Branchiopoda and Copepoda (Crustacea) in Mongolian Saline Lakes

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Abstract

This paper presents a very complete inventory of the branchiopods and copepods that inhabit the salt lakes (salinity >3‰) of Mongolia. The inventory was based on samples collected from 108 salt lakes over the course of seven limnological expeditions in most of the Mongolian territory between 2005 and 2009. The salinity of the lakes ranged from 3.4 to 76‰ S. A total of 43 taxa were identified: 7 Anostraca, 1 Spinicaudata, 1 Notostraca, 1 Leptodoridae, 1 Ctenopoda, 15 Anomopoda and 17 Copepoda. Thirteen taxa are limited to the Asiatic portion and the rest are known throughout the Palearctic region. One taxon, Phallocryptus sp. has not yet been described in scientific literature. The taxonomic position of Artemia sp. in Mongolia has still not been clarified. All of the species are euryhaline and, except for Artemia sp. and Cletocamptus retrogressus, which are the most halophile, they can live in waters with less than 10‰ S. Thirty-three species appear only in mesosaline waters (3–20‰ S), five do not exceed the mesosaline level (>50‰ S) and five can live in hypersaline waters (>50‰ S).

Key words: branchiopoda, copepoda, saline lakes, Mongolia

Introduction

Planktonic and meiobenthic crustaceans spend their entire life cycle in lakes, making these organisms excellent indicators of both water quality and the ecological status of the lacustrine environment in general. Crustaceans are very old in terms of evolutionary history and have a great capacity for dispersion, allowing them to achieve an extremely high level of planetary diversification, which has been configured over time following biogeographical and ecological patterns.

Salinity is one of the factors with the greatest capacity for segregating organisms. In the aquatic environment, Hammer (1986) defined athalassic saline waters as having salinities equal to or greater than 3‰ S and established a classification system that is reflected in the biota: hyposaline waters (3–20‰ S), mesosaline waters (20–50‰ S); hypersaline waters (< 50‰ S). Many species tolerate a wide range of salinities (euryhalines), while others are limited to narrower ranges and can be assigned to specific salinity categories (stenosalines).

Branchiopods and copepods show great sensitivity to salinity which have been studied in previous researchs (Williams, 1990; Alonso, 1990; Hammer, 1993). In general, the organisms most resistant to salinity are the euryhalines, which can live in environments ranging from hyposaline to hypersaline, which is understandable given that the hypersaline environments generally display an evolution in salinity in accordance with the phases of their hydrologic cycle. Nevertheless, freshwater branchiopods and copepods are not typically found in saltwater lakes. This estenoic aspect also makes them very good ecological indicators and they can be used as sensors of medium and long-term changes. Cladocerans in particular, which leave behind permanent remains in the sediment, are very useful for paleolimnological analysis in studies of global change. (Paterson, 1994; Bredesen et al., 2002; Sarmaja-Korjonen, 2003).

This paper describes the branchiopod and copepod fauna in the saltwater lakes (over 3‰ S) of Mongolia, a country that is rich in lakes despite its relatively high aridity. The Tserensodnom catalog (2002) includes 3,060 permanent lakes of over 10 ha, but this number could increase considerably if temporary lakes are also considered. And, more importantly, the majority of these lakes are well preserved, which reduces the sources of variability in studies such as this one, which is designed to establish species-habitat relationships. Many of the Mongolian lakes are saline; two types of saline lakes can be established in Mongolia: 1) large deep permanent hyposaline-
mesosaline lakes; these lakes are found mainly in the northwest of the country, the majority in the Valley of the Great Lakes (Dulmaa, 1979), and they are the remains of much larger lakes, probably with less mineralized water than those of today, that existed in the Tertiary and Quaternary periods (Egorov, 1993); 2) shallow saline lakes undergoing strong hydromorphological fluctuations, showing temporal saline evolution that sometimes reaches hypersaline levels (>50‰); these lakes are widely distributed in Mongolian semideserts and steppes.

Data on branchiopods and copepods in Mongolian saline lakes have been provided by Flosnner et al. (2005) and Penkova et al. (2005). Both authors supplied lists of taxa, the former from three lakes in the Valley of the Great Lakes (Uureg nuur, Baga nuur and Uvs nuur), and the latter from lakes in Central Gobi, indicating their range of tolerance to salinity but not the origin of the inventoried biota.

Materials and Methods

Samples were collected during an extensive survey performed throughout the Mongolian territory (Table 1 and Fig. 1), taking in all of its natural zones (Alpine belts, taiga, forest-steppe, steppe, semidesert and desert zones) between 2005 and 2009. Approximately 450 lakes were sampled, 107 of which were saline (salinity >3‰). Abbreviate descriptions of all the lakes and pictures can be seen at http://geodata.es/mongolian_lakes. The surveys were conducted in September-October, after the rainy season and before freezing of the lake surface; in this period, the crustacean communities reach their peak of maturity and males and gamogenetic females appear in the cladoceran populations. Salinities ranging from 0 to 100‰ S were measured using a handheld refractometer. Samples were obtained from representative habitats in each lake (littoral areas, open water, among vegetation) using two handheld nets with aperture sizes of 100 µm for cladocerans and copepods and 1 mm for large branchiopods. Specimens were preserved in 4% formaldehyde. In the laboratory most taxa were identified to species.

Results

Forty-three taxa were identified of which nine were large branchiopods, 17 cladocerans and 17 copepods (Table 2).

Among the anostracans the most abundant and purely halophile species is *Artemia* sp., whose taxonomical status still remains unclear; it always forms bi-sexual populations, normally in the more saline (hypersaline) and persistent waters.

Table 1. Saline lakes sampled in different Mongolian provinces indicating the field salinity on the sampling date. D.P.S: Deep permanent saline; S.T.C.S: Shallow, temporary, turbid by suspended clay and saline; S.T.H: Shallow, temporary hypersaline.
Figure 1. Natural areas in Mongolia and distribution of surveyed saline lakes, differentiating deep permanent hyposaline-mesosaline lakes from shallow saline (hiposaline, mesosaline and hypersaline) lakes.

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Species inhabiting hyposaline water bodies are *Branchinecta orientalis*, *Branchinectella media*, *Galaziella murae* and *Phallocryptus* sp. *B. orientalis* appear in a wide range of environments, habitually in muddy shallow water bodies but it was surprisingly seen forming a well established population in Toson nuur in Hentii, a large permanent deep not turbid lake. *B. media* was

Table 2. Branchiopoda and Copepoda in Mongolian saline lakes. For each taxa, the number of records is indicated. Number of sampled lakes: 108.

| Taxa | Number of records |
|------|------------------|
| Anostraca |                  |
| Artemia sp. | 30 |
| Branchidopsis affinis Sars, 1901 | 4 |
| Galaziella mongoliana (Uéno, 1940) | 2 |
| Galaziella murae Alonso & Naganawa, 2008 | 4 |
| Branchinecta orientalis Sars, 1901 | 16 |
| Phallocryptus sp. | 8 |
| Branchinectella media (Schmankewitsch, 1873) | 14 |
| Spinicaudata |                  |
| Eocycicus daviid (Simon, 1886) | 2 |
| Notostraca |                  |
| Triops numidicus (Grube, 1865) | 6 |
| Leptodoridiae |                  |
| Leptodora kindtii (Focke, 1844) | 2 |
| Ctenopoda |                  |
| Diaphanosoma mongolianum Uéno, 1938 | 6 |
| Anomopoda |                  |
| Daphnia triquetra Sars, 1903 | 4 |
| Daphnia carinata King, 1853 | 15 |
| Daphnia magna Straus, 1820 | 42 |
| Daphnia longispina var. turbinata Sars, 1903 | 2 |
| Ceriodaphnia reticulata (Jurine, 1820) | 2 |
| Moina salina Daday, 1888 | 60 |
| Moina brachiata (Jurine, 1820) | 33 |
| Moina macroopus (Straus, 1819) | 6 |
| Macrathrix hirsuticornis Norman & Brady 1867 | 5 |
| Macrathrix laticornis (Jurine, 1820) | 2 |
| Bosmina longirostris (Müller, 1776) | 5 |
| Chydorus spheicus (Müller, 1776) | 27 |
| Coronatella reticulata Sars, 1861 | 23 |
| Alona floessneri Sinev et al., 2009 | 27 |
| Oxurella tenicaudis (Sars, 1862) | 2 |
| Diaptomidae |                  |
| Hemidiaptomus ignatovi Sars, 1903 | 4 |
| Arctodiaptomus (A) wierzjeskii (Richard, 1888) | 4 |
| Arctodiaptomus (R.) salinus (Daday, 1885) | 29 |
| Arctodiaptomus (R.) rectispinosus Kikuchi, 1940 | 22 |
| Metadiaptomus asiaticus (Ul’yanin, 1875) | 66 |
| Neutrodiaptomus lobatus (Lilljeborg, 1889) | 2 |
| Mixodiaptomus incrassatus (Sars, 1903) | 1 |
| Cyclopidae |                  |
| Cyclops mongolensis Einsle, 1992 | 4 |
| Megacyclops viridis Jurine, 1820 | 14 |
| Eucyclops serrulatus (Fischer, 1851) | 2 |
| Eucyclops dumontii Alekseev, 2000 | 26 |
| Metacyclops minutus (Claus, 1863) | 4 |
| Metacyclops gracilis (Lilljeborg, 1853) | 2 |
| Thermocyclus kawamurae Kikuchi, 1940 | 19 |
| Microcyclus varians (Sars, 1863) | 2 |
| Harpacticoidea |                  |
| Harpacticoidea sp.pl | 7 |
| Cletocamptus retrogressus Schmankewitsch, 1875 | 10 |
considered not common in Mongolia; it was firstly discovered in Dundgovi province (Naganawa & Zagas, 2002) but according to present data its distribution can been enlarged to Tov, Dornod, Arkhangai and Subbaatar provinces. *G. murae*, a Mongolian endemic species has been only seen in two localities, one in Bayan-Olgii and the another in Arkhangai. *Phallocreptus* sp. is a relatively widely distributed taxon (Tov, Dornod, Arkhangai and Subbaatar provinces), has not been yet described for science and represents a new record for Mongolia; it is close to *P. spinosa* (Milne-Edwards, 1840) with differences in morphology of its antennal appendages and post-genital segments. *Branchidopsis affinis* and *Galaziella mongoliana* usually occur in fresh waters but occasionally appear in the lower limit of hyposaline waters.

Other large branchiopods, *Eocyzicus davidi* (Spinicaudata) and *Triops numidicus* (Notostraca), are very common in freshwater, shallow and muddy water bodies in Mongolia, and they can also live in the same type of lakes although somewhat more saline.

*Leptodora kindtii* was only collected from the Airag nuur. This species is rare in Mongolia and had been reported by Flossner et al. (2005) in a freshwater lake also in the Valley of the Great Lakes (Bayan nuur).

*Diaphanosoma mongolium* is considered a freshwater species that can also live in brackish water bodies and even in marine bays (Korovchinsky, 1992), however in Mongolia it has been found close to the lower limit of hyposaline lakes.

The most characteristic and abundant euryhaline species of Anomopoda are *Alona floessnerii*, a Mongolian endemism, and *Moina salina*, which live in both mesosaline and hypersaline waters. Probably *A. floessneri* was reported fromUvs nuur by Flossner et al. (2005) as *A. elegans* Kurz, 1865 (Sinev et al., 2009). *Moina salina* is a well-known halobiont species widely distributed in the Palaearctic region (Negrea, 1983; Alonso, 1996) and the identity of the Mongolian populations and the westernmost populations, which of the Iberian Peninsula have

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**Figure 2.** Range of field salinities at saline lakes were each taxon was collected.

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been checked in this work. Among the Daphnia genus, D. magna has the highest capacity for colonizing a wide range of environments and is a very frequent species in Mongolia. D. triquetra, a Central Asian species, has been always considered a typical halobiont (Sars, 1903; Benzie, 2005). D. carinata was supposedly a freshwater species (Benzie, 2005) with 4,200 µS/cm (about 3–4‰ S) as its upper limit of water mineralization (Dumont & Van de Velde, 1975). However this study records a salinity range for this species that reaches 9.2‰ S and Penkova (2005) reported a upper limit of 55‰ S. Moina brachiata, M. macrocopus and Macrothrix hirsuticornis are common in shallow steppe freshwater and hyposaline lakes, appearing in Mongolia in the quite mineralized waters. Other species reported in this paper are weakly represented in saline environments although their presence in the less concentrated waters is not a rarity since they are very eurico and cosmopolitan, as in the case of Chydorus sphaericus, Coronatella rectangula and Bosmina longirostris, which occasionally have also been found in some Mongolian hyposaline lakes.

Arctodiaptomus rectispinosus, Metadiaptomus asiaticus and Cletocamptus retrogressus are the most characteristically euryhaline copepods, occurring in lakes ranging from hyposaline to hypersaline. A. rectispinosus is a common species but had not been reported before in Mongolia, perhaps because it was mistakenly identified as A. bacillifer (Koelbel, 1885). Megacyclops viridis, Eucyclops dumontii and Thermocyclops kawamurai are somewhat frequent and can live in the upper range of hyposaline waters. The rest of copepods are freshwater species living in shallow and sometimes temporary lakes with waters that can experience phases with somewhat high mineralization.

Discussion

The relationship between salinity and species richness of crustaceans is well established in the literature (De Deckker & Geddes, 1980; Hammer, 1986; Williams, 1990), and it is generally accepted that the number of species declines rapidly in the 0–10‰ salinity range and slowly in more saline waters. This general conceptual model can be applied to Mongolian lakes (ca 450) in which a total of 121 brachiohopods and copepod species have been identified (unpublished data). This number of species can be distributed accordingly to salinity ranges as follows: 76 species in the 0–3‰ S, 33 species in the 3–20‰ S, 5 species in the 20–50‰ S range and 5 species in waters over 50‰ S.

All species found in Mongolian saline lakes are euryhaline, although three major groups can be distinguished based on the salinity ranges where they are found (Fig. 2). The first group comprises 33 species which appear in mesohaline waters (3–20‰ S). Within this group two types of species coexist: typically freshwater species such as Macrothrix laticornis, Chydorus sphaericus, Coronatella rectangula, Eucyclops serrulatus and Microcyclops varicans, which were collected in the large permanent hyposaline lakes, and species that live in shallow, often temporary waters in deserts and steppes and are characteristically adapted to a wide range of salinities. The best examples of the latter type are Mixodiaptomus incrassatus and Moina brachiata.

The second group comprises five saline species that do not exceed the upper mesosaline limit (50‰ S) and which have been found both in large hyposaline permanent lakes, with Arctodiaptomus salinus being the most abundant species in such environments, and in shallow mesosaline desert and steppe lakes.

The third group comprises five species that can live in hypersaline lakes with over 50‰ S, all of them located in deserts and steppes; within this group of species, Artemia sp. and Cletocamptus retrogressus are the most halophile, always appearing in waters with over 15‰ S.

Of the whole of brachiohopods and copepods recorded in the Mongolian saline lakes, 13 of them are Asiatic namely: Branchidopsis affinis, Galaziella mongoliana, G. murae, Eucycicus david, Triops numidicus, Daphnia triquetra, Hemidiaptomus ignatovi, Arctodiaptomus rectispinosus, Metadiaptomus asiaticus, Neutrodiaptomus lobatus, Cyclops mongolensis, Eucyclops dumontii and Thermocyclops kawamurai. The rest of the species have a wide distribution in the Palaearctic region, reaching the Iberian Peninsula (Alonso, 1998).

Community structures in the Mongolian saline lakes are similar to those in other parts of the world, suggesting the existence of vicarious taxa. If we focus on the most halophile (hypersaline) species of calanoids, we find illustrative relationships. In Mongolia the species are Metadiaptomus asiaticus and Arctodiaptomus...
rectispinosus; in Australia (Victoria) (Williams, 1990) Calamoecia citellata Bayly, 1962 and C. salina (Nicholls, 1944); in Canada (Hammer, 1993), Diaptomus connexus (Light, 1938) and Hesperodiaptomus. nevadensis (Light, 1938); in South America, Boeckella poooensis Brehm, 1956 (Hammer, 1986); and on the Iberian Peninsula, Arctodiaptomus salinus. It is remarkable that A. salinus is the only halophile species in the western Palaearctic that inhabits such a wide range of salinities, from freshwater to hypersaline waters, suggesting that this species has enlarged its ecologic valence because of the absence of other halophile competitors. In fact, in Mongolia, A. salinus is restricted to mesosaline waters. In the case of the halophile branchiopods, the species assemblages are less similar. Mongolian hypersaline lakes have Artemia sp. and halophile Moina- species which are widely distributed genera living in the same environments around the world, however these lakes do not have true halophile Daphnia-species like D. mediterranea (Alonso, 1985) in the Mediterranean countries (Margaritora, 1985; Alonso, 1998) or D. pusilla (Serventy, 1929) in Australia.

Given the great climatic differences between Mongolia and the countries of the western Palaearctic, particularly those of the Mediterranean, the significant faunistic affinities that exist are remarkable. This clearly establishes that the strategies of the species that inhabit these environments can be different to fulfill common needs. For example, the large branchiopods in the Mediterranean countries are obligate temporary water species (except Artemia sp.), which has always been interpreted as a strategy to avoid the domain of predators. However, in Mongolia, these organisms also appear in lakes that do not dry up, but in which the entire water mass can freeze completely (lakes with less than 2 m deep), fulfilling the same objectives for their survival.

Salt lakes are very sensitive to environmental changes. They possess a very characteristic biota which is adapted to specific salinity conditions and which can be displaced with relatively minor modifications. In the shallow saline lakes, it is very difficult to monitor the changes due to the enormous variability that the local microclimates introduce and the yearly meteorological phenomena. For example, there are many salt lakes in the Mongolian Gobi that are flooded only very occasionally. The large deep saline lakes have much greater stability and, fortunately, the majority are subjected to few pressures, which makes them excellent candidates for monitoring the effects of global change. The palaeolimnological work of Soninkhishig et al. (2003), which clearly establishes the fluctuations in salinity that the Telmen nuur has undergone and describes situations in the distant past that are very similar to the current ones, is of particular interest.

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## Хураангуй

Энэхүү өгүүлэл Монгол орны давстай нууруудад (давсжилтын хэмжээ >3‰ S) амьдардаг заламгай хөлт хавч ба сэлүүр хөлт хавч хэлбэртний судалгааны дүнг танилцуулав. Судалгааны ажил 2005-2009 оны уртанд явагдсан 7 удаагийн нуур салалтын экестийн хүрээнд Монгол орны 107 нуураас цуглуулсан дээжинд тулгуурлан хийгдсэн юм. Нуур нуурууд давсжилтын хэмжээ 3.4–76‰ S байв. Судалгааны дүнд нийт 43 зүйл нь илрүүлсний 7 зүйл нь Anostraca, 1 Spinicaudata, 1 Notostraca, 1 Leptodoridae, 1 Ctenopoda, 15 Anomopoda, 17 Copepoda тус тус бичигдээ. Эдгээр зүйлүүд нь зөвхөн Азид тархан байхыг хүртэл үндэслүүлээгүй байна. Artemia sp., Cletocamptus retrogressus зэрэг зүйлүүд бага давсжилттай (<10‰ S) усан санд, харин бусад зүйлүүдийг дунд зэргийн давсжилттай (3-20‰ S) усан санд амьдардаг. Тэгээд зүйлүүдийн 33 зүйл нь дунд зэргийн давсжилттай (3-20% S) усан санд амьдардаг байхад 5 зүйл нь дунд зэргийн давсжилттай дээд түвшний агууламж бүхий (50% S) усан санд, харин 5 зүйл нь хэт их давсжилттай усан санд (>50% S) тухайдоно.