Ethiop. J. Biol. Sci. **16(Suppl.): 171–180, 2017**

ISSN: 1819-8678

STUDIES OF THE CLADOCERA (CRUSTACEA: BRANCHIOPODA) OF ETHIOPIA: CURRENT STATE AND FURTHER PERSPECTIVES

Anna N. Neretina[1,2]*, Wondie Zelalem[3] and Alexey A. Kotov[1]

ABSTRACT: The cladoceran fauna of Ethiopia (East Africa) was analyzed based on original sampling data, obtained during activity of the Joint Ethio-Russian Biological Expedition. In total, we found 63 species of Cladocera in Ethiopian water bodies: 26 species of Chydoridae, 18 species of Daphniidae, 6 of Moinidae, 5 of Macrothricidae, 5 of Sididae, 2 of Ilyocryptidae and 1 of Bosminidae. The highest cladoceran diversity (39 taxa) was marked in the mountainous Lake Tana; some of them are typical only for this lake. Diverse lakes, rivers and temporary pools have lower species diversity (24 taxa in total). Water bodies of Bale Mountains are characterized by significantly low cladoceran diversity and high proportion of endemic taxa which are still waiting for detailed description. In general, Ethiopia is inhabited by typical tropical cladocerans with broad distribution ranges, cosmopolitan, circumtropical and Afrotropical-Palearctic species, as well as endemic taxa for Africa and Ethiopian high mountains regions. A cladoceran collection created as a result of our work will be a base for future taxonomic and ecological studies in Ethiopia.

Key words/phrases: Africa, Biodiversity, Cladocera, Morphology, Taxonomy.

INTRODUCTION

Ethiopia is among the African countries with a large human population, which has increased very rapidly and, according to estimates of 2014, has reached about 96 million (African Economic Outlook, 2016). The increasing population requires more resources and dramatically enhances human impact on nature. Water resources of Ethiopia are the most vulnerable among others in this case (The International Bank for Reconstruction and Development, 2016). To date Ethiopia occupies the sixtieth place in the world in a total volume of renewable water resources, but the excessive use of fertilizers (including use of high concentrations of nitrogen and phosphorus-containing fertilizers), overfishing and water pollution by industrial and household wastes, as well as sewages, has degraded water

[1] A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Leninsky Prospect 33, Moscow 119071, Russia. E-mail: neretina-anna@yandex.ru, alexey-a-kotov@yandex.ru
[2] Department of Ecology, Faculty of Science, Charles University in Prague, Viničná 7, 128 44 Praha 2, Prague, Czech Republic. E-mail: neretina@natur.cuni.cz
[3] Bahir Dar Fishery and Other Aquatic Life Research Center, Bahir Dar, Ethiopia. E-mail: wondiehm@gmail.com
*Author to whom all correspondence should be addressed

bodies throughout the country and significantly impaired the quality of human life (Kloos and Legesse, 2010). Since water resource availability is critical for human life and is a limiting factor for economic growth, the investigation of Ethiopian water ecosystems was one of key directions of the activity of the Joint Ethio-Russian Biological Expedition (JERBE).

Although Ethiopia is entirely located within the tropical bioclimatic zone, it is the most mountainous country of Africa (Billi, 2015) with strong altitude differences (Fig. 1: A). The climatic conditions are very diverse; it varies from mild and humid in Ethiopian Highlands to hot in eastern lowlands. The combination of landscapes (mountains, plateaus, lowlands) and climate conditions contributes to existence of a huge diversity of water bodies in Ethiopia (Tudorancea *et al.*, 1999). Hydrobiologists within the frame of JERBE activity tried to embrace all aspects of investigations of aquatic organisms, because, as it is well known, they are important for a stable functioning of all water bodies (Kloos and Legesse, 2010).

Cladocera (Crustacea: Branchiopoda) is an example of such groups of microscopic water inhabitants (Kotov, 2013). Although most cladoceran species are tiny and hardly visible with the naked eye, they are important links in the food chains of freshwater ecosystems. They consume primary producers of organic matter (e.g. bacteria and algae) and comprise the food for secondary consumers, such as numerous species of fish, many of which are traditional food for local people in Ethiopia. It is known, that an anthropogenic-caused decrease of the cladoceran diversity will be immediately reflected on higher levels of a food chain. Also, some cladoceran taxa are sensitive indicators of water quality (chemical composition, presence of anthropogenic pollutants, etc. (see Smirnov, 2013).

An approach of the environmental control based on intensive qualitative and quantitative studies of the cladoceran species composition is quite common in some European and North American countries and is successfully applied for evaluation of some environmental characteristics, ecological modeling or even special forecasts for ecosystem development (Lampert, 2011). Application of this approach to Ethiopian water bodies is very promising, although the country needs adequate approaches to the water quality assessment. But data on the preferences of particular cladoceran species earlier obtained for Europe cannot be directly used for evaluation of water quality in Ethiopia because (1) they ignore some obvious specific traits of Ethiopian cladoceran taxa and communities; (2) degree and pattern of anthropogenic impact on water bodies are significantly different between Ethiopia and Europe. In addition, adequate ecological modeling is impossible without adequate knowledge on the species composition of the cladocerans in particular regions. Thus it is important to identify each cladoceran taxon as carefully as possible (Korovchinsky, 1996; 2006).

However, no identification keys have been published for Ethiopian cladocerans to date. In such situation, the authors had to use some general books published in other areas (and based on non-African material) for identification of the specimens up to some level (species, species group or even only genus). The most serious problem for all African countries, not only for Ethiopia, is lack of reliable data on the local cladoceran diversity. Old publications frequently contain outdated taxonomic information and could not be used for ecological purposes. In ecological works on biomonitoring, evaluation of water quality, or on peculiarities of fish feeding in Africa, the authors deal with "cladocerans *in sensu lato*", rather than some recognizable traits. It is evident that this approach strongly compromises results of ecological investigations.

During last decades, cladoceran taxonomy has been changing very rapidly (Frey, 1987; Korovchinsky, 2006; Kotov, 2013). Standards of morphological analysis are also strongly re-evaluated towards more detailed descriptions of taxa and obligatory comparison with congeners for final conclusions on each taxon status (Kotov, 2013). Also, recent investigators often use some genetic data to evaluate the cladoceran biodiversity (e.g. Xu *et al*., 2009; Sharma and Kotov, 2013; Bekker *et al*., 2016). Except for what could be screened from JERBE studies, to date few detailed morphological works have been published on Ethiopian cladocerans (Kotov and Taylor, 2010; Neretina and Kotov, 2015; Neretina and Sinev, 2016). Although some papers included genetic data (e.g. Mergeay *et al*., 2005; 2006), there are few comprehensive publications combining morphological and genetic data (Kotov and Taylor, 2010). Therefore the aim of the long-term works in JERBE was to perform an inventory of the Ethiopian cladocerans supplemented by comprehensive morphological and genetic analysis of particular taxa.

MATERIALS AND METHODS

As material for our work, we used numerous samples obtained as a result of the activity of JERBE. Since 1987, more than 750 samples were collected by Russian and Ethiopian scientists from different water bodies: lakes, reservoirs, ponds, rivers, spring, irrigation canals and even temporary pools

(Fig. 1: B). In order to collect as much species as possible, we used two approaches: (1) long-term investigations on the cladoceran fauna in several stations of the Bahir Dar Bay of Lake Tana (Fig. 1: C); (2) short-term expeditions to other water bodies (Fig. 1: B), with special attention to the temporal pools (Fig. 1: D). Formaldehyde-fixed material was sorted and preliminarily identified under a dissecting binocular microscope. Particular taxa were investigated under scanning electron microscopes Jeol JSM-840 A, CamScan and Tescan Vega TS5130MM. Some cladoceran specimens preserved in ethanol were used for genetic studies. According to common techniques, we sequenced the 5' region of the CO1, 12S, 16S and 28S genes and compared obtained sequences with data from GenBank and with each other.

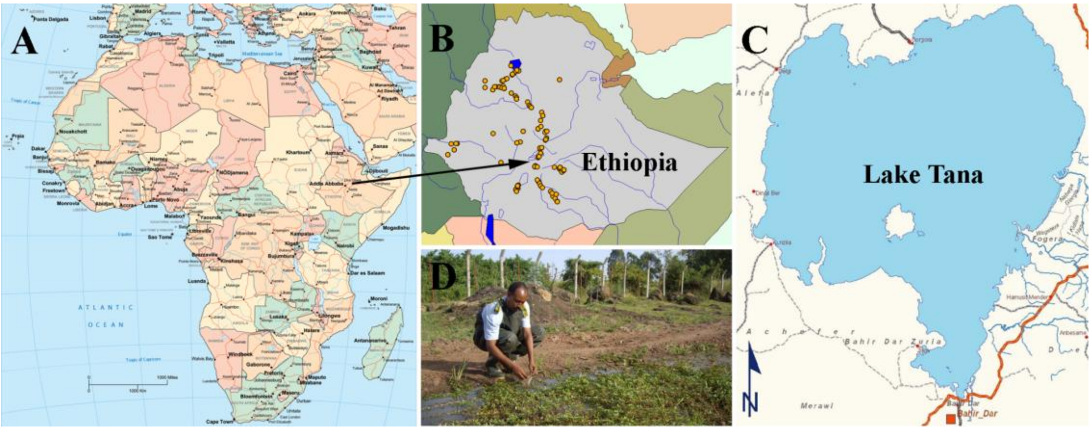

Fig. 1. Overview of locations in Ethiopia.
A – a position of Ethiopia on African continent; B – our sampling localities within Ethiopia; C – Lake Tana – a region of our main interests; D – Mr. Wondie Zelalem during the sampling in Bahir Dar.

RESULTS AND DISCUSSION

In *toto*, we recorded 63 species of the Cladocera in Ethiopia: 26 species of Chydoridae, 18 of Daphniidae, 6 of Moinidae, 5 of Macrothricidae, 5 of Sididae, 2 of Ilyocryptidae and 1 of Bosminidae (Table 1, Figs. 2, 3).

Table 1. Taxonomic diversity of the Cladocera in Ethiopia.

Group	**Number of taxa**	**% in the fauna**
Chydoridae	26	41.3
Daphniidae	18	28.6
Moinidae	6	9.5
Macrothricidae	5	7.9
Sididae	5	7.9
Ilyocryptidae	2	3.2
Bosminidae	1	1.6
Totally	63	100.0

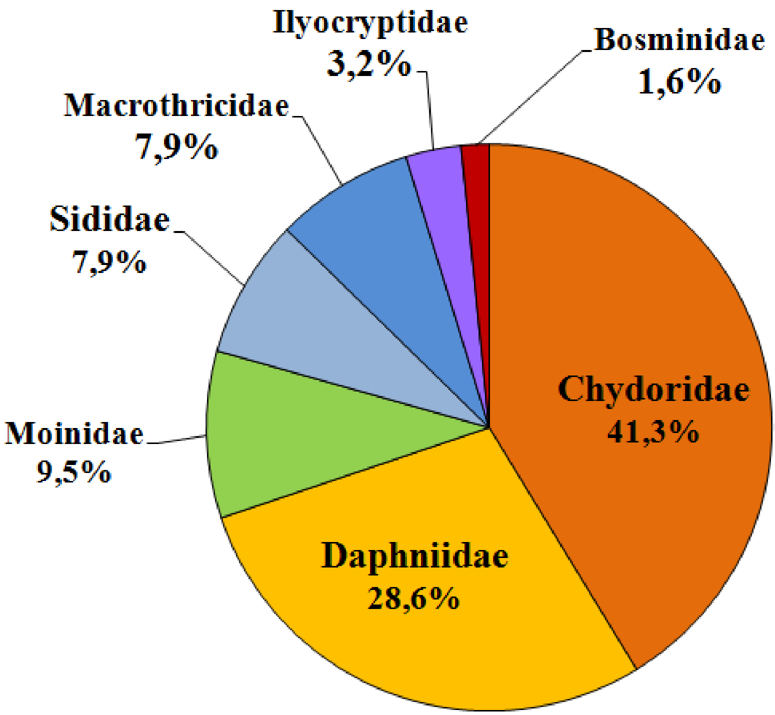

Fig. 2. Diversity of the cladoceran families in Ethiopia.

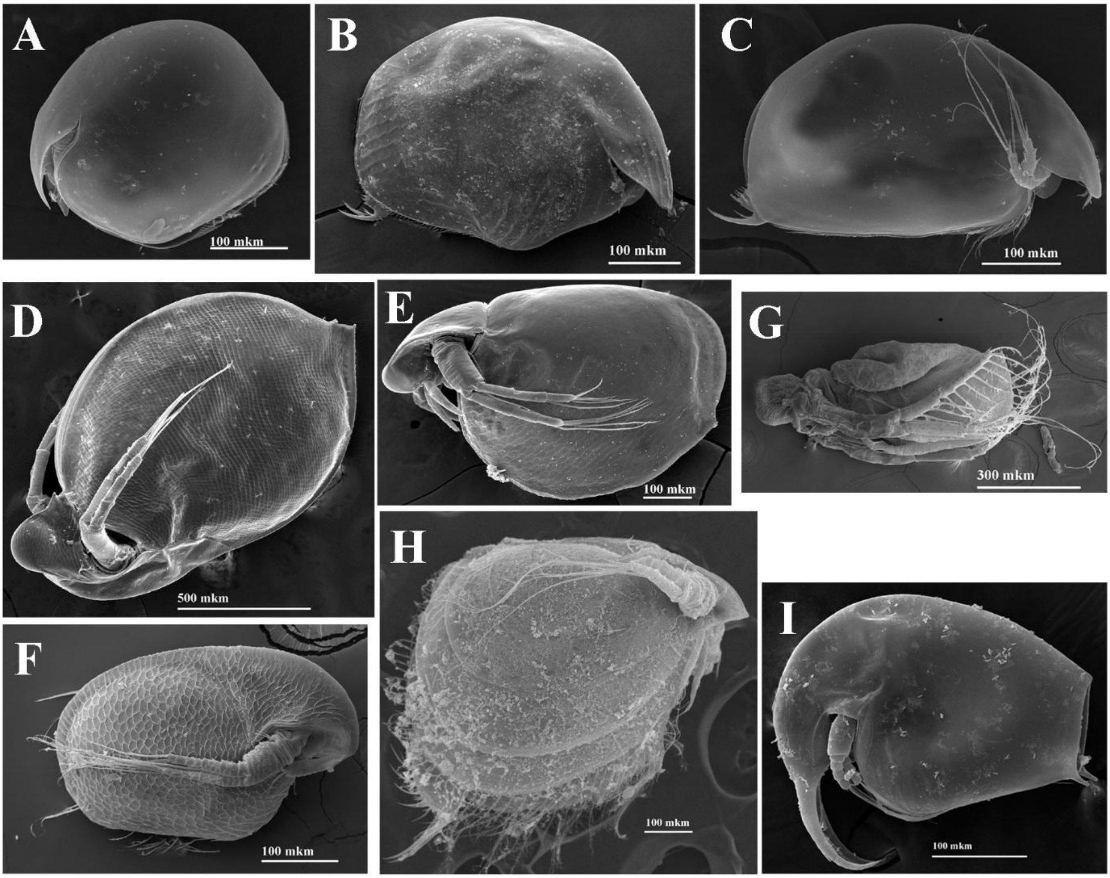

Fig. 3. Some cladocerans from Ethiopian water bodies.
Chydoridae: A – *Chydorus* cf. *sphaericus* (O. F. Müller, 1776); B – *Leberis punctatus* (Daday, 1898); C – *Ovalona cambouei* (Guerne and Richard, 1893). All taxa collected in the Bahir Dar Bay of the Lake Tana.
Daphniidae: D – *Daphnia izpodvala* Kotov and Taylor, 2010, collected in Bale Mountains.
Moinidae: E – *Moinodaphnia macleayi* (King, 1853) from the temporary pool, Bahir Dar.
Macrothricidae: F – *Macrothrix spinosa* King, 1853 from the temporary pool, Bahir Dar.
Sididae: G – *Diaphanosoma orghidani* Negrea, 1982 from the Lake Tana.
Ilyocryptidae: H –*Ilyocryptus spinifer* Herrick, 1882 from the temporary pool, Bahir Dar.
Bosminidae: I – *Bosmina longirostris* (O. F. Müller, 1776) from the Lake Tana.

The highest diversity of the cladocerans was recorded in the mountainous Lake Tana and different water bodies in its vicinities – 39 taxa. Moreover, *Acroperus africanus* Neretina and Kotov, 2015; *Camptocercus uncinatus* Smirnov, 1971; *Graptoleberis testudinaria* (Fischer, 1851); *Scapholeberis kingii* Sars, 1888; *Grimaldina brazzai* Richard, 1892 and some other taxa were found only in Lake Tana itself.

At the same time, lakes, rivers and temporary water bodies located in the mountains and lowlands had significantly lower species diversity: 24 taxa in *toto*. Bale Mountains is a particular region with few cladoceran taxa, but they are considerably different from those in other investigated water bodies. Species confined to this region include *Daphnia izpodvala* Kotov and Taylor, 2010, *Alona* cf. *costata* Sars, 1862; *Alonella* cf. *excisa* (Fischer, 1854); *Alonella* cf. *exigua* (Lilljeborg, 1853) and *Chydorus* sp., although some other cladocerans distributed in lowlands water bodies (e.g. *Leydigia ciliata* (Gauthier, 1939)) were found as well. The majority of cladoceran taxa from Bale Mountain were provisionally determined to the genus level or to the level of species group, because they are significantly different from specimens from type localities of the taxa where they are provisionally placed. Both morphological and genetic analysis confirm that most possibly some of them represent taxa new for science, still waiting for formal description. The first species, *D. izpodvala,* was described based on morphological and genetic data determined several years ago (Kotov and Taylor, 2010). Distinctiveness of the cladocerans fauna in Bale Mountains confirms a hypothesis of the mountain endemism of this group (Van Damm and Eggermont, 2011) within Ethiopia. But still hard work is necessary to examine other localities in nearest countries for clarifying the real distribution ranges for each mountainous endemic taxon. In any case, high mountain water bodies in Ethiopia require special attention and some efforts for their protection as unique ecosystems harboring endemic species.

Usually lowland lakes of the Rift Valley have poor fauna of the cladocerans (3-6 taxa only) as compared with Lake Tana. The most common species are *Ceriodaphnia cornuta* Sars, 1885; *Chydorus parvus* Daday, 1898; *C.* cf. *sphaericus* (O. F. Müller, 1776); *Macrothrix spinosa* King, 1853; *Moina micrura* Kurz, 1875; *Ovalona cambouei* (Guerne & Richard, 1893). On one hand, such patterns of species distribution may reflect a strong anthropogenic impact on the lowlands as compared to Lake Tana. On the other hand, the aforementioned lower diversity could be explained by some peculiarities of the local climate. During the dry and wet seasons the water temperature in Lake Tana varied stronger in contrast to the lowland water bodies. It enabled some boreal and tropical taxa to occur in the same mountainous water body, but during different seasons. In the course of our long-term studies on Lake Tana, we did not find the significant difference in the planktonic species composition between different seasons (during whole period of observations, the plankton was represented by *Bosmina longirostris* (O. F. Müller, 1776); *M. micrura*, *Ceriodaphnia* and

Diaphanosoma species). In contrast, seasonal changes in the littoral cladoceran fauna were revealed. Some typical tropical taxa (such as *Euryalona orientalis* (Daday, 1898); *G. brazzai, Kurzia longirostris* (Daday, 1898); *Macrothrix odiosa* Gurney, 1916 and *Moinodaphnia macleayi* (King, 1853)) were associated with wet season, while some boreal taxa (e.g. *C. uncinatus*, *G. testudinaria*) were common during dry season.

In general, Ethiopia is inhabited by taxa from six faunistic groups of cladocerans: (1) typical tropical cladocerans with broad or relatively broad distribution ranges in the Old World (*A. africanus*; *Leberis punctatus* (Daday, 1898); *Macrothrix triserialis* Brady, 1886 and others); (2) cosmopolitan species which need to be revised (such as *Alona guttata* Sars, 1862; *B. longirostris*, *Simocephalus mixtus* Sars, 1903); (3) circumtropical species (*Ceriodaphnia cornuta* Sars, 1885; *M. spinosa*; *Ilyocryptus spinifer* Herrick, 1882); (4) Afrotropical-Palearctic taxa (*C. uncinatus*, *G. testudinaria*); (5) endemic African species (*Daphnia barbata* Weltner, 1898; *Moina belli* Gurney, 1904) and (6) endemic species of high mountain water bodies.

Our works allow us to re-describe morphology of some African endemics. We compared our material of *M. belli* with type material of Gurney's (1904) and confirmed the taxon identity. Males and ephippial females of this species were described by us for the first time. *M. belli* is a very rare species, found in lakes of arid regions, while *D. barbata* is typical for some lowland lakes.

Non-tropical taxa in Ethiopian Cladocera fauna are especially interesting due to their long-term isolation from ancestral ranges, new undescribed species may be hidden among them. For instance, a detailed morphological comparison for populations of *Acroperus* Baird, 1843 from Lake Tana and Palearctic region allowed us to reveal and describe a new species – *A. africanus* Neretina and Kotov, 2015. However, for some species we did not find any differences between Ethiopian and Palearctic populations after a detailed morphological analysis of parthenogenetic females (e.g. for *G. testudinaria*, *C. spaericus*). May be we have reached the limits of resolution for classical morphological methods. Comparison of 5' region of the CO1 and 16S genes for population of *C.* cf. *spaericus* from Lake Tana with Palearctic and tropical *Chydorus* species demonstrated that it belonged to a specific tropical phylogroup and needs more careful morphological investigations, including study of gamogenetic males and females. At the same time, we concluded based on morphological and genetic analyses that population of *B. longirostris* from Lake Tana is identical to that from the Palearctic region.

Recent detailed morphological comparison and genetic data make the situation with species identification in Ethiopia more reliable. New data allowed us to improve some previous taxon identifications made for difficult groups (such as *Ceriodaphnia, Coronatella, Karualona* and *Notoalona*). In the near future, in collaboration with Ethiopian experts, we will publish a special identification guide to the cladocerans of Ethiopia.

As a result of our work, the cladoceran fauna of Ethiopia is now better known. Specific traits of the Ethiopian cladoceran fauna as compared to whole African continent and its particular regions are shown. Moreover, a large collection of Ethiopian cladocerans, fixed in formaldehyde and ethanol, has been stored. We hope that this collection will be a base for future taxonomic and ecological studies on Ethiopian cladocerans. We believe also that new expeditions to Ethiopian water bodies will lead in new findings of Cladocerans and help us also to evaluate the ecological situation in the region more precisely.

ACKNOWLEDGEMENTS

We are deeply grateful to coordinators of Joint Ethio-Russian Biological Expedition, Andrei A. Darkov and Yury Y. Dgebuadze, for their help in the organization of our field trips and work in Ethiopia. Also, we thank Sergey I. Metelev (I.D. Papanin Institute of Inland Water Biology) and Alexey N. Nekrasov (Institute of Experimental Mineralogy) and Roman A. Rakitov (A.A. Borisyak Paleontological Institute) for their technical assistance to ANN in SEM investigations. All samples used in this work were collected exclusively in the frame of activity of JERBE. All morphological studies were made in Russia at the base of A.N. Severtsov Institute of Ecology and Evolution, I.D. Papanin Institute of Inland Water Biology and A.A. Borisyak Paleontological Institute. Molecular genetic analysis was carried out by ANN in the Department of Ecology (Charles University in Prague) and supported by Czech grant 1620/414-509327 and Stipendium of President of Russian Federation for studying abroad.

REFERENCES

African Economic Outlook (2016). **Sustainable Cities and Structural Transformation**. OECD Publishing, Paris.

Bekker, E.I., Karabanov, D.P., Galimov, Y.G. and Kotov, A.A. (2016). DNA barcoding reveals high cryptic diversity in the North Eurasian *Moina* species (Crustacea: Cladocera). *PloS One* **11**(8): e0161737.

Billi, P. (ed.) (2015). **Landscapes and Landforms of Ethiopia**. Springer, Dordrecht.

Frey, D.G. (1987). The taxonomy and biogeography of the Cladocera. *Hydrobiologia* **145**: 5–7.

Gurney, R. (1904). On a small collection of a freshwater Entomostraca from South Africa. *Proc. Gen. Meetings Sci. Business Zool. Soc. Lond.* **2**: 298–301.

Kloos, H. and Legesse, W. (2010). **Water Resources Management in Ethiopia: Implications for the Nile basin.** Cambria Press, Amherst, New York.

Korovchinsky, N.M. (1996). How many species of Cladocera are there? *Hydrobiologia* **321** (3): 191–204.

Korovchinsky, N.M. (2006). The Cladocera (Crustacea: Branchiopoda) as a relict group. *Zool. J. Linn. Soc.* **147**: 109–124.

Kotov, A.A. (2013). Morphology and phylogeny of Anomopoda (Crustacea: Cladocera). KMK, Moscow. [In Russian with English abstract].

Kotov, A.A. and Taylor, D.J. (2010). A new African lineage of the *Daphnia obtusa* group (Cladocera: Daphniidae) disrupts continental vicariance patterns. *J. Plankton Res.* **32**(6): 937–949.

Lampert, W. (2011). Daphnia: development of a model organism in ecology and evolution. **Excellence in Ecology Series**, pp. 1-250 (Kinne, O., ed.). Book 21. International Ecology Institute, Oldendorf/Luhe.

Mergeay, J., Verschuren, D. and De Meester, L. (2005). Cryptic invasion and dispersal of an American Daphnia in East Africa. *Limnol. Oceanogr.* **50**(4): 1278–1283.

Mergeay, J., Verschuren, D. and De Meester, L. (2006). Invasion of an asexual American water flea clone throughout Africa and rapid displacement of a native sibling species. *P. Roy. Soc. B. Bio.* **273**(1603): 2839–2844.

Neretina, A.N. and Kotov, A.A. (2015). A new species of *Acroperus* Baird, 1843 (Cladocera: Chydoridae) from Africa. *Zootaxa* **4039**: 516–528.

Neretina, A.N. and Sinev, A.Y. (2016). A revision of the genus *Leberis* Smirnov, 1989 (Cladocera: Chydoridae) in the Old World and Australia. *Zootaxa* **4079**: 501–533.

Sharma, P. and Kotov, A.A. (2013). Molecular approach to identify sibling species of the *Ceriodaphnia cornuta* complex (Cladocera: Daphniidae) from Australia with notes on the continental endemism of this group. *Zootaxa* **3702**(1): 79–89.

Smirnov, N.N. (2013). **Physiology of the Cladocera**. Academic Press, London.

The International Bank for Reconstruction and Development (2016). Ethiopia: Managing water resources to maximize sustainable growth. A World Bank water resources assistance strategy for Ethiopia. The World Bank, Washington.

Tudorancea, C., Zinabu Gebremariam and Elias Dadebo (1999). Limnology in Ethiopia. In: **Limnology in Developing Countries,** Volume 2, pp. 63–118 (Wetzel, R.G. and Gopal, B., eds.). International Association for Limnology (SIL).

Van Damm, K. and Eggermont, H. (2011). The Afromontane Cladocera (Crustacea: Branchiopoda) of the Rwenzori (Uganda - D.R. Congo): taxonomy, ecology and biogeography. *Hydrobiologia* **676**: 57–100.

Xu, S., Hebert, P.D.N., Kotov, A.A. and Cristescu, M. E. (2009). The non-cosmopolitanism paradigm of freshwater zooplankton: insights from the global phylogeography of the predatory cladoceran *Polyphemus pediculus* (Crustacea, Onychopoda). *Mol. Ecol.* **18**(24): 5161–5179.