Ethiop. J. Biol. Sci., 5(1): 75-115, 2006

ISSN: 1819-8678

REVIEW ARTICLE

STATUS AND CHALLENGES OF AQUATIC INVERTEBRATE RESEARCH IN ETHIOPIA: A REVIEW

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ABSTRACT: Ethiopia is endowed with several aquatic resources, including over 20 natural lakes, 12 large river basins, over 70 wetlands, and 10 reservoirs. Micro-dam construction and river impoundment have intensified in recent years and created innumerable small water bodies. Yet research on the aquatic fauna in these waters is limited to only a few records of zooplankton and benthic invertebrates in the rift valley lakes. There are no established institutions pursuing research on aquatic invertebrates; as a result, most research initiative has been limited to individual pursuits in universities and some amateur collectors. Thus, although fragmented and sporadic reports on the composition of invertebrate specimens collected at different times are available in the literature, systematic compilation on the status of research on aquatic invertebrates in Ethiopia is lacking, and this review is an attempt to fill this gap. Collection of biological specimens formed part of the colonial mission of Italian and British expeditions in the 1930's and many invertebrate collections are still found in foreign museums such as the Natural History Museum of London, where they remain relatively inaccessible for close study by researchers from developing countries. Historical and recent surveys on aquatic invertebrates in Ethiopia document quite a high degree of endemism in some groups such as the Simulidae (blackflies), Nematoda, Trichoptera (stoneflies), Ostracoda (clam shrimps) and Gastropoda. Mostly, invertebrate taxa reported in Ethiopia are of Afro-tropical forms, but a few Eurasian forms were also recorded from high altitude water bodies. Threats to aquatic biota have accelerated in recent years due to increased human and livestock populations, water abstraction projects, siltation, pollution and catchment degradation. The impacts of such threats on aquatic biodiversity is not known. The record also indicates disparity in the research attention accorded to different invertebrate groups. For example, some aquatic invertebrates such as Protozoa, Diptera, Oligochaeta and Lepidoptera have received only marginal attention, while others such as zooplankton, Ostracoda, Nematoda, benthic insects and mollusks have received better attention. On the whole, research on aquatic invertebrates is poor and there is need to bridge the gap between different groups in the future. The need for establishment of a national center for invertebrate research is noted.

Key words/phrases: Aquatic invertebrates; Ethiopia; Research; Review.

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INTRODUCTION

The immense diversity of invertebrates makes their identification and ecological analysis a daunting task. It is suspected that there are more then 3 million living species of invertebrates, but only about 42% or 1.27 million species have been described so far (Primack, 1993; UNEP, 2000). Aquatic invertebrates constitute a considerable portion of the total invertebrate taxa in our planet. They form a very conspicuous and critical component of the earth's life forms, being important in agriculture, ecosystems functioning, medicine, health, as food, pathogens, disease vectors, pests and even pets.

Neglect of invertebrate research is a universal phenomenon in general. Kellert (1993) asserts that many in the general public view invertebrates with aversion, fear, avoidance and ignorance. This goes for governments and even universities; hence it is no surprise that research on invertebrates in general lags far behind that of vertebrates, microbes or plants. In Ethiopia, apathy of research initiative on invertebrates in general, and aquatic invertebrates in particular, is therefore to be expected.

Ethiopia is a signatory to many international treaties and conventions designed to protect and conserve biological resources. A few to cite are the Convention on Biological Diversity (CBD), the Framework Convention on Climate Change (FCCC), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the UN Convention on the Law of the Seas. Despite these promises, the starting point of stock taking of the biological diversity of the country has hardly begun, not least when invertebrates are concerned. The Convention on Biological Diversity is an international understanding signed by 168 states, including Ethiopia, about the need for, and urgency of inventory and protecting the biodiversity of our planet earth. Aquatic biodiversity is highly stressed in the document as a broad theme: "aquatic biodiversity includes not only the target plants and animals that are harvested or farmed but also the many microbial, plant and animal species that feed and shelter them and that maintain the environment".While we are signatory to the CBD, relatively little work has been done to document the biodiversity resources, including the aquatic ones, in Ethiopia in general.

Research on aquatic invertebrates is almost non-existent or perhaps at its infancy in Ethiopia. Even with regards to fish - the most obvious component of aquatic habitats - the focus and attention given to the aquatic resources has been minimal at least, and none at best. There may be several reasons to this apparent neglect - the cultural bias towards terrestrial food sources, lack of awareness about the biological and mineral wealth present in waters, religious and cultural prejudices against aquatic life-forms such as crocodiles, alligators, leeches, mosquitoes and snails, and several local and unique factors at interplay. Whatever the case, the country has not benefited from its vast aquatic resources, be it for consumption, recreation, external commerce, eco-tourism or scientific studies. Already, we may have lost a vast array of invertebrate biodiversity with innumerable ecological functions. But what can we do from here-on? This review is an attempt to highlight some of the problems responsible for the neglect, and to point new charts that will help to lay ground for sustainable exploitation of our invertebrate resources. To address this issue, I will include a short exposition on the chemical limnology of the major lakes so as to indicate the type of ecology suitable for invertebrate life-forms. Then, the status of taxonomic and ecological research of some invertebrate taxa will be briefly mentioned. Finally, the threats and dangers to aquatic invertebrates and the conservation measures needed to avert further extinction, and future prospects for advancement of research and knowledge on the aquatic biodiversity in Ethiopia will be briefly addressed.

HISTORICAL PERSPECTIVES

The earliest pioneers to study aquatic invertebrates were colonial collectors who came behind the military invaders into the country in the early 1930's. The objectives of these 'quasi-scientists' were not as such the pursuit of scientific curiosity and knowledge, but rather to make an inventory of the resources of the country for latter pillage and exploitation, including the aquatic resources. Such inventory was not even organized properly, and the collectors sporadically amassed specimens as they camped and trekked along different parts of the country with the military personnel. As such these studies give only limited insight into the diversity of the aquatic invertebrates surveyed during this period.

Prominent among such collectors were the entomologist Hinton, the aquatic ecologist Omer-Cooper and other British expeditionary forces. The scientists who analyzed the specimens collected were notably Lowndes and Hutchinson. Lowndes (1932) worked on aquatic invertebrate specimens collected by Mr. J. Omer-Cooper. His taxonomic studies on the Copepoda is classical and detailed - we used his type specimens of calanoids to authenticate our identifications recently. His description of the Cyclopoida is less resilient, and many of the genera reported have become revised since then, including the old genera *Platycyclops*, *Cryptocyclops* and

Leptocyclops. Despite the limited coverage of the collection - in ponds around Addis Ababa, Mount Chilalu, DjemGjem forest and the Bishoftu crater lakes - the study is the first taxonomic report of the Copepoda in Ethiopia and represents a historical scientific landmark in this respect.

Hutchinson's 1930 paper in the *Proceedings of the Zoological Society of London* dealt with the aquatic hemipteran insects collected by Mr. Omer-Cooper during Dr. Hugh Scott's expedition to Abyssinia in 1926. Only some parts of the then central Abyssinia such as rift valley lakes, crater lakes and Mt. Ziquala were covered. Of notable significance is the high degree of endemic species reported by Hutchinson (1930). He found that of the 10 species of Notonectidae, half were new to science, and endemic to Ethiopia, including *Enithares perseus*, *Anisops robustus* and *A. balcis*. Of the 15 Corixids collected, 8 were new and endemic, including *Micronecta denticulata*, *M. omeriana*, *M. eupome*, *Glenocorixica sacra* and *Sigara hugoscotti*. Interestingly, he reported a palearctic and nearctic species, *Agropocorixa*, widely distributed in Ethiopia and forwarded zoogeographical hypothesis about its dispersal mechanism. The ecological status of these invertebrates has not been followed since then, although some corixids and notonectids are commonly observed on lake shores of Lake Abijata and the Bishoftu crater lakes. The collections of Filipjev (1931) of aquatic nematodes and Bryce (1931) of rotifers and their taxonomic contributions to the Ethiopian fauna is noteworthy. However, most of the specimens collected from these expeditions are deposited in foreign museums such as the Natural History Museum (London), where they remain prohibitively expensive to access for scientific study by scientists from developing countries.

The post-colonial period was followed by the establishment of the Haile Selassie I University (HSIU) in 1950 (the now Addis Ababa University). Scientific research on biological resources was restricted mainly to the Red Sea and inland fisheries. Almost no report exists about aquatic biota during the 1950's and 1960's, except perhaps to what some amateur and professional collectors studied on their own and published in obscure untraceable journals abroad. The author is not aware of these works, but surely, some should exist in obscure journals and monographs scattered here and there.

With the establishment of the Natural History Museum at HSIU in 1955, a few expatriate biologists started collection and documentation of terrestrial and aquatic vertebrate and invertebrate specimens. The pioneer contributions of Prof. and Mrs. Chojanicki, Prof. Tjonneland, Dr. R.B. Wood, Prof. J. Birket-Smith, Dr. J. Largen and Dr. E. K. Urban to the museum at large, and to its invertebrate collection in particular, should be underscored. Invertebrate collections from the Red Sea still form a conspicuous section of the Zoological Natural History Museum. Most of the other invertebrate collections were terrestrial butterflies, beetles, dipteran flies and mollusk shells. Of the aquatic group, some marine sponges, corals and echinoderms from the Red Sea and mollusk shells from freshwater lakes make up the major accessions. It appears that the museum did not have the resources or the expertise to preserve aquatic invertebrates in wet and dry mounts, slides and dissected sections. This capacity of the museum to preserve aquatic invertebrates has not been upgraded even at the time of this review, but has only been started due to generous funding by the Development Initiative Fund (DIF) of the World Bank.

The AAU effort aside, other institutions and projects tried to collect and document aquatic invertebrates at different times. The Alemaya (Horomaya) University has a large collection of agriculturally-important invertebrates, including insects, nematodes, earthworms and insects. Unfortunately, the emphasis has been only on the beneficial or harmful adult stages, leaving the aquatic larval stages largely ignored. The Ethiopian Institute of Agricultural Research (EIAR) has similar collections in the different parts of the country where its research centers are located. One can cite other projects like the Joint Ethio-Russian Biological Expedition (JERBE) where many collections of fish (and other aquatic invertebrates) were done for many years. Again, almost all of these specimens are deposited at the National Russian Museum in Moscow, and no duplicates have been deposited in Ethiopia, partly because there was nobody to receive the duplicates. The Plant Protection Unit of the Ministry of Agriculture and Rural Development collects and archives invertebrates of medical importance, those affecting crops, horticulture and forests, and the Veterinary Laboratory at Sebetta studies parasites of livestock and domestic animals. The Aklilu Lemma Institute of Pathobiology has a large collection of snail vectors of Schistosomiasis (Bilharzia). The Zoological Natural History Museum of Addis Ababa University has a modest collection of aquatic invertebrates, albeit incomplete in taxonomy and in substandard curatorial conditions.

Recent initiatives to collect and document invertebrates in Ethiopia have continued. The BIONET and the BOZONET fora are encouraging starts, although funds are still a shortfall. There is scope to form an umbrella institute where the taxonomy, ecology and economic studies will be garnered under one organization and scientific personnel. This review of the status of research on aquatic invertebrates, thus, serves as a useful springboard to indicate where we stand with regards to research on the aquatic invertebrate groups and to point the way forward.

AQUATIC SYSTEMS AND RESOURCES

Ethiopia is endowed with over 20 natural lakes and 12 large river basins, in addition to several impoundments whose numbers have been increasing in recent years. Yet, the major living resource so far utilized in these water bodies is fish, while others such as algae, crustaceans, crocodiles, hippos, birds and amphibians have largely been ignored. Many of these living aquatic resources give indispensable ecological, economic and social services and some have regional and global values in terms of biodiversity conservation and importance (Zinabu Gebre-Mariam and Elias Dadebo, 1989).

People are aware mainly about the physical and economic perspectives of water in Ethiopia. Although the country has excess water than it needs at present levels of consumption and despite its euphemistic name "water tower of Africa", the deplorable situation is that it is one of the most water-stressed countries on earth, and one with grossly underutilized water resource wealth. This is due to several reasons: (a) Almost 97% of the surface water is discharged outside to neighboring countries (Sudan, Egypt, Somalia) or is lost in sand (River Awash). Of the 14 river basins, 11 are international and contentious politically with riparian countries, (b) Due to poor economic performance and lack of capital, of the irrigation and hydropower potential of the surface and ground water, only 4.8% and 3%, respectively, have been utilized to date (Solomon Seyoum, 2000). This utilization has considered only the non-biological economic assets of the water bodies (see Table 5), (c) Water distribution is uneven with the eastern and western parts being water deficit for most of the year, and lack of any perennial flow in areas below 1500 m (Nicol, 2006). Water research is almost unknown in the arid and semi-arid dry-lands of the country, and (d) The silt load that is lost to downstream countries is only appreciated economically for its impacts on reservoir operation and turbine damage; yet the loss of biodiversity and biotic wealth of the same has never been documented in any basin master plan study or government archives.

The aquatic systems of Ethiopia have diverse physical and chemical settings and this is reflected in the rich biological diversity of the living resources.

High endemism is noted in some biological groups such as Nematoda, Ostracoda and Insecta. Unique aquatic flora and fauna abound in highly saline lakes such as Afdera, Metehara and Shala. Alkaline saline lakes have tremendous potential for the harvesting and culture of algal resources (e.g. *Spirulina/Arthrospira*) and exploitation of their unique thermophilic microbial communities. Trans-boundary waters such as Omo, Turkana, Nile and Wabe Shebelle possess unutilized aquatic resources of plankton, fish, birds, amphibians and reptiles. Much research and inventory work is required to disclose the full potential of the living aquatic resources in Ethiopia.

Crater lakes - Bishoftu (Debre-Zeit)

The Bishoftu crater lakes are about seven volcanic explosion lakes located about 45 km from the capital city, Addis Ababa near the town of Debre-Zeit (Bishoftu). Some chemical features of these lakes are presented in Table 1.

Table 1 Chemical composition of the crater lakes (After Wood and Talling, 1988; Tudorancea and Taylor, 2002 and various sources). Note that the maximum values reported are shown here.

Lake	Salinity (g/l)	Conductivity (µS/cm)	pH	∑cations (meq/l)	∑anions (meq/l)	SiO_2 (mg/l)	PO_4 (µg/l)	Chl a (µg/l)
Hora (Biete Mengist)	2.56	2340	9.2	29.5	32.9	53	<5	29
Kuriftu	0.26	3190	8.4	3.12	3.46	-	-	61
Babogaya (Pawlo)	0.94	1000	9.2	10.8	11.7	38	14	54
Bishoftu	1.92	1830	9.2	23.61	24.7	38	<5	34
Arenguade (Hora Hado)	5.54	6000	9.4	79.8	65.3	50	4100	5000
Kilotes (Kilole)	5.7 (0.57)	5930	9.6	75.7	77.4	45	5000	400
Chelekleka (ephemeral)	-	-	-	7.3	7.0	1.5	-	-
Ziquala	0.22	238	7.5	2.69	2.93	-	-	-

Despite the closed (endorrheic) nature of the lakes, most of the crater lakes are not saline (cf. Baxter, 2002). The most saline of them, such as Lakes Arenguade and Kilotes (Kilole), have become dilute in recent years, the latter due to diversion of the River Mojo (Brook Lemma, 1994). The reasons for the dilute nature of the waters may be the surface influx from freshwater springs and inflows and groundwater intrusion. Only the saline lakes show some discrepancy in the ionic proportions of the waters, possibly as a result of excess leaching of cations from lake basement. This may definitely affect algal composition and hence the diversity of the zooplankton and benthos in the lakes. It should be stressed, however, that the specific chemical composition of a lake depends on several factors such as the length of time the lake has existed, volume and composition of inflows, rate of evaporation from lake's surface and retention time of the water (Baxter, 2002), and may account for the wide diversity in the water chemistry of Ethiopian lakes.

Nutrients such as silicate and phosphate do not appear to be limiting in most of the Bishoftu crater lakes, with the exception of Lakes Hora and Bishoftu. And yet, these lakes are teeming with blooms of *Microcysis* most times of the year. Perhaps Nitrogen is a limiting factor, as is true for most tropical African lakes (Talling and Lemoalle, 1998). The huge reserve of phosphate in Lake Arenguade was partly responsible for the blooms of *Spirulina* (*Arthrospira*) that the lake used to enjoy some years earlier. Silicate is high in all the crater lakes, but they are dominated by blue-greens, not diatoms. Evidently, other factors such as light limitation, stratification, nutrient dynamics and mixing depth could be of overriding importance in determining primary production in these crater lakes (cf. Baxter, 2002). Many studies have indicated that cyanobacteria dominance in tropical lakes is attributed to high temperature, low CO_2 under high pH conditions, low nitrate concentration, low N:P ratio and low underwater climate condition (Reviewed in Elizabeth Kebede, 2002). There are, however, no long-term studies on nutrient and primary production studies in the crater lakes, as compared with the rift valley ones (cf. Zinabu Gebre-Mariam and Zerihun Desta, 2002).

The last two lakes are the least known. Only Getachew Teferra (1980) made a seasonal limnological study of Lake Chelekleka, which dries up completely every few years. Observations indicate that it can harbor a rich and diverse benthic community during the drying-up phase, which support a large diversity of bentivorous bird and invertebrate fauna. Unfortunately, sampling is almost impossible at this time because of the soft, sinking muddy bottom. Not much is known about the last crater Lake Ziquala, which occupies a crater depression on Mount Ziquala and has rarely been sampled.

The Bishoftu crater lakes are facing imminent danger because of accelerated human impacts in and around the lakes. High-standard hotels and resorts have already been built around the rims of Lakes Hora, Kuriftu, Babogaya and Bishoftu, with more to be constructed in the future. The use values of the lakes have increased because of high population pressure in the catchment and lots of industrial and commercial demands on the lakes. There is therefore high likelihood of species disappearances in these lakes, as some historical data on invertebrates seems to corroborate.

Rift Valley (RV) lakes

Table 2 summarizes the chemical and biological limnology of the eight RV lakes based on studies done since the early 1980's.

With the exception of Lakes Langano, Abijata and Shala, the other lakes are less saline and alkaline, and have conductivities below 1500 μS/cm. They fall within a wide range of salinity-alkalinity series, from freshwater (<0.5 g/l) to mesosaline (20-50 g/l) conditions. Sodium makes up the major portion of the cations and bicarbonates the major anion. Although not shown in the table, flouride is relatively high in the lake waters of Awassa, Abijata and Langano, and causes fluorosis in teeth and bones of the surrounding residents. The transparency of Lakes Zwai, Langano and Abaya is quite low (Secchi depth below 45 cm) possibly because of the siltation and stable colloidal suspension of ferric silt (Lake Abaya). The low light regime and euphotic depth of these lakes limit primary productivity; but despite this, Lake Zwai has relatively high algal production which supports large zooplankton, snail and fish biomass. Lakes Abaya and Langano, although with poor algal biomass, have rich zooplankton of calanoids and support viable fisheries, but little has been done on the benthic communities of these lakes.

The ionic composition of the RV lakes shows some anomalies, especially with respect to the balance between cations and anions. The discrepancy is highest in the more saline Lakes Abijata and Shala where the predominance of carbonate-bicarbonate anions shifts the pH to high values between 9 and 10, and which, in effect, limits the biological communities to alkalophilic types of bacteria, blue-green algae, *Spirulina* (*Arthrospira*) and few diatom, zooplankton and zoobenthos communities. The sparseness of divalent ions is also noted in these two lakes, and the high salinity they register is predominantly due to the sodium, and carbonate-bicarbonate and chloride species. Such lakes are of the soda type (Elizabeth Kebede, 2002) and are present in a few other lakes in the eastern part of the Great African Rift Valley in Kenya and Tanzania (Talling and Talling, 1965).

Table 2 Chemical composition of the rift valley lakes (After Wood and Talling, 1988; Tudorancea and Taylor, 2002 and various sources). Note that the maximum values reported are shown here.

Lake	Salinity (g/l)	Conductivity (μS/cm)	pH	∑cations (meq/l)	∑anions (meq/l)	SiO_2 (mg/l)	PO_4 (μg/l)	Chl a (μg/l)
Abaya	0.77	900	8.9	10.5	10.6	40	128	69
Abijata	16.2	30 000	10.3	285	316	128	50	75
Awassa	0.65	1030	8.8	12	12	96	<5	40
Chamo	1.09	1100	8.9	13.6	13.5	48	30	89
Chitu	38.3	28 600	9.8	556	539	320	1700	2600
Langano	1.88	1900	9.4	20.5	20.8	54	90	7
Shala	21.5	29 500	9.9	278	306	130	760	6
Zwai	0.35	370	8.9	4.5	4.8	47	-	91

In terms of nutrients, the RV lakes show high levels of soluble organic phosphate (SRP) and silicate, well above the values typical for eutrophic temperate lakes (SRP = 100 μg/l and Si = 2 mg/l). Nevertheless, despite these available nutrients, phytoplankton growth can be limited by others such as nitrate and Ammonia, especially during the dry months when these nutrients are in short supply (Elizabeth Kebede *et al.,* 1992). Low values of SRP and silicate in Lakes Zwai and Chamo reflect their uptake by biotic communities, including the high algal biomass of blue-greens and diatoms.

As a result of the algal biomass and turbidity, the RV lakes assume a diversity of lake coloration. Lakes Langano and Abaya are reddish-brown, whereas Lake Shala is deep blue. Lakes Zwai, Chamo and Awassa are brownish to greenish in appearance due to phytoplankton and inorganic turbidity. Lake Abijata is green from high algal biomass. Lake Turkana has a brownish appearance at its northern shores where the River Omo discharges its load of silt and debris.

The relative productivity of the lakes can be inferred from their algal biomass. The most productive are Lakes Zwai and Chamo, followed by Abijata and Awassa. The low primary productivity of Lakes Langano and Abaya is due to the high turbidities, while Lake Shala, although transparent, has low algal biomass because of its depth (266 m) and high salinity, which prevent mixing and limit nutrient availability (meromixis). No fish are present in Lake Shala except perhaps at the inflow shores of the freshwater hot-springs, but a unique zooplankton of harpacticoids dominate in this system. Lakes Awassa, Zwai, Langano, Chamo and Abaya support viable artisanal fisheries.

More detailed studies of the production and energy cycles, trophic ecology and plankton dynamics of the RV lakes are underway and some are complete, but holistic studies on the functioning efficiency of all the ecosystems is regrettably lacking, except for Lake Awassa (Tadesse Fetahi and Seyoum Mengistou, 2006) and Lake Tana (Ayalew Wondie and Seyoum Mengistou, in prep.)

Highland lakes

Lake Tana has been comparatively better studied of the other highland lakes. These consist of some lakes in Wollo (Lake Hayk and Lake Hardibo) and Tigray (Lake Ashenge). The only limnological study of the Bale mountain afro-montane lakes is that of Baxter and Golobitsch (1970) and Loffler (1978). Some data pertaining to the highland lakes are shown in Table 3.

The highland lakes all appear to be freshwater, but more alkaline. Not much discrepancy is seen between cation and anion ratios, and nutrients appear to be scarce but non-limiting. A two-year study of plankton biology in Lake Tana showed that factors such as availability of nutrients due to daily water mixing and low turbidity during the two months of the post-rainy season were the major reasons for the short pulsed primary production in this turbid lake (Ayalew Wondie *et al.*, 2007, in press). Despite the low primary production, Lake Tana has high fish diversity and biomass of barbs, consuming a wide variety of foods including invertebrates such as mollusks, insect larva, zooplankton and benthos. The algal biomass in most of the highland lakes is poor, and even indiscernible in some (e.g. Bale mountain tarns). Nevertheless, interesting Eurasian forms of zooplankton have been recorded from the Bale mountain lakes (Loffler, 1978).

Table 3 Chemical composition of the highland lakes (After Wood and Talling, 1988; Tudorancea and Taylor, 2002 and various sources). Note that the maximum values reported are shown here.

Lake	Salinity (g/l)	Conductivity (µS/cm)	pH	∑cations (meq/l)	∑anions (meq/l)	SiO_2 (mg/l)	PO_4 (µg/l)	Chl a (µg/l)
Tana	0.14	137	8.6	1.68	1.62	14.5	1000	3.34
Ashenge	1.2	1530		-	-	-	-	-
Hayq	-	750	9.0	10.2	10.3	2	131	54
Hardibo	-	-	-	-	-	-	35	8
Bale Garba Guratcha	0.06	131	7.4	0.79	0.79	-	-	sparse

Recent sampling indicate that Lake Hayq has high biomass of zooplankton with species such as *Moina*, *Ceriodaphnia*, *Daphnia*, *Mesocyclops*, *Thermocyclops*, etc, all showing eye pigmentation, possibly as protection against uv radiation in this high altitude lake (Kebede Alemu, 1995; Personal observation), despite the claim of Elizabeth Kebede *et al.* (1992) that Cladocera were absent in the lake during their study in 1992. An interesting large daphnid was sampled from Lake Ashenge (Personal communication: Koos Vijverberg, 2006), despite the presence of fish in the lake. The littoral area of Lake Hardibo is believed to harbor a high diversity of biota (Tenalem Ayenew and Molla Demellie, 2004). The benthic fauna of the highland lakes are only reported sporadically here and there in older literature, but no recent information is available to confirm previous findings. In general, the taxonomy of invertebrates in the highland lakes is poorly known and little studied. There is urgent need to document and conserve the invertebrate fauna in the northern lakes, in view of the increasing use of most of them for agricultural purposes (e.g. Irrigation in Lakes Hayq and Hardibo: Tenalem Ayenew and Molla Demellie, 2004).

Afar lowland lakes

These are the lowest (often below sea level) of all lakes in the Ethiopian rift valley. Their water chemistry is dominated by concentrations of chloride anions and, with sodium as the only cation, often form concentrated brine solutions which dry out as large slacks of salt because of the high temperature. Salinities are high, except for Lake Gamari and Lake Metehara; the latter was diluted recently due to freshwater influx from the Awash river (Table 4). The pH may even shift to the acidic range in Lake Afdera. Despite the high salinity, some of them have endemic fish species (Lake Afdera) and crocodile populations (Lake Metehara). One can see lots of chironomids and brine flies on lake shores, but biological studies have focused only on the ichthyofauna.

Table 4 Chemical composition of the Afar lowland lakes (After Wood and Talling, 1988; Abebe Getahun and Stiassny, 1998 and other sources). Note that the maximum values reported are shown here.

Lake	Salinity (g/l)	Conductivity (µS/cm)	pH	∑cations (meq/l)	∑anions (meq/l)	SiO_2 (mg/l)	PO_4 (µg/l)	Chl a (µg/l)
Afdera	1.58	250 000	6.55	2846	2676	74	-	-
Abhe	160	-	10.3	2562	2562	416	-	-
Assal (Djibouti)	276.5			4793	4793	2	131	54
Gamari	0.70	130	8.0	9.19	8.48	35	-	-
Metehara (Beseka)	56 (0.6)*	72 500	9.9	46.5	71.2	105.8	1302	13

* not part of Afar lakes

Rivers and streams

Ethiopia has over 7 000 km of rivers whose drainage basin covers the whole country including the semi-arid lowlands. There are 12 river basins with a total annual surface runoff of 123 billion m^3 (Solomon Seyoum, 2000). Ten of these rivers and their basins are trans-boundary, except for Awash and Rift Valley. These are: Tekezze, Abay, Baro-Akobo, Omo-Ghibe, Ghenale-Dawa, Wabe Shebelle, Ogaden, Danakil, Mereb and Aysha river basins. The topography of the country dictates the direction of river flows, with the main drainage basins flowing away from the rift system. The major rivers bisect the country along different drainage systems. The northern and central highlands are drained by the westward flowing rivers (Abay, Angereb, Tekezze, which form part of the Nile drainage basin); the eastward flowing rivers drain into the rift valley (Katar, Meki, Mojo) (Abebe Getahun and Stiassny, 1998). The southwestern highlands are drained by the tributaries of the Abay, while the southwestern part of the eastern highlands is drained by the Ghenale and Dawa rivers and the Shebelle and Fafan rivers. The Ethiopian rift valley and the Afar lowlands are drained by the Awash river and its tributaries. Table 5 shows the main river basins of Ethiopia and indicates how the country has focused more on the non-biological utilities of the rivers such as hydropower and irrigation, and has paid literally no attention to the biological resources in the rivers such as fish, invertebrates, crocodiles, algae, etc.

Limnological studies on rivers has lagged far behind lakes, for no apparent reason other than the skewed attention the few indigenous limnologists give to lakes as opposed to rivers. Nevertheless, numerous sporadic scientific and amateur expeditions have been conducted by foreigners and some collections of riverine specimens taken. In addition, in recent times, various lake and river basin studies have been carried out by government ministries and the data compiled in grey literature (River basin integrated development master plan reports). Biological resources are regrettably rarely mentioned in these studies; moreover, it has not been easy to access the grey literature, so this review of aquatic invertebrates in rivers should be construed as referring only to the limited literature that has been perused by the author.

Table 5 Major river basins and their non-biological utilization (After Tesfaye Gizaw and Kemal Zekarias, 1989). Asterisks indicate negligible use so far.

No.	*River basin*	Hydropower potential (GWH/year)	Irrigation potential (ha)
1	Abay	78 800	977 915
2	Rift valley lakes	12 240 *	122 300
3	Awash	5 589	204 400
4	Omo-Ghibe	35 000	450 120
5	Ghenale-Dawa	12 508 *	435 000 *
6	Wabe Shebelle	6 143	204 000
7	Baro-Akobo	19 826 *	748 500 *
8	Tekezze-Angereb	8 960 *	312 700 *

Wetlands

With the exception of coastal and marine-related wetlands and extensive swamp-forest complexes, all forms of wetlands are represented in Ethiopia (Yilma Abebe and Geheb, 2003). Wetlands in Ethiopia are defined as land covered by shallow water encompassing lakes, rivers, swamps, floodplains, ponds, aquifers and dams (Leykun Abunie, 2003). According to Hughes and Hughes (1992) two wetland types - swamps and marshes - are the dominant wetland types especially in southwestern part of Jimma, Illubabor and Wollega. Swamps are permanently flood areas (wetlands) with herbaceous vegetation (trees and shrubs), which are usually greater than one meter in height. Marshes are permanently flooded areas (wetlands) with emergent herbaceous (non-woody) vegetation adapted to wet soil conditions and are usually less than one meter in height. The two wetland types in Ethiopia are noted for their rich resources including endemic species of plants and animals.

The areal coverage of the Ethiopian wetlands is not known. Different estimates have been given regarding the total wetland area of the country. According to some individuals, the total area of wetland may exceed 2% (22,500 km^2). However, Hillman (1993) estimated that Ethiopian wetlands cover a total area of 13,699 km^2 (1.4%) of the country's land surface. The distribution of wetlands is uneven, with the southwestern and western parts such as Illubabor and Gambella taking the major share, and isolated pockets of marshes and swamps scattered in the north and central parts of Ethiopia. The total wetland formation is estimated to cover 18,587 km^2 (1.5%) of the total land area of Ethiopia distributed throughout the country.

Wetlands in Ethiopia have different socio-economic values. These include food crop supply through agriculture by draining and recession, important sites for dry season grazing, resource extraction, raw materials supply (reeds for thatching purposes, papyrus), fish harvesting, source of medicinal plants and sites of tourist attraction and various traditional ceremonies.

However, many wetlands in Ethiopia are being affected due to overextraction of wetland resources beyond their rejuvenating capacity: draining for growing food crops, the introduction of perennial crops, e.g., *Eucalyptus* and urban encroachment for livestock husbandry and brick and pottery industry. In most parts of southwestern Ethiopia, headwater wetlands have been particularly subjected to drainage for dry season maize cultivation (Zerihun Woldu and Kumilachew Yeshitila, 2003). Deforestation and overgrazing of grass (de-vegetation) are also threats that promote increased erosion to the wetlands in Ethiopia. Increased accumulation and sedimentation will ultimately accelerate the ontogeny of the wetland, i.e., the rate of conversion of the aquatic system to a terrestrial one.

In addition to this, studies also indicate that people in the wetland vicinities de-vegetate herbaceous vegetation to avoid the harboring of mosquito flies and snakes. Urban wastes are discharged into wetlands in a number of vicinities, thereby polluting the wetlands beyond their purification capacity. As a result of these and related reasons, most of the wetlands' are severely degraded and most of the fauna and flora species are endangered. Yilma Abebe and Geheb (2003) list a total of 73 Ethiopian wetlands, but about half of these are what are normally called permanent lakes by other workers.

STATUS OF INVERTEBRATE RESEARCH IN AQUATIC SYSTEMS

Freshwater lakes

These are better studied than other aquatic systems in Ethiopia, especially with respect to their limnology and fisheries. These include Lakes Abaya, Awassa, Chamo, Hayq, Tana and Zwai, all with salinity below or close to 1.00 g/l. The crater lakes Hora, Bishoftu, Kuriftu and Babogaya can also be placed in the freshwater category. Lake Awassa is the better studied of the whole lot, with detailed scientific reports on its limnology and fisheries (e.g. Tudorancea and Taylor, 2002), zooplankton (Seyoum Mengistou and Fernando, 1991a; 1991b), benthic fauna (Tilahun Kibret and Harrison, 1989; Elias Dadebo, 2001), and lately, a whole-lake food web analysis of the system using Ecopath model (Tadesse Fetahi and Seyoum Mengistou, 2006).

The zooplankton of Lake Zwai has been investigated by Semeneh Belay (1988) and Fernando *et al.* (1990) and the benthic fauna was studied by Tudorancea (2002).

The northern freshwater Lake Tana has been a subject of investigation since the Italian invasion in the 1940's. The zooplankton of Lake Tana has recently been investigated in detail through the PhD studies of Tesfaye Wudneh (1988), Eshete Dejen (2003) and Ayalew Wondie (2006). The water weed and benthic fauna have been reported by Ayalew Wondie and Seyoum Mengistou (2006).

Some works reported on Lake Hayq include that of Baxter and Golobitsch (1970) and Elizabeth Kebede *et al.* (1992) and Kebede Alemu (1995). Except for the zooplankton, the benthos and other invertebrates were not considered in detail.

The crater lakes near Debre-zeit were studied much earlier with respect to their physical limnology (discussed in Tudorancea and Taylor, 2002), but comparatively little work was done on the biota. Green (1986) and Green and Seyoum Mengistou (1991) inventorized the zooplankton community in some of the crater lakes, while Tudorancea (2002) did the same for the benthic fauna.

Relatively less scientific information is available about the invertebrates in Lake Abaya but other aspects of Lake Chamo were studied by Amha Belay and Wood (1982), Getachew Teferra (1993), Elias Dadebo (2001), Hailu Anja and Seyoum Mengistou (2001) and Yirgaw Teferi *et al.* (2000; 2001).

Saline lakes

The saline lakes are relatively less researched than the freshwater ones, probably because of their limited utility for human use, although some of them have high industrial value (e.g. Lake Abijata). These saline lakes (all with salinities above 5 ppt) include Lakes Abijata, Shala, Chitu, Arenguade, Metehara (Beseka) and the Afar lakes Afdera, Assal and Abhe. Of the crater lakes, Lake Arenguade and Kilole can be placed in the saline category, although the latter has been diluted to freshwater status by diversion of the River Mojo into the lake since 1989 (Brook Lemma, 1994).

Wetlands

The most comprehensive report on Ethiopian wetlands is the monograph edited by Yilma Abebe and Geheb (2003). Some scientific aspects of Ethiopian wetlands were discussed in the annual conference of the Biological Society of Ethiopia and the information compiled in the conference proceedings (2003). Afework Hailu and Abbot (1998) and Zerihun Woldu (2000) summarized their major findings on the only long-term projects done in the wetlands in Illubabor, southwest Ethiopia, while Tesfaye Hundessa (1991) discussed the conservation status of wetlands and waterfowl in Ethiopia. Many of these grey literature are not readily accessible for retrieval, however.

Rivers and reservoirs

A few rivers in and near the capital city Addis Ababa were investigated by Harrison and Hynes (1988) and Tesfaye Berhe *et al.* (1989). Except for government reports on the master plan studies of the major river basins in the country, no systematic survey has been done on the aquatic biota of rivers. Even these impressive huge documents on the natural resource potential of the river basins do not mention the aquatic life-forms as such a capital, with the obvious exception of fish. It is heartening to note however, that recently a lot of interest in river macro-invertebrates is emerging because of the world-wide application of these organisms for assessment and monitoring of pollution and degradation of streams and rivers (cf. Baye Sitotaw, 2006; Hayal Desta, 2006).

Reservoirs in Ethiopia are a recent phenomenon, but more and more are being designed and built every year. The aquatic biota in earlier reservoirs such as Koka, Lege Dadi and Finchaa have been reported in Melaku Mesfin *et al.* (1988) and Tudorancea and Taylor (2002). Almost no biological information is available on Melka Wakena, Gilgel Ghibe and Tekezze reservoirs. Innumerable micro-dams and ponds are built for water storage and fish stocking each year, but no information is available on the aquatic fauna or flora in these water bodies.

AQUATIC INVERTEBRATE TAXA

Subkingdom Protozoa

The probable number of global protozoan species is somewhat more than 65 000. Of these about 10 000 are parasitic and about 20 000 are fossil, and therefore better known than the free-living or the extant forms, because of focused attention by paleontologists and medical scientists. Very little work has been done on the Protozoa in Africa (Dragesco, 1980), or Ethiopia, despite the importance of amoebids and ciliates in soil ecology. From what little we know, the African amoebids include genera such as *Pelomyxa*, *Vahlkampfia*, *Thecamoeba*, *Hartmanella* and *Difflugia*. About 130 species of ciliates have been recorded from Africa, as opposed to more than 300 species from Europe. The degree of endemism of African ciliates was found to be high, with almost 38 species (26%) of those described. Common ciliate genera include *Paramecium*, *Stentor*, *Euplotes*, *Prorodon* and *Nassula*. Probably, all are present in Ethiopian water bodies, the last ones being frequent in sewage and septic tank plants. However, the only serious studies on ciliates in Ethiopia is that of Zinabu Gebre-Mariam and Taylor (1989) in Lake Awassa, and Elizabeth Kebede *et al.* (1992) in Lake Hardibo. The authors recorded high biomass of the oligotrich ciliate *Strombidium sp.* in Lake Awassa and *Halteria*, *Cyclidium* and *Lagynophyra spp.* in Lake Hardibo. In other 12 East African lakes studied (Yasindi and Taylor, 2006), the oligotrich ciliates of the genus *Strombidium*, *Strobilidium* and *Halteria* were the most abundant and were mainly grazed by metazoan zooplankton. It is clear that more intensive studies will have to be continued on the aquatic Protozoa of Ethiopia, since Protozoa are believed to be critical in aquatic food webs, especially of the microbial loop type.

Subclass Copepoda (Class Crustacea)

Considering that only 120 copepod species have been described from Africa (Dussart, 1980), the fact that about 73 species have been documented from Ethiopian water bodies shows that some recognition has been given to this invertebrate group. Ecological and taxonomic studies on copepods have been carried out since the 1980's and are quite widespread (Loffler, 1978; Kassahun Wodajo and Amha Belay, 1984; Defaye, 1988; Semeneh Belay, 1988; Fernando *et al.*, 1990; Seyoum Mengistou *et al.*, 1991a; 1991b; Tesfaye Wudneh, 1998; Brook Lemma, 2002; Eshete Dejen, 2003; Tadesse Fetahi and Seyoum Mengistou, 2006; Ayalew Wondie and Seyoum Mengistou, 2006). All three copepod orders are documented, although Harpacticoida are observed only in the saline alkaline Lake Shala. The only other study regarding Harpacticoida is that of Tudorancea (2002) where he claimed that 2 species of Harpacticoida were present in Lakes Zwai and Langano (*Cleocamptus dietersi* and *Echinocamptus monodi*) and *Nitocra lacustris* in the saline Lakes Abijata and Shala. We could not confirm the presence of the former two harpacticoids during our numerous samplings since 1990, however. The total number of copepod species so far recorded in Ethiopia is about 73. No lake has more than 6 species, and most lakes have about 4 species. Calanoids are the least diverse copepod group in Ethiopian water bodies, despite the fact that about 94 calanoid species and subspecies have been recorded from Africa (Dussart, 1980), out of a total of 200 calanoids world-wide. The most common calanoids are *Paradiaptomus (Lovenula) africana* in the rift valley and crater lakes and *Thermodiaptomus galebi* in Lake Tana. Other genera include *Arctodiaptomus* in the Bale mountains, *Metadiaptomus*, *Thermodiaptomus* and *Calanoipia*. Possibly new subspecies of calanoids could be present in some rift valley lakes, and await future authentication. Calanoids have useful ecological functions as grazers on the algae and as important food items for fish. Cyclopoids are the most numerous copepods, with over 50 described species, with four being endemic, including *Afrocyclops sparus*, *Ectocyclops mixtus*, *Neocyclops affinis* and *Thermocyclops ethiopiensis*. Species diversity is high in the *Eucyclops*, *Mesocyclops* and *Thermocyclops* genera, the last two co-occurring together in most of the lakes. The latter also are reputed as important raptorial predators and have been used as biological control agents to control mosquito vectors of malaria and Dengue fever. Of particular note is the presence of palearctic forms of copepods in the Bale mountains such as the calanoid *Arctodiaptomus n.sp.* and the cyclopoid

Megacyclops viridis (Loffler, 1978).

Order Cladocera (Class Crustacea)

Popularly known as water-fleas, these are cosmopolitan small crustaceans that are important food for many aquatic consumers. The genus *Daphnia* is one of the best-studied animals in science in the temperate countries. In the tropics though, daphnids are rare (Fernando, 1980), and only 60 cladoceran species are reported as opposed to 90 species in the temperate regions (Fernando, 1980). The possible reason given for the relative paucity of cladocerans in the tropics is higher fish predation which tends to eliminate the rather large-sized daphnids as opposed to smaller-sized cladocerans such as *Bosmina*, *Ceriodaphnia*, *Diaphanosoma*, etc. This is evidenced quite well in Ethiopian water bodies also, where few cladocerans exist in most lakes (maximum of 2 to 3 species), whereas more species (up to 7) are recorded from fishless ponds and lakes (cf. Green and Seyoum Mengistou, 1991; Taylor *et al.*, 2002).

A total of 22 cladoceran species have been recorded from Ethiopia, the most common genera being *Alona*, *Bosmina*, *Ceriodaphnia*, *Diaphanosoma*, *Moina*, *Macrothrix*, *Simocephalus*, *Pleuroxus* and *Daphnia*. More than three *Diaphanosoma* species co-occur in Lake Tana (Eshete Dejen, 2003), while *Diaphanosoma excisum* is the dominant cladoceran in most lakes (Personal observation). Despite its rarity in tropical waters, *Daphnia* is fairly common in the turbid lakes such as Chamo, Tana, Abaya and Zwai. The species recorded include *D. barbata*, *D. longispina*, *D. lumholtzi* and *D. obtusa*. A daphnid taken from one of the Bale mountain tarns appears to be new to science (Personal communication with Dr. V. Korinek, Charles University, Prague), but no subsequent collections could be made to authenticate this claim. It was also noted that some apparently benthic cladocerans such as *Alona davidii* show the ecological tendency to be planktonic in the rift valley Lakes Awassa and Zwai (Fernando *et al.*, 1990). Recently, a taxonomic key of African Cladocera has been published (Korinek, 1999) while a monograph of the Cladocera of Ethiopia is at the inception stage.

Phylum Rotifera (Rotatoria)

Despite their small size, this ubiquitous group of planktonic invertebrates have been studied even in Ethiopia since the colonial time, over seventy years ago. Sporadic mention of rotifers is given in the papers of Bryce (1931) and Cannicci and Almagia (1947). De Ridder (1987), quoting other sources, reported that a total of 76 species of rotifers have been documented from Ethiopia. There are reports of species described from single specimens such as *Dilpois daviesiae*, *Cephalodella catellina*, *Lecane tenuiseta*, *L. ungulata*, *Monostyla bifurca*, *M. elachis*, *Lecane zwaiensis*, *Mytilina ventralis* and *Lepadella ovalis*. All of these were subsequently authenticated in Green and Seyoum Mengistou (1991), with the exception of *Monostyla*. Green (1986) deals with rotifers from some crater lakes, while Seyoum Mengistou *et al.* (1991b) discuss the composition and dynamics of Rotifera in Lake Awassa.

The most comprehensive study on Ethiopian Rotifera is that of Green and Seyoum Mengistou (1991) who summarized the rotifer species from the various water bodies that they were able to sample. A total of about 100 species of rotifers were recorded, with two of them confirmed to be new species - *Brachionus dimidiatus* var.n. and *Lecane zwaiensis*. The total number of rotifer species recorded from a single lake is about 32, while most lakes have no more than 4 rotifer species at any time. In general, the rotifer community is dominated by four genera - *Brachionus* (17 species), *Keratella* (5 species), *Lecane* (13 species) and *Monostyla* (10 species). Other genera recorded as common are *Anureopsis*, *Euchalanis*, *Filinia*, *Hexarthra*, *Polyarthra* and *Trichocerca*. Rare ones include *Ascomorpha*, *Cephalodella*, *Conochilus*, *Diplois*, *Lepadella*, *Synchaeta*, *Tetramastix* and *Tricocera*. The carnivorous *Asplanchna brightwelli* commonly co-occurs when the rotifer diversity is high in a water body. The ubiquitous nature of rotifers makes their taxonomic finding a matter of luck and chance. Therefore, the species list of rotifers, including novel ones, could be much higher than that reported here. Surely, the compendium of Green and Seyoum Mengistou (1991) should only be considered as a start, and more rigorous collections and characterizations of the Rotifera should continue in the future.

Subclass Ostracoda (Class Crustacea)

Ostracods are small meroplanktonic crustaceans that resemble bivalve clams. They are found in most temporary aquatic habitats such as ponds, dry-out ditches, lakes, river backpools and stagnant springs. On account of their hard exoskeleton, they rarely serve as food for consumers, and are interesting more for their cytogenetic contribution to scientific inquiries and zoogeography. They have been collected by paleontologists, hydro-geologists and biologists, and as such no organized study of them is recorded. A total of 23 species have been screened in Ethiopia from the literature. Lowndes (1932) reported 9 genera and 13 species of Ostracoda from Ethiopian lakes. Nine new species were recorded in six genera including *Stenocypris* (4), *Gomphocythere* (2), *Oncocypris* (1), *Stenocypris* (1), *Cypronotus* (1) and *Cypretta* (1). Other most common genera reported at various times include *Limnocythere*, *Gomphocthere*, *Potamocypris*, *Stenocypris* and *Oncocypris*. Less common ones include *Candanopsis*, *Cypria*, *Darwinula*, *Cyprinota* and *Cypretta*. Tilahun Kibret and Harrison (1989) found benthic ostracods associated with weed-beds in Lake Awassa, mostly belonging to *Gomphocythere* and *Limnocythere* species. The Limnocytherinae were also reported to be the most important ostracod group in the saline Lakes Shala and Abijata (Tudorancea and Harrison, 1988). *Darwinula stevensoni*, which was reported earlier by Lowndes(1932) is also widely distributed in Ethiopian lakes.

Martens (2002) reported the ostracods in the Zwai-Shala-Awassa basins and described 15 sub (species) in 10 genera. He reported *Gomphocythere angulata* as the most common species. Earlier, Martens (1990) had reported moderate levels of endemicity in the genus *Lymnocythere* (5 endemic subspecies), with each lake having its own endemic subspecies - *L. thomasi thomasi* in Lake Zwai, *L.t. langanoensis* in Lake Langano, *L. barosi barosi* in Lake Abijata, *L.b. shalaensis* in Lake Shala and *L.b. awassaensis* in Lake Awassa. Further, the taxonomic and biogeographical anomalies of ostracods was noted by Martens (1990) who speculated on the possible speciation chronology and phylogenetic affinities within the *Lymnocythere barosis-thomasi* species flock.

AQUATIC INSECTS

Order Ephemeroptera (mayflies)

The larvae of these insects are aquatic and prefer unpolluted fast-flowing rivers, where they graze on algae and are food for fish themselves. They serve as useful bio-indicators of unperturbed river conditions and are used to evaluate river 'health status' in biomonitoring and assessment studies. Of the 19 families of Ephemeroptera known world-wide, about 10 families have been recorded from Ethiopia. Some include Baetidae, Heptagenidae, Ephemeridae, Caenidae, Leptophlebidae, Baetiscidae, Tricorythidae and Potamanthidae. Baetidae are the most diverse with over 10 described species, with about half being new to science (Harrison and Hynes, 1988). The altitudinal distribution of mayflies is also striking, with *Cloeon* dominating above 3000 m, being replaced by *Centroptilium* below 2500 m, and finally by *Baetis* below 2000 m (Harrison and Hynes, 1988), Lubini (1998) recorded 12 species of Ephemeroptera from the Semien mountain streams, 5 of which were from Baetidae and two possibly new species. The most common genera encountered are *Baetis*, *Afropltilium*, *Afrocaenis*, *Caenis* and *Chlorotherpes sp*.

Order Odonata (dragonflies and damselflies)

The adult dragonflies (suborder Anisoptera) and damselflies (suborder Zygoptera) are very common around rivers and lake shores where they hover incessantly to hunt for prey along water courses. Of the 8 families in Anisoptera world-wide, about three families have been recorded in Ethiopia - Aeshnidae with 3 species (*Aeshna*, *Anax* and *Gynacantha*), Libellulidae with 7 species (*Mesociothemis*, *Ortheretum*, *Brachythemis*, *Acisoma*, *Trithemis*, *Palpopleura* and *Zygonyx*) and one Gomphidae. The Libellulidae are particularly striking in that the endemic *Atoconeura biordinata aethiopica* has been reported recently from this group (Clausnitzer and Dijkstra, 2005). The authors report that this dragonfly is listed as vulnerable on the IUCN Red List and call for conservation efforts to save the species from imminent extinction.

The Zygoptera damselflies are more diverse world-wide (about 17 families) but only 4 families have been reported so far from Ethiopia. The most familiar is the family Lesticidae (*Lestes sp*.), followed by Agridae, Calopterygidae (*Phaon* and *Platycypha spp*.) and Caenogrionidae (*Cerriagrion* and *Pseudogrion spp*.). The damselflies dominate in backpools and quiet spots of Ethiopian rivers (Harrison and Hynes, 1988). The Italian Academia Nazionale dei Lincei expedition of 1973 and 1975 made note of some Odonata they collected from Lakes Chamo and Abaya region. They recorded Aeshnidae (*Aeshna*, *Anax* and *Gynacantha* species), Libellulidae (*Mesociothemis*, *Ortheretum*, *Brachythemis*, *Acisoma*, *Trithemis*, *Palpopleura* and *Zygonyx* species) from the Anisoptera, and Calopterygidae (*Phaon sp*.), Caenogrionidae (*Cerriagrion*, *Pseudogrion spp*.) from the Zygoptera. Despite their commonness and importance as bio-indicators of relatively unpolluted rivers, this group has not been studied extensively and the taxa reported here are only a fraction of the actual number of species present in the country.

Order Trichoptera (caddisflies/net spinners)

Adult caddisflies are little noticed near rivers because they are cryptic and can be mistaken for moths, to which they are related phylogenetically. The larva are however characteristic in flowing waters where one can find them under stones, rocks, or other hard substrata. In fact, their cases are found easily under such places and crude identification can be made based on the uses of the silk they produce - as nets, tubes, cases or gluing sand, pebbles etc. There are about 12, 627 described species of caddisflies world-wide arranged into 46 families and 610 genera. Schmid (1984) suspects there may be as many as 50 000 caddisfly species. In Ethiopia, studies of this enigmatic group has been sporadic and restricted to some streams in Central Ethiopia and the Semien mountain. Lubini (1998) recorded 7 families - Hydroptilidae, Hydropsychidae, Psychomyidae, Leptostomatidae, Philopotamidae, Limnephilidae and Leptoceridae. Species identification was given only for *Goerodes scotti* (Leptostomatidae) and *Oecetic setifera* of Leptoceridae. The family Ecnomidae with 2 species *Ecnomus thomasseri* and *E. ugandensis* has also been recorded. The Hydroptilidae appears to have three species - one still undetermined as Hydroptilid *sp.* A, and *Orthotrichia* and *Stacobius spp.* Harrison and Hynes (1988) recorded only 3 families - Philopotamidae (*Chimarra sp.*), Hyrdopsychidae (several unidentified *Cheumatopsyche* species) and Lepidostomatidae (*Goerodes sp.*). Recently, Baye Sitotaw (2006) found more caddisflies belonging to the families Hydropsychidae (common net-spinners), Glossosomatidae (saddle case makers), Philopotamidae (finger-net), Phryganeidae (giant case-makers), Hydroptilidae (micro caddisflies), Rhyacophilidae (free-living caddisflies) and Brachycentridae (humpless case-makers). The degree of endemism in Trichoptera is high in Ethiopia (Kimmins, 1963), where 17 of the 53 species examined were found to be endemic. Five of the 7 species of *Ceomatopsyche* found in highland streams in Central Ethiopia were found to be endemic (Harrison and Hynes, 1988). However, not many extensive studies have been done on caddisflies in Ethiopia, despite their importance as excellent bio-indicators of organic pollution and stream degradation.

Order Coleoptera (aquatic beetles)

Adult beetles are more familiar than the aquatic larval stages. The Order Coleoptera is the largest order of insects with over a million species, however, only 5000 species have aquatic stages. These are grouped into 18 families and it is remarkable that about 10 of the families of aquatic beetles are present in Ethiopia. The most common ones are the Dytiscidae (diving beetles), Gyrinidae (whirligig beetles) and the Elmidae (riffle beetles). Other less common ones include Hydrophyllidae (water scavenger beetle with 3 species - *Orthotrichia*, *Paracymus* and *Laccobius*), Hydraenidae (moss beetles), Carabidae (ground beetles), Chryosomelidae (leaf beetles), Curculionidae (weevils) and Psephenidae (water penny - *Eubrianx sp.*). Unlike other aquatic insects, the importance of aquatic beetles is not as indicator of environmental health but rather they indicate the physical type of habitat they occupy. The riffle beetles however serve as indicators of good water quality. The gyrinids are the most conspicuous aquatic beetles which swim erratically on water surface as they hunt for prey both above and below water using their four eyes. Brinck (1955) reports several species of this family including *Gyrinus*, *Aulogyrus*, *Dineutus*, *Orectogyrus* and *Lobogyrus* from highland streams > 2000 m. The diving beetles (Dytiscidae) are equally fascinating with their diving behavior. Four species have been documented - *Hydrogylus*, *Agabus*, *Herophydrus* and *Potomonectes*. The Elmidae (riffle beetles) are the most diverse and Harrison and Hynes (1988) could not identify 9 of the various specimens which they collected, and simply reported them as types 1-9, apparently all new to science! They suspect that all these new species could be endemic as well. Recently, Hayal Desta (2006) identified 5 families of aquatic beetles from wetlands in SW Ethiopia including Helodidae (marsh beetles), while Baye Sitotaw (2006) reported unfamiliar aquatic Coleoptera such as Dryopidae (long-toed water beetles) and Haliplidae (crawling water beetles) from some Ethiopian rivers. This brings the total families of aquatic beetles known in Ethiopia to 12, which indicates the high coleopteran biodiversity of the country, even if extensive studies have not yet been carried out.

Order Hemiptera (true bugs)

The cosmoplitan true bugs include the Hemiptera and Heteroptera which will be treated together in this review, but not to be lumped with th terrestrial Homoptera (aphids, leaf hoppers, scale insects, etc). Of the 4 families described world-wide, about 9 families have been reported fro Ethiopian water bodies. Because of the high species diversity of the grop (about 35 000 described Hemiptera) and the lack of taxonomic expertise n the group in the country, we may not be able to know the exact number f Hemipteran species in Ethiopia. The genera most commonly repord include Corixidae (water boatmen), Notonectidae (back swimme), Nepidae (water scorpions), Belostomatidae (giant water scorpio), Gerridae (water striders), Pleidae (pygmy backswimmers), Naucorie (creeping water bugs) and Veliidae (broad-shouldered water strid). Brinck (1955) reported hemipterans of the genera *Laccotreps*, *Micronecta*, *Plea*, *Spaheroderma*, *Sigara* and *Anisops* from Ceal Ethiopia. Many of these species were re-collected by other wors. Harrison and Hynes (1988) report other strange taxa such as *Rhagova*, *Hynesionella* and *Mesovelia* from highland springs in Ethiopia. Accoig to their wide collection, the most diverse are the Corixidae, with 6 gra including many new species - *Micronecta*, *Agrapocorixa*, *Glenocorixa*, *Sigara* and *Corixa.* The Notonectidae with 4 genera (*Micronecta*, *Enithares*, *Anisops* and *Nychia*) follow, while taxa with few species include *Plea*, Mesovellids and Nepids. Gerrid water striders are very common in lake shores and rivers where they 'walk' on the water surface hunting for food below the water. They are abundant in backwaters and quiet spots and have high indicator value for unpolluted waters. Tilahun Kibret and Harrison (1989) report many of these hemipterans in the littoral of Lake Awassa. The corixids *Micronecta denticulata* was the most abundant species in water-bed areas dominated with *Nymphaea* and *Paspalidium*. Recent studies by Baye Sitotaw (2006) revealed the presence of the following Hemiptera in rivers and wetlands in Ethiopia - Corixidae, Nepidae, Notonectidae, Geriidae, Naucoridae, Veliidae, Rhagoveliinae and Salididae (shore bugs). Hayal Desta (2006) recorded the following hemipteran families and species from some wetlands in southwest Ethiopia - *Pelocoris sp.* (Notonectidae), *Trepobates sp.* (Gerridae), *Renatra* (Nepidaea), Hydrometridae and Notonectidae.

Order Chironomidae (midges/lake flies)

The chironomids (midges) compose the largest order within the Diptera (Allan and Flecker, 1993). These cosmopolitan mosquito-like flies are globally distributed and quite common around lake shores where they emerge in large numbers at night and cause havoc and nuisance to people and lights. People usually mistake them for mosquitoes and avoid them but their plumose antennae are easily distinguishable. The larva are aquatic and due to their haemoglobin, quite frequent in lake and river bottoms devoid of oxygen - hence their importance as bio-indicators of polluted waters, besides food for fish. The family is diverse with 11 subfamilies and more than 5000 species. The taxonomy of the group is unsettled with rife revisions and synonyms, and over 179 undetermined collections from the Afrotropical region alone. Therefore, considering that only a few workers have reported on the chironomids in Ethiopia, the exact number of chironomidae species may vary by several numbers from what is reviewed here. Four subfamilies are the most frequently encountered - Chironominae, Diamesinae, Orthocladinae and Tanypodinae. The Orthocladinae are the most diverse with 9 species - *Cricotopus*, *Corynoneura*, *Nanocladius*, *Cardiocladius*, *Paratrichocladius*, *Rheocricotopus*, *Tvetenia*, *Parametrocnemus* and *Thienemanniella*, followed by Chironominae with 7 species - *Dictrotendipes*, *Nilodrum*, *Parachironomus*, *Polypedilum*, *Einfeldia*, *Tanytarsus* and *Rheotanytarsus* and the Tanypodinae with 6 species - *Ablabesmyia*, *Procladius*, *Larsia*, *Conchopelopia*, *Nilotanypus*, and *Parameriana*. Of special interest is the Diamesinae which may have disappeared long ago with the Ethiopian glaciers (Harrison and Hynes, 1988). The Ceratopogonidae are represented by as yet undetermined *Bezzia*-type larva. It is suspected that there are two or three apparently new species of chironomids which could be endemic to Ethiopia (Harrison and Hynes, 1988).

Recently, Baye Sitotaw (2006) and Hayal Desta (2006) recorded specific chironomid subfamilies from different localities in Ethiopia and have come to the tentative conclusion that the family Chironomidae as such is not a reliable bio-indicator of pollution, as was frequently believed in temperate waters, but that subfamilies and lower taxa may be better indicators of certain ecological stresses more than others.

Order Diptera (true flies and mosquitoes)

The terrestrial members of this group are better known by the layman as the bothersome flies and mosquitoes. Even in the aquatic environment however, Diptera is the most diverse order of all freshwater invertebrates (Erman, 1996). Many species are semi-aquatic, and spend most of their lives in the riparian area and the land-water interface. The larva are strict aquatic forms of families such as the Culicidae (mosquitoes), Psychodidae (moth flies), Simulidae (blackflies), Tipulidae (crane flies), Tabanidae (horse flies) and Stratiomyidae (soldier flies). Some like Culicidae and Simulidae have been better investigated because of their importance as vectors of diseases such as malaria and river blindness. Kifle Uemoto *et al.* (1977) reported several new species of Simulidae while Harrison and Hynes (1988) recorded seven *Simulium* species, all of which were described forms. Tilahun Kibret and Harrison (1989) recorded many *Culex* species and unidentified forms of Stratomyidae. The Tabanidae were investigated by Turnbull *et al.* (1992) in the Ghibe valley, and a new species, *Tabanus gibensis* was recorded. Recently Baye Sitotaw (2006) recorded the following unusual dipterans from rivers in Ethiopia, besides the usual mosquitoes, house flies (Muscidae) and Tabanidae. These are Ephydridae (shore flies), Psychodidae (moth flies), Rhagionidae, Sciomyzidae (snail-killing flies, marsh flies), Stratiomyidae (soldier flies), Syrphidae (rat-tailed maggot flies), Empididae (dance flies) and Tipulidae (crane flies). Hayal Desta (2006) found some Sciomyzidae (marsh flies) from wetlands in SW Ethiopia. More intensive research needs to be continued to exhaust the taxonomy and ecology of dipterans in Ethiopia.

OTHER INVERTEBRATE GROUPS

Hydracarina (water mites)

Aquatic water mites are not insects but chelicerates and like their terrestrial counterparts tend to be small and thus escape notice in water samples. They are rampant in both running and standing waters where they parasitize aquatic insects and their post-larval stages feed on zooplankton, but they themselves are repugnant to fish. Globally, there are about 5000 species of water mites arranged into 40 families. No detailed study of this group has been done in Ethiopia and the few authors who report water mites simply lump them under Hydracarina. Typical Afrotropical forms reported from South Africa include the genera *Hydrachna*, *Eylais* and *Piona*, and these probably are the commonly occurring ones in Ethiopia also. Harrison and Hynes (1988), Tilahun Kibret and Harrison (1989) and Tudorancea (2002) report Hydracarina from Ethiopian lakes and rivers. Typical records include species of *Arrenurus*, *Axonopsis*, *Bargena*, *Eylais*, *Hydrachna*, *Limnesia* and *Neumania*. In view of the increasing threat posed by water mite infestations in floriculture ditches and lake shores, Hydracarina should receive more attention in taxonomic, ecological and economic impact studies in the future.

Oligochaeta

Of the 300 described species of Oligochaeta, members of the Order Opistopora, Family Lumbricidae, genus *Lumbricus* are the most common and important ones in terms of soil fertility and vermiculture (large-scale culture of earthworms for specific applications such as poultry feed, sewage treatment, composting, etc). The lumbricids are essentially terrestrial, although they require moist soil (> 20 % humidity) for survival. Gezahegne Degefe (2006) identified earthworms of the genera *Allelobophora*, *Bismatos*, *Lumbricus*, *Eiseniella* and *Dendrobaena*, from some farm soils in Bale and Assela. The aquatic oligochaetes which include the Tubificidae, Naididae and Enchythridae are important as bio-indicators of 'river health' and aquatic ecosystems in general. Harrison and Hynes (1988) reported the tubificid *Bothrioneuron* and *Audodrilus* and the Naidid *Prisitinella*, *Pristina* and *Dero* from mountain streams in Central Ethiopia. Tilahun Kibret and Harrison (1989) found the naidid *Nais* and *Limnodrilus* in Lake Awassa. Tudorancea (2002) reported oligochaetes such as *Psammoryctides maravicus*, *Potomothrix tudorancea*, *Audrilus piqueti* and *Stephensoniana trivandrama* from Lakes Zwai and Abijata, some of which were recognized as new species. Very little taxonomic and ecological work has been done on

Ethiopian aquatic oligochaetes.

Invertebrates associated with water weeds (littoral)

Some research has been done on the littoral invertebrate fauna, especially those associated with the water weed vegetation. Prominent workers in this field include Tilahun Kibret (1985); Harrison (1987); Tilahun Kibret and Harrison (1989), and Tudorancea *et al.* (1989). Almost all the information pertains to the rift valley lakes. The common emerged plants encountered were *Scirpus*, *Cyperus*, *Paspalidium* and *Typha* whereas the floating and submerged vegetation included *Nymphaea*, *Potamogeton* and *Eicchornia*. The most common invertebrates on the emergent vegetation included naidid oligochaetes, copepods, ostracods, water mites (genera *Limnesia*, *Hydrachina*, *Bargena*, *Eylais* and *Axonopsis spp.*), chironomids, Ephemeroptera (*Caenis* and *Cleon spp.*), Odonata and dysticid Colepotera (diving beetles). The dipterans were represented by the corixids, gerrids, notonectids, naucorids and lepidopteran larva. There were more invertebrates in the *Paspalidium* stands than in the *Cyperus* ones .

The floating and submerged vegetation harbor more or less the same type of invertebrates, although slightly higher diversity of chironomids is reported. Culicidae (mosquitoes), Stratomyidae, Gerridae (water striders), Veliidae (broad-shouldered water striders), Nepidae and Pleidea are more common and abundant on the floating vegetation, which they use for food, oviposition and predator avoidance.

Aquatic nematodes

The freshwater forms of aquatic nematodes fall largely in three families - Trilobidae, Dorylamidae and Plectidae (Eyualem Abebe, 2000; 2002; Eyualem Abebe *et al.*, 2006). Nematodes are one of the most common aquatic fauna but little studied group on account of lack of expertise and their small size. In Ethiopia, this group has been sporadically reported by expatriate scientists such as Filipjev (1931), Zullini (1988), Tudorancea (2002) and Tsalolikhin (1996). The paucity of taxonomy expertise can be judged from the literature where some workers simply report them as nematodes without even identification at the family level (Tilahun Kibret and Harrison, 1989). The taxonomist Zullini (1988), however, described a new genus (*Lanzavecchia*) and five new species from Ethiopian lakes - mostly in the *Aphanolaimus*, *Prodesmodora*, *Tobrilus*, *Mesodorylaimus* and *Actinolaimus* species. However, it is Eyualem Abebe, a young Ethiopian nematologist that set aquatic nematodology on good scientific footing. His studies included both the taxonomy and ecology of the aquatic nematodes (See his review Eyualem Abebe, 2000 and references cited therein). Altogether 91 species of nematodes, arranged in 24 families and 42 genera, have been recorded from Ethiopian water bodies. The rift valley lakes harbor 22 species while 69 nematode species have been reported from outside the rift valley. What is more remarkable is the large number of new species (more than 16) recorded from only limited sampled areas (Eyualem Abebe and Coomans, 1996 a,b,c,d). Whether these new species are also endemic to Ethiopia is not concluded because the distribution status of the new records is not known in Africa or the palearctic (Eyualem Abebe, 2000). The most diverse genera are *Monhystera* (with 9 species), *Monhystrella* (9 species), *Eumonhystera* (12 species), *Dorylaimus* (6 species) and *Ironus* and *Laimydorus* with 4 species each. The most widely distributed nematode is *Brevitobrilus graciloides*, while the families Neodiplogatridae, Nordiidae and Monorchidae are probably restricted to Ethiopia as they have not been reported from other Afrotropical regions. Undoubtedly, more collections from unexplored parts of Ethiopia will unravel several more new taxa of aquatic nematodes in future. Unfortunately, the facilities and the expertise to undertake this task are not in place, as Dr. Eyualem has himself transferred to the USA.

Lepidoptera (aquatic butterflies)

Butterflies are essentially terrestrial, but most lay eggs in water and the larval forms develop there. They are treated in this review because the composition and abundance of butterfly species along river banks can give some idea about the health of the river ecosystem. A recent web site gives the total number of butterfly species in Ethiopia at 324, with 7 being endemic to the country. However, D'Abrera (1980) who made the pioneer study of butterfly species (Rhopalocera) in Ethiopia, estimated them at 251 species (without Hesperidae). The most common families include Papillioniodae, Pieridae, Nymphalidae, Lycaenidae and Hesperidae, with Nymphalidae being the most diverse with over 30 species. Evans (1990) made collections of butterflies from the Nech Sar National Park and identified 69 species belonging to 9 families. He documented additional families such as Libythidae, Danaidae, Acraeidae and Satyridae. Of particular note was the high degree of endemicity recorded in Acraedae and Danaidae. The poised *Colotis* are the most diverse species in the Pereidae and unmistakable in many rivers and lake shores in the rift valley and elsewhere because of their colorful wing patterns.

Molluska (aquatic snails)

There are over 70 000 described mollusk species world-wide (UNEP, 2000). Intensive collections were done by the IPB although the focus was on disease vectors of Schistosomiasis. Genera such as *Planorbis*, *Bulinus*, *Biomphalaria* (introduced), *Afrogyrus*, *Gyraulus* and *Ancylus* are the most common in rivers and lakes. The bivalve *Melanoides* and *Corbicula* can reach nuisance proportions in some lakes at certain times of the year, polluting the lake shore and giving off offensive smell when decomposed. Earlier, Brinck (1955) recorded about 20 genera of Molluska from lakes, rivers and ditches. Unfamiliar genera such as *Ampullaria*, *Aetheria*, *Aspathria*, *Helicarion*, *Ligatella*, *Limnicolaria*, *Rhacis*, *Succinea*, *Thiara* and *Zingis* are mentioned in his report. Cannicci and Almagia (1947) report a number of interesting mollusks from Lake Abaya in the southern tip of the Ethiopian rift valley including *Cleopatra*, *Limnocalaria*, *Zingis* and *Viviparus spp*. It would be interesting to verify if these genera are still present or have disappeared due to ecological perturbations. Brown (1965) and Harrison and Hynes (1988) report the palearctic snail *Ancylus fluviatilis*, and others such as *Physa acuta* and *Barnpia caffra* from Central Ethiopian streams. Tilahun Kibret and Harrison (1989) reported the genera *Afrogyrus*, *Bulinus*, *Gyraulus* and the introduced *Biomphalaria* species in Lake Awassa, the latter as a vector for Schistosomiasis in the region.

Aquatic flatworms

The only report about free-living flatworms is that of the tricladid planarian of the genus *Dugesia*. Stocchino *et al.* (2002) report an endemic species, *D. aethiopica* within the *D. gonocephala* group of freshwater flatworms from Lake Tana.

ENDEMISM IN AQUATIC INVERTEBRATES

The high degree of endemism of terrestrial mammals in Ethiopia is equally matched by a fair number of invertebrates, based on the limited research and areas covered. The groups mostly often searched for endemism are those deemed to be profitable to yield results, and therefore are not representative of the whole invertebrate fauna. Benthic and localized invertebrate groups are often targets of search for novel and endemic invertebrate forms. For example, Kifle Uemoto *et al.* (1977) described 4 new species of Simulidae from a limited sample area. Eyualem Abebe (2000) described over 7 new species (some of which are suspected to be endemic) of nematodes from a few lakes in northern Ethiopia. Table 6 shows some of the documented cases of endemic aquatic invertebrates from Ethiopia, in contrast to the total number of species of each group reported so far.

The degree of endemism of many invertebrate groups cannot be ascertained until their occurrence elsewhere is authenticated, which is especially difficult for the less explored Afrotropical forms. As a result, although it is believed that many endemic invertebrates should exist due to the high geographical and ecological diversity within the country, we must wait some time before the endemicity status of the reported taxa is conclusively verified.

In view of the increased threat posed to endemic fauna (as opposed to non-endemic ones), the need for the protection and conservation of endemic invertebrates becomes particularly pressing and indispensable. However, we do not have the expertise or the tools for such a daunting task in Ethiopia, as conservation efforts even for large mammals fall short of minimum expectations in poor countries such as Ethiopia (Hillman, 1993).

Table 6 Documented cases of endemic aquatic invertebrates from Ethiopia (references included).

Invertebrate group	Endemics	Total reported	Reference (s)
Calanoida (Copepoda)	3	10	Dussart and Defaye, 1985
Cyclopoida (Copepoda)	4	57	Defaye, 1988
Rotifera	1	98	Green and Mengistou, 1991
Nematoda	12	91	Eyualem Abebe, 2000; 2002, and Coomans, 1996a, b, c, d; Tudorancea and Zullini, 1989; Zullini, 1988
Tricoptera (stoneflies)	17	53	Kimmins, 1963
Gyrinidae (beetles)	3	240	Brinck, 1955
Baetidae (mayflies)	2		Gilles, 1982
Hydropsychidae (mayflies)	6		Ulmer, 1930
Hydroptilidae (mayflies)	2		"
Elmidae (beetles)	6		Hinton, 1940
Ostracoda (clam shrimps)	9		Martens, 1990
Corixidae (water boatmen)	9	35	Hutchinson, 1930
Notonectidae (backswimmers)	5		"
Mollusk snails	16	67	Brown, 1965
Chironomidae	3	90	Harrison, 1987
Simulidae (blackflies)	6		Kifle Uemoto *et al.*, 1977
Lepidoptera (butterflies)	13	324	Evans, 1990
Odonata	5	23	Harrison and Hynes, 1988

THREATS AND CONSERVATION

Global threats to world lakes have been identified as excessive diversions for irrigation and hydropower, nutrient pollution, toxic contamination, invasive plant/animal species, sedimentation caused by erosion resulting from deforestation, unsustainable use of lake fisheries, acidification and global climate change (Lakenet International, 2006). Various workers have discussed the major threats to aquatic biodiversity loss and erosion in Ethiopia (Zinabu Gebre-Mariam, 2002; Zinabu Gebre-Mariam and Zerihun Desta, 2002; Zinabu Gebre-Mariam and Elias Dadebo, 1989; Seyoum Mengistou and Zenebe Tadesse, 2006). All these workers have identified the following as major threats to invertebrate biodiversity in Ethiopia - desertification, shore damage, bed erosion/alteration, pollution, biocides, introduction and transfer, habitat modification, population growth and poverty.

The particular threats posed to most lakes and rivers in Ethiopia was documented by Seyoum Mengistou and Zenebe Tadesse (2006). Overall, the same global factors listed above apply to the Ethiopian condition also. However, localized and particular threats were identified for Ethiopian water bodies (Table 7). From this table, it is clear that catchment degradation and water abstraction are the two most serious threats to the continued existence of the water bodies, and to the invertebrate communities residing therein. The high demographic pressure and urbanization, increasing demand for agricultural water and land, the grinding poverty and limited employment avenues for the poor drive people towards reckless misuse and overexploitation of the water resource and its biota. Already, Lakes Horomaya and Abijata have dried up due to excessive water abstractions and unsustainable water use methods. Poverty is the root cause for all environmental ills in the third world. People in dire poverty can destroy environmental and biological resources recklessly. This is the tragedy we see in the Ethiopian forests, wildlife, parks, fisheries, bird-life, and in the aquatic invertebrate fauna as well.

Table 7 Some of the major threats to water bodies in Ethiopia (Modified from Seyoum Mengistou and Zenebe Tadesse, 2006, and other sources).

No.	Water body	Major threats	Conservation status
1	Lake Tana	Sedimentation, water abstraction, unsustainable fisheries	Unprotected
2	Lake Zwai	Overfishing, water abstraction, floriculture pollution	Unprotected
3	Lake Koka	Catchment degradation, floriculture pollution, water hyacinth infestation	Unprotected
4	Lake Langano	Recreational pollution, water draw-down	Unprotected
5	Lake Abijata	Water and soda ash abstraction, habitat dry-up, livestock pollution	Protected as national park, no enforcement
6	Lake Shala	Catchment degradation, human encroachment	as for Lake Abijata
7	Lake Awassa	Pollution (industrial and urban), water abstraction, overfishing, lake level rise	Unprotected
8	Lake Abaya	Catchment degradation, overfishing and encroachment, shared ownership	Unprotected
9	Lake Chamo	Overfishing, river diversion, pollution (agricultural, industrial and urban)	Partially protected in the Nech Sar N.P.
10	Lake Hayq	Overfishing, catchment degradation, encroachment, water withdrawal	Unprotected
11	Lake Afdera	Salt and water extraction, habitat alteration	Unprotected
12	Lake Ashenge	Overfishing, catchment degradation	Unprotected
13	Lake Horomaya	Water abstraction (dry-up), pollution, catchment degradation	Has almost disappeared as a lake
14	Lake Kilotes	River diversion and dilution	Unprotected
15	Blue Nile River	Siltation, flow alteration, catchment degradation	Unprotected
16	Baro River	Catchment degradation, overfishing	Unprotected
17	Wabe Shebelle River	Catchment degradation, damming and channelization	Unprotected
18	Omo-Ghibe River	Damming and channelization, siltation, habitat fragmentation	Unprotected
19	Awash River	Damming, flooding, bank erosion and habitat fragmentation	Unprotected
20	Melka Wakena Reservoir	Flow alteration, macrophyte infestation, encroachment	Unprotected

Threatened and endangered aquatic invertebrates

Only 33% of the endangered species on the IUCN Red List are invertebrates, despite making up more than 94% of the global animal diversity. For Ethiopia, the IUCN Red list states 3 mollusks and 12 other invertebrate fauna as being threatened. On the other hand, the list of 40 mammal and 21 bird species of the same category reinforces the suspicion that invertebrates have not been researched and documented as well as vertebrates in Ethiopia. For, example, intensive studies done on one odonate, the Ethiopian Highlander (Libellulidae: *Atoconeura aethiopica*) have documented that this is a vulnerable species in Ethiopia due to habitat destruction caused by water pollution and widespread forest clearance (Clausnitzer and Dijkstra, 2005). The Xerces Society pleads for urgent conservation measures to protect the last remaining individuals of this species in the Ethiopian highlands. Such efforts should also be continued for other aquatic invertebrates such as Copepoda (both Calanoida and Cyclopoida), Diptera, Homoptera, Lepidoptera, Odonata and Plecoptera as they are also listed as globally threatened invertebrates in the IUCN Red List. The Odonata alone (damselflies and dragonflies) have over 174 threatened species (Black *et al.*, 2001).

We have to mitigate the negative factors that exacerbate the endangerment of aquatic invertebrate diversity. Wilson (1992), who pioneered the concept of biodiversity conservation, lists the causes of invertebrate endangerment as being habitat destruction, displacement by introduced species, alteration of habitat by chemical pollutants (such as pesticides), hybridization with other species and overharvesting. However, no systematic work has been done on identification of the extent to what level these factors have contributed to the endangerment and extinction of aquatic invertebrates in Ethiopia.

CHALLENGES AND THE WAY FORWARD

The underlying causes of the loss and degradation of aquatic biodiversity in particular are the increasing demands for biological resources stimulated by population and economic development, failure of people to consider the long-term consequences of their actions, often due to a lack of basic biological knowledge, failure of economic markets to recognize the true value of biodiversity, institutional failures to regulate the use of biological resources as a consequence of changes in human values related to the urbanization of societies, institutions, property rights and cultural attitudes, failure of government policies to correct for the resultant misuse of biological resources and increased human migrations, travel, and international trade. While these trends associated with human civilization and globalization are expected to continue in the foreseeable future, unless the necessary awareness and actions are taken, there will be inevitable clash between the end of this progress at the expense of the demise of the biological resources. So, what should be done both to maintain the pace of human material growth and the conservation of its biological resources at a sustainable level through the course of time ?

The most serious culprit in invertebrate conservation is the apathy and indifference accorded to the group by all bodies concerned - the general public, scientists and the government at large. Also, the world-wide shortage of invertebrate taxonomists and systematists creates an obstacle to furthering our understanding of issues of changing biodiversity and the impacts on environmental degradation (Erman, 1996). Lack of, or obsolete taxonomic keys pose additional challenge to the few enthusiasts in this area. Many former keys and monographs were written for taxa collected more from idiosyncratic rather than systematic inventory point of view, and the taxonomy of the less-sensational aquatic invertebrates has not been exhaused. In many developing countries, skewed attention is given to invertebrates of medical, agricultural, ecological or anthropological importance. Several other scientific shortcomings, such as absence of invertebrate curators in many African museums, have hindered the progress of the collection and curation of aquatic invertebrates in Africa.

Priority task to push the issue of collection, taxonomy and curation of aquatic invertebrate is then to put responsible institutions, policies and laws in place. Almost no policy or law bothers to mention aquatic invertebrates in Ethiopia. The Environmental Policy (April, 1997), Biodiversity Conservation and Research Policy (April, 1998) and the Water Resources Management Policy (1999) do not have any provision for the utilization, conservation and management of aquatic invertebrate resources of the country. Even so, promulgation of policies and laws has not served much purpose in the Ethiopian context, as long as they have not been enforced and implemented. This perhaps is the biggest challenge facing conservation efforts in this country (e.g. Hillman, 1993). Consequently, conservation efforts on aquatic invertebrates will have to focus on preventive and mitigation measures of those factors which accelerate aquatic biodiversity erosion and demise - habitat protection and increased awareness of all involved stakeholders.

The most urgent task then is to establish a National Center for Invertebrate Research (NCIR), and strengthen its institutional capacity to undertake the following actions:

- establish reference streams/rivers and baseline taxonomic data,
- lay out inventory and monitoring plan for all aquatic habitats,
- create awareness about aquatic biodiversity threats through media, workshops, etc,
- incorporate conservation and protection schemes for aquatic invertebrates in the existing national parks, sanctuaries, river and lake basin master plans... etc,
- reduce livestock grazing in riparian and aquatic habitats,

- establish *in situ* conservation measures for the most endangered aquatic invertebrates,
- establish *ex situ* conservation measures for the vulnerable and threatened invertebrates.

The NCIR could be established as a semi-autonomous unit within any of the governmental ministries such as Water Resources, Agriculture, Environmental Protection or as a section in the Ethiopian Institute of Agricultural Research (EIAR), Institute of Biodiversity Conservation or the Higher Learning Institution systems. Whatever the case, the need for such an institution for Ethiopia is long overdue.

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