Its carapace is used as forage for cattle, and it serves as a bio-indicator of trace metals which it accumulates in its tissues.

## 7 The White and Blue Nile

The known macrobenthos of the White Nile system is represented by 52 species (see earlier, for a caveat on this figure). Monakov (1969) produced a seminal paper on the benthos that still forms the backbone of our knowledge. The sandy bed of the White Nile is sparsely populated by larvae of Chironomidae (*Glyptotendipes* sp., *Cryptochironomus* sp.); Oligochaeta (*Limnodrilus hoffmeisteri*) predominate on clay or sandy bottoms with small quantities of silt, near river banks or at shallow depths. Molluscs were often absent while Hirudinea, Trichoptera larvae (*Oecetis* sp., *Chematopsyche* sp.,) and larvae of Ephemeroptera were rare. The general biomass of the benthos was low in the bed of the river (0–0.2 g $m^{-2}$), increasing to 4.9 g $m^{-2}$ near the banks. There was little difference in number of bottom animals between autumn and spring. The benthos of the Sobat River differed little from that of the White Nile. The clayey bottom of the bed was sparsely populated by Chironomidae (*Polypedilum* sp., *Clinotanypus* sp., *Stictochironomus* sp., *Cryptochironomus* sp.) and Trichoptera. The total biomass of the benthos in the middle of the river was about 0.2 g $m^{-2}$. But near the mouth of the Sobat, large zones were invaded by the big bivalve, *Etheria elliptica*. The colonies of these molluscs provided a habitat for a rich fauna of Ephemeroptera and Trichoptera. The genera *Amphipsyche*, *Cheumatopsyche*, *Aethaloptera* and *Ecnomis* predominated. In the same place *Eupera parasitica* (Mollusca) was found.

The bottom fauna of Jebel Aulia reservoir differed greatly from that of the river and flood-plain water bodies. The share of Mollusca increased (17 species recorded). *Corbicula consobrina*, *Corbicula cunningtoni*, *Sphaerium abyssinicum* and *Cleopatra bulimoides* predominated. Chironomidae were represented primarily by species of the genus *Cryptochironomus* and *Stictochironomus* but the total number of species of Chironomidae also increased. Among Oligochaeta, *Limnodrilus hoffmeisteri, L. udekemianus,* and *Stylodrilus heringianus* predominated (Monakov, op. cit.).

Information about the benthos of the Blue Nile is scarce (Vijverberg et al., 2009). The inshore benthic fauna is poor, probably because of drastic seasonal changes of water level (Rzóska, 1976). Hammerton (1976) reported the presence of large numbers of the giant mussel *Etheria elliptica* attached to rock outcrops in the river between Diem and Roseires.

# 8 Lakes

Lakes show considerable heterogeneity in spatio-temporal benthos distribution. Because the bottom of turbid shallow lakes is often situated in the aphotic zone, anoxic conditions tend to develop here, especially where highly organic sediments occur, and the benthos of such muddy bottoms is poor in species. Typical inhabitants of such sediments are tubificids and chironomids. The benthic fauna of tropical lakes has been largely neglected by limnologists despite its role in the transfer of matter and energy. Generally, however, benthic invertebrates of African lakes appear to have low species diversity in comparison with temperate lakes.

## *8.1 Lake Victoria*

In the past four decades Lake Victoria has undergone ecological changes that have affected all levels of its ecosystem (Witte et al., 1992; Lehman, 2009). The result has been a dramatic reduction in species richness and extinction of indigenous fauna and flora. The phytoplankton is dominated by Cyanobacteria. The zooplankton moved from a calanoid to a cyclopoid-dominated community. Among fish, about 200 cichlid taxa have been lost (Barel et al., 1991). The native tilapia (*Oreochromis esculentus*), previously a fish of great commercial importance, has fallen to insignificant numbers (Goldsmidt & Witte, 1992). It is almost certain that many the macrobenthos components insects, crustaceans and molluscs have also been affected by this altered trophic structure. In 1984, 12 species of mollusc, 14 species of insects and three species of oligochaetes were identified in the open lake and Winam gulf (Muli & Mavuti, 2001). Nematodes and ostracods were also present but did not make up a major part of the community. The gulf had higher species richness than the main lake. The molluscs were dominated by the gastropods *Melanoides tuberculata* and *Bellamya unicolor* and by three species of Bivalvia, *Caelatura hauttecouri*, *Mutela bourguignati*, and *Corbicula fluminalis*. Oligochaeta were represented mainly by *Branchiura sowerbyii* and *Alma emini*, with *B. sowerbyii* dominant. Other abundant macroinvertebrates included the larvae of aquatic insects of the families/orders Chironomidae, Ephemeroptera, Odonata and Trichoptera (Muli & Mavuti, 2001). In 1994/1995, the benthic fauna of main lake and Winam gulf had simplified and was composed mainly of oligochaetes and molluscs. Insect nymphs and Hirudinea were also present but did no longer make up a major part of the community. Nematodes and ostracods were not encountered. Twelve species of molluscs, 19 species of insects, four species of oligochaetes and two species of Hirudinea were identified throughout the lake. The gulf still had higher species richness (31 species) than the main lake (22 species). Comparing the two sampling periods, there has been a shift in abundance, from an Oligochaeta and Insecta dominated community in 1984, to a community dominated by Mollusca and Oligochaeta. The abundance of Tubificidae and Sphaeriidae seems on the increase, while that of insects still decreases (Muli & Mavuti, op. cit.). Mbahinzireki (1994) and Ligtvoet & Witte (1991) observed a similar trend in the Uganda and Tanzania portions of Lake Victoria.

The accidental introduction of water hyacinth (*Eichhornia crassipes*) in 1988, beside a number of negative effects, gave a new boost to benthic diversity and abundance. The floating mat of *Eichhornia* provides habitats for colonization by aquatic macroinvertebrates. The outer fringes of the vegetation at the interface with the open water are well oxygenated and support abundant invertebrate communities. Deeper into the bed of vegetation, the oxygen concentration in and below the root mat declines. This is mirrored by a decline in abundance and diversity of invertebrates and an increase in low oxygen-tolerant species (Masifwa et al., 2001).

## *8.2 Lake Turkana*

Substrate variability in the shallow waters of lake Turkana is high. Much of the lake's shoreline is sand or rock-shingle bottoms, particularly on the south and west sides. Muddy and vegetated shallows are more restricted. Deep water substrates are almost entirely fine-grained silty muds. The lake is holomictic except in a few shallow silled embayments. Dissolved oxygen is almost always plentiful (for more details, see Johnson & Malala, 2009). The known benthic community of the lake is represented by a sponge (unidentified), a bryozoan (unidentified), 8 gastropods, 3 bivalves, 17 ostracods, 23 insect species and several hydracarines and annelids. Three benthic faunal associations have been identified: (1) a littoral, soft bottom association, dominated by the ostracod *Hemicypris kliei*, naucorid water bugs, and the corixid, *Micronecta* sp. This association is found throughout the basin in water depths less than two meters. Most lakeside lagoons contain these two species exclusively. The ostracods *Ilyocypris gibba*, *Potamocypris worthingtoni*, *Cyprideis torosa*, naucorids and several species of swimming beetles are also associated with vegetated soft bottoms. (2) A littoral, rocky bottom association composed of stonefly and mayfly larvae, gastropods (*Gabbiella rosea, Ceratophallus natalensis*), a leech (*Placobdella fimbriata*) and a sponge. Ostracods are rare on both vegetated and barren littoral rocky bottoms, except where they border on mud bottoms. This association is mostly found in the southern part of the lake, where hard bottoms are common. (3) A profundal, muddy bottom association, composed of stunted gastropods

(*Melanoides tuberculata*, *Cleopatra bulimoides*, *Gabbiella roses* and *Gyraulus* sp.), chironomids and ostracods. Sandy bottoms are generally devoid of benthos at all depths (Cohen, 1986). Infaunal invertebrates, particularly bivalves, which frequent high energy sandy bottoms in other African lakes, are absent from Lake Turkana. Epifaunal ostracods are prevented from feeding on shifting sandy substrates, and macrophytes also have difficulty in colonizing them. Geographic distribution of benthic invertebrates within the lake mostly follows habitat variations with depth. With the exception of some of the rocky bottom species from the South Basin, all common taxa occur throughout the lake wherever local substrate, water chemical and feeding conditions are appropriate. Most of the invertebrate species present in the lake benthos have adaptations for long range, passive dispersal. Depth range and faunal association studies of the common invertebrate taxa show two associations related to water depth and which parallel the two soft bottom associations mentioned above. Most probably, these associations are only secondarily correlated with water depth, being principally regulated by food availability (Cohen, op. cit.).

## 8.3 Lake George

The benthos is dominated by dipteran larvae, viz. two species of *Chaoborus* and many unidentified chironomid larvae. Oligochaetes are the second important constituent. Mollusca are represented by *Melanoides tuberculata*, mainly at the shores, owing to the unstable soft mud of the central region. The benthos found in the top 20 cm is composed of chironomids, *Chaoborus*, and ostracods. Oligochaetes even occur up to depths of 40 cm. This community is depauperate in species and groups, because of the deoxygenated substrate and has a mean standing crop of 1.2 g $m^{-2}$ (dry weight). All species are detritivores, except one or two chironomids which are partly carnivorous, and *Chaoborus* which retreats into the mud during the day, but moves into the water column to feed on zooplankton at night. Only close to the shore, where sand, clay and gravel occur, a richer community, composed of molluscs, nematodes, and insects is found. Its dependence on the nature of the substratum is similar to that in Lake Chad (Dumont, 1992). Beadle (1981) considered that the low diversity of benthic fauna in Lake George may be a result of its young age (4,000 years ago), following a period of volcanism and desiccation.

## 8.4 Lake Tana

Relatively little is known about the benthic invertebrate of this large, relatively shallow lake at the origins of the Blue Nile (Vijverberg et al., 2009). Bacci (1951–1952) recorded 15 mollusc species, of which *Bellamyia unicolor abyssinica* is likely endemic. Recent work showed that oligochaetes, *Chaoborus* spp. and chironomids occur both inshore and offshore (Tewabe et al., 2005).

## 8.5 Delta Lakes

The Nile Delta supports salt marshes and brackish shallow lakes (Mariut, Edku, Borullus and Manzalah). Before the Nile damming (1902, 1970), the lakes were under strong marine influence for about two thirds of the year, to be flushed and freshened by the river flood in the remaining third. The first more or less reliable data on invertebrates appear in a paper by Steuer (1942). The invertebrates were a mix of marine and freshwater species, with plenty of biota tolerant of strong fluctuations in salinity. Thus, marine-origin cirripeds (*Balanus improvisus*) settled on the stems of Phragmites, side by side with the Caspian-origin colonial cnidarian *Cordylophora caspia*. The macrobenthos also contained two species of mysids, two polychaetes of the genus *Nereis*, the serpulid *Ficopomatus enigmatica*, and three amphipods, including the burrowing *Corophium orientale*, besides freshwater organisms like insect larvae of several midge groups (e.g. *Cricotopus*) and even damselfly larvae (Steuer, op cit.). After AHD (Aswan High Dam) construction, the benthic communities became subject to dulcification and eutrophication. The species preferring eutrophic habitats (tubificidae and gastropods) increased, true marine species disappeared, some brackish-water species survived. Progressive extension of the area of aquatic vegetation (*Potamogeton* belt) lead to a diversity and abundance of species that live on water plants, at the expense of those living on uncovered bottom. El-Shabrawy (2002) listed 33 macrobenthic species in Lake Borullus, 13 arthropods, 8 annelids and 12 molluscs. That number is three times that of 1978 (Aboul Ezz, 1984), reflecting an increasing macrophyte cover (Fig. 5), since 21species were associated with lake macrophytes (El-Shabrawy, op. cit.). In the meiobenthos, Ostracoda are normally as trustworthy indicators of salinity as zooplanktonic copepods. Ramdani et al. (2001) mentioned three extant species: *Cyprideis torosa* extends from oligohaline to mesohaline environments; *Limnocythere inopinata* and *Loxoconcha elliptica* are oligohaline species. In

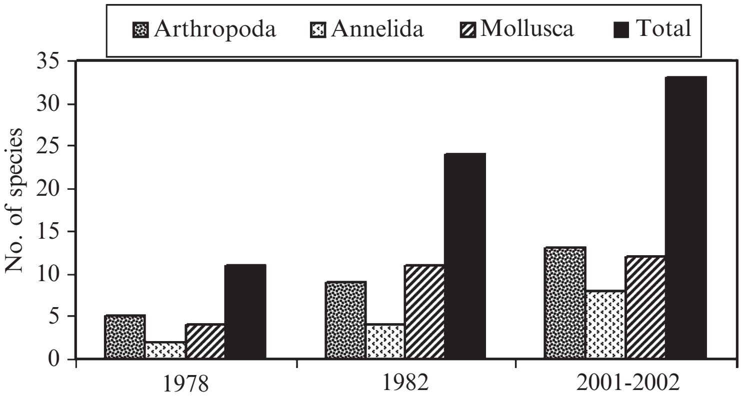


**Fig. 5** Changes in the diversity within macrobenthic groups in Lake Borullus from 1978 to 2002 (original)

sediment deposits, only *Cyprideis* was found throughout a core spanning at least the twentieth century; the two freshwater species appeared before 1950, possibly shortly after 1900, suggesting a saline crisis around the beginning of the twentieth century. Abdel Mola (2003) recorded 15 macrobenthic species, belonging to 4 groups viz. 6 arthropods, 4 annelids, 4 molluscs and 1 coelenterate in Lake Manzalah. *Balanus* sp, *Gammarus locusta*, *Sphaeroma serratum, Corophium orientale*, *Chironomus* larvae, *Ficopomatus enigmaticus, Hedastia diversicolor, Polydora ciliata*, *Chaetogaster limnaei*, and *Semisalsa sp,* were abundant. The standing crop showed lowest density (ca 700 ind $m^{-2}$) in winter, and was highest (7,000 ind $m^{-2}$) in summer. In 2007, El-Shabrawy (unpublished) found that macrobenthos (representing 26 species) was high in spring and winter (970 and 720 ind $m^{-2}$), and at minimum in summer, 330 ind $m^{-2}$ (Fig. 6). Chironomids, *Limnodrilus hoffmeisteri* and *Melanoides tuberculata* were abundant and widely distributed. The first survey on Lake Mariut by Samaan & Aleem (1972) revealed that a mac-

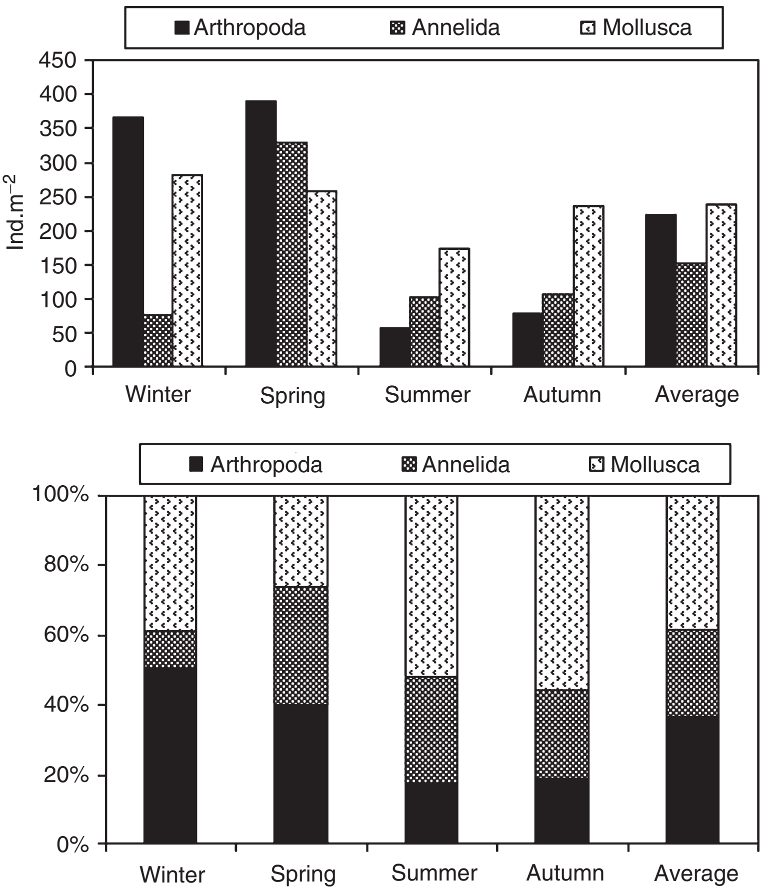


**Fig. 6** Mean abundance and proportion of the three main groups of the macrobenthos by season in Lake Manzala (original)

robenthos assemblage of mainly three species, *Nereis diversicolor, Corophium volutator* and *Melanoides tuberculata*, composed 95% of total biomass. Abdel Aziz (1987) came to the same conclusion. Bernasconi & Stanley (1994) found a bottom fauna characterized by 78% of gastropods. Kossa (2000) recorded 14 benthic species, dominated again by gastropods. Aboul Ezz & Abdel Aziz (1999) listed 30 species, belonging to six groups: Oligochaeta (1 species), Polychaeta (3 species), Nematoda (1 species), Crustacea (8 species), insect larvae (3 species), Gastropoda (12 species), and Bivalva (2 species). *Hydrobia stagnorum*, *Paludestrina minuta*, and *Pomatiopsis* sp. were dominant. Insecta were represented by chironomids and Odonata (Fig. 7).

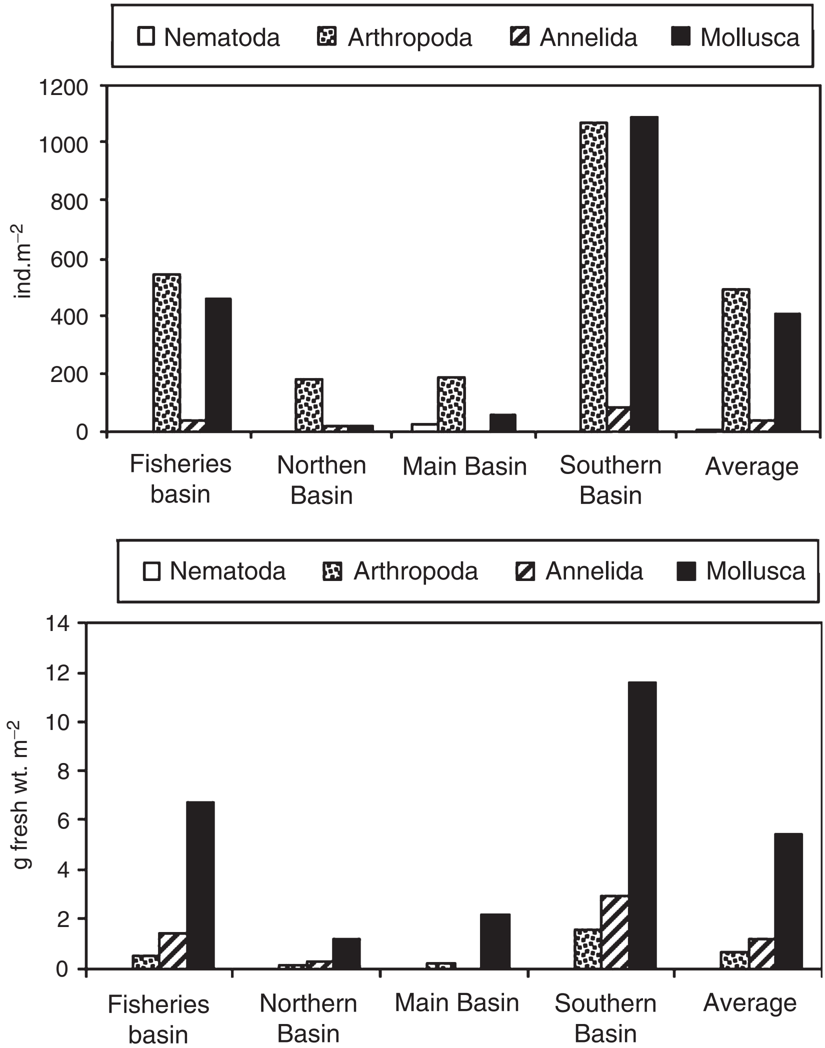


**Fig. 7** Mean abundance and biomass of the three main groups of the macrobenthos by geographic sector in Lake Mariut (original)

## 9 Determinants of Diversity and Density of Benthos

The Nile benthos, in spite of gaps outlined earlier, exhibits a marked variation in taxonomic structure and abundance. Substratum type, water depth, sediment chemical properties, salinity (in the delta, Toshka and Fayum lakes), predation, and food come forward as the determining factors (Sibley et al., 1998). Soil texture plays a major role too: grain size should neither be too coarse nor too fine, but such effects vary with taxonomic groups. Winnel & Jude (1984) stated that bottom-dwelling invertebrates avoid coarse sediment, which could damage their soft integument by abrasion. Wiley (1981) mentioned that chironomids are burrowers, that actively seek out soft sediment. McLachlan & McLachlan (1971) found an adverse effect of coarse sand on Chironomidae. In Lake Nasser, El-Shabrawy & Abd El-Regal (1999), found a negative correlation between coarse sand and benthos, while *Limnodrilus* and *Chironomus* larvae were abundant on clay and loam. Benthos abounds in the Ethiopian rift lakes on medium and fine grained sand, while a reduced number of species occurs on silty and organic bottoms as well as on coarse sands (Tudorancea et al., 1989). In Lake Chad, molluscs and tubificids were associated with clay, while most insects are associated with sand (Dejoux et al., 1971). In Lake Kariba, Zimbabwe, coarse sand had an adverse effect on chironomids in the littoral, while a positive relation was found between organic carbon and chironomid biomass in profundal mud in winter (McLachlan & McLachlan, 1971). Particle size may favour some organisms but cannot be entirely responsible for their distribution. Other factors associated with the substrate are sediment consistency and chemistry. In lake Awasa, where the mid-lake sediment is semi-liquid and flocculent, no benthic fauna exists beyond 8–10 m depth (Tudorancea et al., op. cit.).

Abdel Gawad (2001) & Fishar (1995) claimed that in the Nile and Lake Nasser shallow water is beneficial to benthos. Average biomass in the littoral (7.21 g) is higher than in the main channel (3.45 g) (El-Shabrawy & Abd El-Regal, 1999). Benthic depth distribution in most Ethiopian Rift valley lakes is also characterized by peaks in shallow zones (Tudorancea et al., 1989). Finally, higher abundance of benthic organisms in the shallows were observed in African lakes such as Chilwa (McLachlan, 1979), Nakuru & Turkana (Cohen, 1986).

Dissolved oxygen in water and sediment may be a significant limiting factor in tropical lakes with marked thermoclines and oxylines (Beadle, 1981). Thus, during summer and autumn chironomids in the main channel of Lake Nasser respond to anoxy of the sediment by and migrating to shallower places with a better oxygen content.

Chemical properties of sediment affect benthos distribution. Mercedes (1987) found a correlation between *Limnodrilus hoffmeisteri* and conductivity in the Parana River, Argentina. Verdonschot (1987) recorded a positive relation between *L. hoffmeisteri* and pH, bicarbonate, calcium and nitrate. McLachlan & McLachlan (1971) observed a correlation between organic enrichment and Chironomid larvae and Oligochaeta. In Lake Nasser, *Limnodrilus hoffmeisteri* positively related with EC ($r = 0.66$) and organic mater ($r = 0.57$) (El-Shabrawy & Abd El-Regal, 1999).

Environmental effects on particular organisms indirectly affect other organisms which interact with them as prey, predators, competitors or symbionts. Competition and predation between benthic species has, however, been little studied in a Nilotic context. Only circumstantial evidence is available. Thus, Roback (1980) claimed that *Chironomus* larvae inhabit the littoral of lakes characterized by abundant macrophytes for protection. The abundance of benthos in the littoral of Lake Nasser may be due to the abundance of such "shielding" macrophytes (see Zahran, 2009).

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