Uniformity in a Diversity of Landscapes – Branchiopod Communities in Eastern and Central Mongolia

Ansgar Poloczek
Humboldt-University Berlin, poloczea@student.hu-berlin.de

Michael Mühlenberg
Georg-August University of Göttingen, mmuehle@gwdg.de

Ingo W. Stürmer
Research, Exploration and Consulting (IDBio) e.V.

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Uniformity in a diversity of landscapes – Branchiopod communities in eastern and central Mongolia

A. Poloczek, M. Mühlenberg & I.W. Stürmer

Abstract

While investigating the branchiopod fauna of Mongolia, the uniformity of these crustacean communities through a multitude of different ecological conditions is conspicuous.

We sampled branchiopods in 24 sites through Central- and East-Mongolia, as living animals as well as cysts in soil samples. These sites represent the main types of Mongolia's vegetation- and ecological-zones: Taiga forests in the western and eastern edge of the Khentey-Mountain ridge, the central and eastern steppe regions, and the Gobi-desert in the south.

In this large amount of differing ecological conditions with a changing human impact, compared to the width of the covered area, we found a relatively uniform structure of "large branchiopod" communities. The main type of Branchiopod assemblies were a community formed by up to four different species (*Branchipodopsis affinis, Triops numidicus, Eocyzicus davidi, Lynceus dauricus*), which represent the four main groups within the "large branchiopods" (Anostraca, Notostraca, Spinicaudata, Laevicaudata).

Exemplary for this "Mongolian standard Branchiopod Community" we investigated several waterponds, inhabited by these Branchiopods at *Khonin Nuga* – Research station in the western Khentey Mountains to study the population's development and living conditions.

The short life span of those ephemeral puddles only allows the occurrence of short-living and fast developing species. Thus, only one generation of large branchiopods inhabits one aqueous phase at any given time. After the large branchiopods have completed their life cycle, *Daphnia* dominates.

Key words: Branchiopoda, Khentey Mountains, temporary waters, artificial habitats, population development

Introduction

Due to its dry and continental climate, most of Mongolia's water bodies were ephemeral. They fill with water in the beginning of the rainy season in summer and mostly dry out towards autumn. Their size ranges from a few m^2 to more than 30 ha.

During the summer months water levels are subject to strong fluctuations. During the day the water surface temperature can reach 30 °C, and daytime temperature differences of 11 °C within 10 h and 18 °C within 14 h were recorded in Khentey Mountains and expected to be even higher in Gobi – desert.

Their water can be fresh or more and less saline and their origin is mostly natural, although some of these ponds can be classified as artificial habitats, mostly correlated with the construction of roads and the driving activity of vehicles.

Despite from their huge differences in shape, dimension, salinity and also turbidity, the absence of predaceous animals inside made these ephemeral ponds a unique habitat for highly specialised invertebrate communities. The temporary nature of these waters, prevent the durable colonisation by fish and the lack of structured edge vegetation makes them unsuitable for most of the predaceous insects like dragonfly-larvae. Branchiopods are one of the most common taxa occurring in temporary ponds, due to their vulnerability against predation and therefore the development of resting stages to successfully colonize ephemeral habitats (BRENDONCK et al. 2002).

Temporary waters are threatened ecosystems, hence in many places the large branchiopods become endangered because of habitat loss (ANGELER et al. 2008, BRENDONCK et al. 2008). Despite their often-inconspicuous habitats, they can play an important role in regional food webs (ZIMMERMANN 1986, ANGELER et al. 2008).

In the present study we divided the sampled branchiopods into Cladocerans and “large branchiopods”, a term which hasn’t any systematical evidence, but is common and useful (OLESEN 2009) as well as accurately defined (e.g. BRTEK 1997).

In the last decade a large amount of studies dealing with East Asian and especially Mongolian Branchiopods was carried out, including the description of a new species of chirocephalid anostraca (ALONSO & NAGANAWA, 2008). NAGANAWA & ZAGAS (2002) refer to 16 species of large Branchiopoda occurring in Mongolia.

Methods

In 2010 we evaluated ephemeral ponds all around the eastern part of Mongolia. In some of them we were able to collect living branchiopods from the water; in others we collect the cysts. Those were sampled by picking up some dry soil from the former lakes and ponds. The soil material was rewetted in an aquarium, and if branchiopods hatch they were collected when they were big enough to identify. All collected animals were stored in 70 % Ethanol.

Additional we identified sampled material given to us, collected from various other localities throughout central Mongolia.

We compared this data with our results from investigations of branchiopod communities in the west Khentey Mountains.

Altogether we were able to collect large Branchiopods from 24 sites in Mongolia (fig. 1).

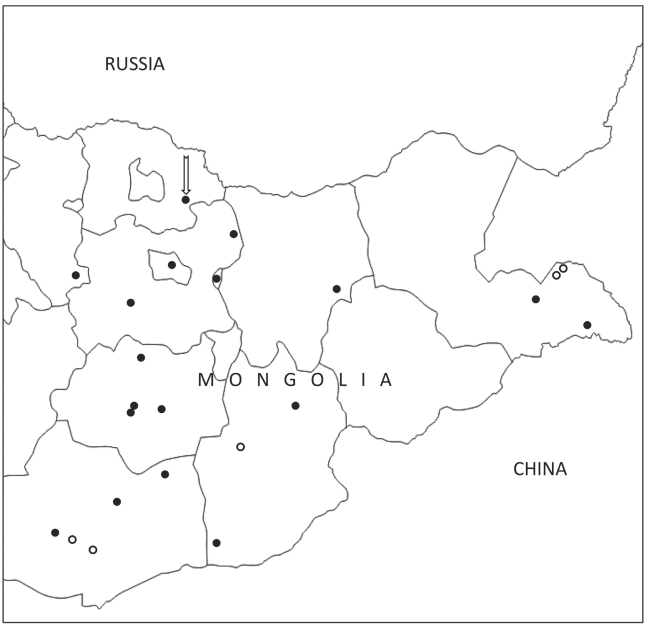

Fig. 1: The sampling sites in central and eastern Mongolia. Black dots indicate ephemeral waters inhabited by the MSBC, white dots indicate sampled waters with other branchiopod communities.
The arrow marks the ecological Field station Khonin Nuga.

Area of examination in the western Khentey Mountains

The research station „*Khonin Nuga*“ is situated in the western buffer zone of the „strictly protected area *Khan Khentij*” in North Mongolia. The broad valley of Eroo River is characterised by alluvial forests, shrublands and different grassland types. Outside the river valley a dark Taiga (*Pinus* – *Picea* – *Abies*) interspersed with a lighter Taiga (*Betula* – *Larix*) dominates. Here the south-facing slopes are mostly bare of forest and characterised by steppe-like vegetation. The elevation varies between 900 m in the valley and up to 1600 m on top of the mountains (DULAMSUREN et al. 2005).

All areas of examination were in the vicinity of the research station in the Eroo river valley and its source the Sharlan River. During winter and spring it is very dry in the Khentey Mountains. Maximum precipitation is in July and August. Average precipitation is 250 – 260 mm per year (DULAMSUREN et al. 2005).

Throughout the river valley there are small collections of water, which are mostly only filled periodically; they fill with water in summer and dry out towards autumn. During aqueous phases, water levels are subject to strong fluctuations. All the water bodies had sufficient oxygen levels (10 milligram per litre) and were ph neutral.

Depending on their structure, water bodies were separated into 3 different categories:

Ponds:

Ponds can be found in grassland depressions, which are covered in a diverse range of plants. Their bottom is formed by plant material and their edges are vegetated. All ponds were mostly above 30 m^2 in size and more than 50 cm deep; in one pond depths of over 1m were reached.

Pools:

Like the ponds, pools are found on the meadows. They do not form in large depressions but in special structures such as vehicle tracks. Their bottom consists of earth and plant material. Their edges are vegetated and they are generally a lot smaller than 10 m^2 in size. In contrast to ponds, pools are subject to occasional disturbances such as cars or horses. The frequency of these disturbances varies greatly between the pools.

Puddles:

Puddles can be found in depressions and holes in the road that runs along the edge of the valley toward the research station. Puddles are variable in size but are usually below 20 m^2. In general water depth is less than 10 cm; however, after strong rainfalls some puddles were considerably deeper (up to 30 cm). The bottom of the puddles consists of solid materials such as sand, grit and gravel and some larger rocks. The edges are, with a few exceptions, free of vegetation. Puddles are subject to strong mechanical disturbances from humans, horses and automobiles.

Sampling procedure

All samplings took place in summer 2006 and 2007.

Every sampling area was tested for macro organisms (body length over 0.5 cm) and microorganisms (body length smaller than 0.5 cm). Both sampling procedures were conducted on the same or the following day.

For the macro sample a bottomless plastic bucket with a diameter of 21 cm was placed on the bottom of the water body in one swift motion and subsequently sifted for organisms with a dip net (mesh size ~ 0.1 cm). All living organisms were transferred to a sampling tube for further examination. A single sample was sifted until no more animals were found in the net. The organisms were identified to species level, recorded quantitatively and set free when not needed for further examination.

To ensure thorough coverage of the water bodies, the macro sample was divided into 6 individual samples that were placed on two transects within the sampling area. If this was not possible, as in long and narrow puddles, all the sampling points were placed along one single transect.

For the micro samples a total of 1 litre of water was extracted from each sampling area and filtered through gauze bandage. Using small plastic tubes, 6 cl water were extracted from different locations in the sampling area and subsequently added to the 1 litre bottle. This was to ensure that the sample is representative of the entire sampling area, which is especially important in the case of *Daphnia* a species generally found in groups.

Mid September 2007 a mud sample was taken from a puddle, which seemed suitable due to its species diversity and richness. The substrate was dried, and in spring 2008 added to a 16.5 litre aquarium filled with water. From the substrate *Triops numidicus*, *Branchipodopsis affinis*, and *Daphnia curvirostris* developed. These organisms were used to conduct development and behavioural studies. The results were compared to the rewetting experiments in the field.

Continuous observation

Some of the puddles, seven in total, which circumference ensured that they were permanently filled with water for long periods of time, were selected for continuous observation. In the beginning and the end of August samples were taken from these puddles to track the population development.

Many puddles had dried out by the 14.08.2007, but refilled after rainfalls between 17. – 19.08. As off the 17.08., two further small puddles (A and B) were regularly micro sampled and their recolonization documented. After the development of grown – up individuals, the Micro-samplings were stopped and the observation was done by sight, to prevent a too high disturbance of the developing populations with regular samplings. With the gradual onset of the autumnal dry season at the beginning of September these puddles had to be refilled manually using water fetched from Eroo River (05.09.). No Crustaceans were found in the river, except of ground-dwelling Cladocera. Puddle B was kept wet until the end of investigations, while puddle A dried out towards September 10th and was artificially rewetted on September 12th.

Results

Altogether we found eight species of large Branchiopopds during our investigations (table 1). Despite the multitude of landscapes and ecosystems in the eastern part of Mongolia, the fauna of Branchiopod crustaceans is quite uniform. The vast majority of sampled sweet-water lakes and ponds was inhabited by a large-branchiopod community formed by three (in the north: four) species: *Branchipodopsis affinis* SARS, 1901; *Triops numidicus* (GRUBE, 1865); *Eocyzicus davidi* (SIMON, 1886) and *Lynceus dauricus* THIELE, 1907. The nomenclature follows BRTEK (1997).

We like to characterize this community as the “Mongolian standard Branchiopod community” (MSBC), although *L. dauricus* occurs only in the northern parts of Mongolia. Remarkably, in the MSBC every main group among the Branchiopods is represented by one species. This community occurs in nearly every ecosystem of eastern and central Mongolia, from small puddles on gravel roads through Khentey – Mountain’s Taiga – forests to larger ephemeral lakes in semi-desert regions of the Gobi.

Due to special conditions among their habitats, like salinity or even just a higher degree of isolation, rarely other species can be found and we consider their occurrence in Mongolia to be local and patchy.

Aspects of the ecology of MSBC using the example of the western Khentey Mountains

In the area around *Khonin Nuga* Research station the four MSBC – Species can be found alongside that, we discovered three genera of Cladocerans with at least five species (table 2). Although, the fauna in the three categories of water-bodies differs a lot concerning to composition and abundance.

Ponds:

Of all the water body categories the ponds were the most species rich; aquatic invertebrates were numerous. All ponds resemble each other in species composition and abundance. The fauna of the ponds is characterised by large insect larvae amongst which there are many carvivores: Zygoptera, Anisoptera, *Dytiscus*. In some ponds a few individuals of *Lynceus dauricus* were found as the only large crustacean species.

Table 1: Occurrence of Branchiopoda – Species among the different Aimags of eastern Mongolia as observed during our samplings. The greyish colour indicates the occurence of the species in this Aimag

		Selenge	**Khentij**	**Ulaanbaatar**	**Tov**	**Dornod**	**Dorno-Gov**	**Omno-Gov**	**Dund-Gov**	**Bulgan**
Anostraca	*Branchipodopsis affinis*	■		■	■	■	■	■	■	
	Branchinecta orientalis						■			
	Chirocephalus spec.							■		
	Artemia spec.					■				
Notostraca	*Triops numidicus*	■	■	■	■	■	■	■	■	■
	Lepidurus mongolicus							■		
Spinicaudata	*Eocyzicus davidi*	■	■	■	■	■	■		■	■
Laevicaudata	*Lynceus dauricus*	■	■							

Table 2: Occurrence of Branchiopoda – Species among the different water body categories in the vicinity of Khonin Nuga research station. The greyish colour indicates the occurence of the species in this category

	Ponds	**Pools**	**Puddles**
Branchipodopsis affinis			■
Triops numidicus			■
Eocyzicus davidi			■
Lynceus dauricus	■		■
Daphnia curvirostris	■	■	■
Daphnia pulex	■		
Simocephalus spec.	■	■	
***Bosmina* spec. 1**	■		
***Bosmina* spec. 2**	■		

Pools:

The results from macro sampling in the pools were highly variable. The most important difference between the pools was the type and density of edge vegetation. Edge vegetation abundance correlates with species abundance; the most species rich pools were also those with the most abundant edge vegetation. In general the pool's species composition was quite similar to those of the ponds, but the individual numbers were lower. Significant differences can only be seen in the abundance of crustaceans (fig. 2).

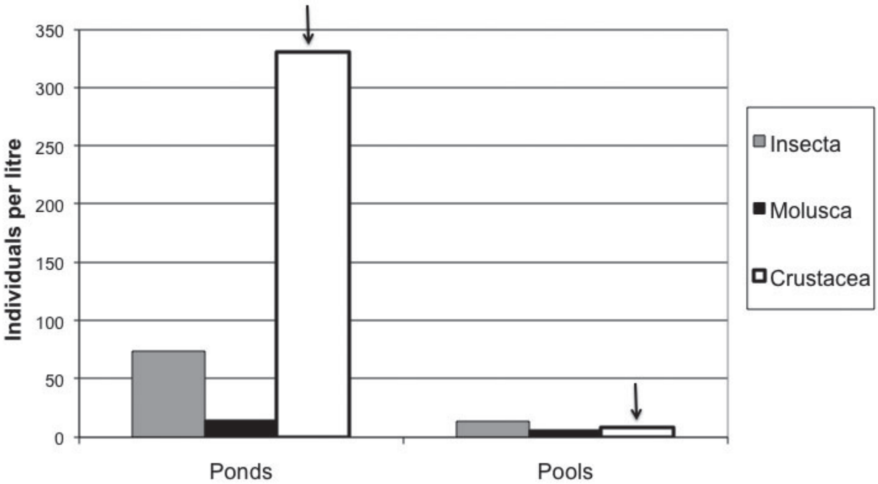

Fig. 2: Comparison of ponds and pools, concerning the average abundance of some invertebrate groups. Ponds: n = 3. Pools: n = 10. The arrows mark significantly different groups ("Man – Whitney U" – Test).

Puddles:

Apart from several Diptera larvae, other aquatic insects (e.g. Corixidae) and Nematomorpha (*Gordius spec*.), Crustaceans were by far the dominant life - form in puddles. In the vast majority of the observed puddles, *Branchipodopsis affinis* dominates the assembly of crustaceans by far in individual numbers, in a few puddles occurring together on an approximately 20 m long road track, *Eocyzicus davidi* took this role. *Lynceus dauricus* was the least frequent species, occurring only in a minority of observed puddles.

No correlation between crustacean density and puddle size could be observed. For the large branchiopods the "Pearson product-moment correlation coefficient" was r = 0.01, for *Daphnia* it was r = – 0.21.

Population development

The changing dominance between large Branchiopoda and Cladocera was detected in several puddles. The repeated sampling in the beginning and in the end of august indicated a gradual decline of large branchiopods and a simultaneous rapid increase of *Daphnia* (fig. 3).

In order to test population development statistically a "*Wilcoxon* – test for paired data*"* was carried out. This shows that either the populations of large branchiopods as those of *Daphnia* were significantly different between beginning and end of August.

The development of *B. affinis* and *Daphnia* populations in the aquarium was similar, whereby the first generation of *B. affinis* and *T. numidicus* developed rapidly from the dry soil substrate. When the last individuals of large branchiopods had died, *Daphnia* became dominant. The development of *Daphnia* resembled a mass reproduction. After the death of the last large Branchiopods no further individuals developed. Large Branchiopods developed only when the aquarium dried up entirely and was rewetted after a few days.

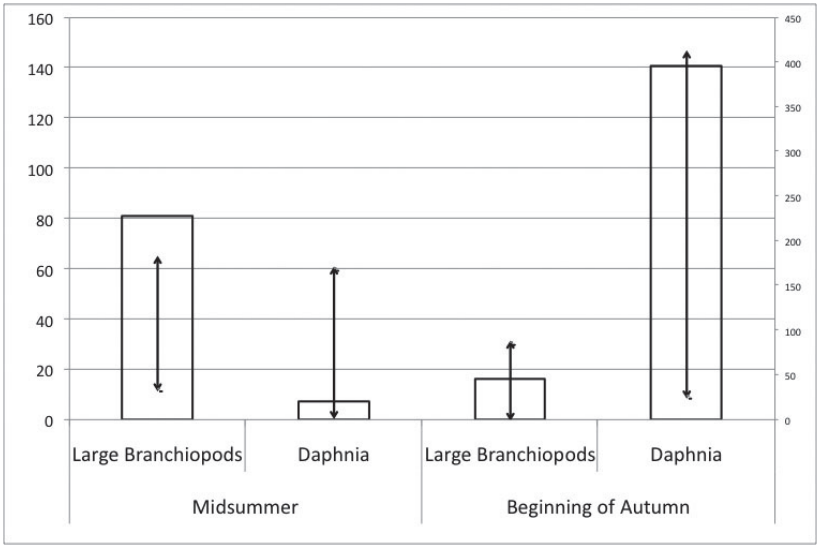

Fig. 3: Comparison of large branchiopod and Daphnia – density in puddles during summer and towards autumn.
White blocks: Average number of individuals per sampling (left axis). Comparison of Macro- (large branchiopods) and Micro-sampling (Daphnia). The arrows indicate the span of the total amount of sampled individuals (right axis).
Puddles with repeated samplings: n = 7
Summer – Sampling dates were August 7th, 8th and 11th.
Autumn – Sampling dates were August 26th, 30th and September 1st.

Continuous observation

As off the 17.09.2007, the small Puddles A and B were refilled with rainwater. After only two days, Nauplius stages were detected in the puddles. In A Metanauplii were found, although it has to be pointed out that the development from nauplii to metanauplii only takes a few hours (DUMONT & NEGREA 2002). After three days Puddle B even had young *Triops numidicus*. The first reproductive individuals in Puddles A and B were discovered in ten and twelve days respectively (table 3 and 4). Puddle A dried up by the 10.09.2007, after rewetting on September 12th, no recolonization took place.

Predation

Predation pressure from outside the puddles, especially from birds, may be substantial. Direct observations and analysis of footprints demonstrated that *Tringa ochropus, Motacilla alba* and *M. cinerea* spend time at the puddles. The *T. numidicus* – population of one puddle was extinct after *T. ochropus* was seen frequently at the puddle’s shore.

Table 3: Puddle A; Micro sampling results after rewetting

Date	*B. affinis*	T. *numidicus*	Remarks
19.08.2007	0	1	*Triops*: Metanauplius
20.08.2007	2	1	*Triops*: Metanauplius; *B. affinis*: M.-nauplius
21.08.2007	3	0	*B. affinis*: Metanauplius
22.08.2007	5	1	Tripos + *B. affinis*: juv.
25.08.2007	6	0	No fertile *B. affinis* ♀♀
27.08.2007	2	0	1 fertile *B. affinis* ♀♀
29.08.2007	0	0	
04.09.2007	5	0	
06.09.2007	0	0	Observation of *Triops*

Table 4: Puddle B; Micro sampling results after rewetting. After 14. 09. samplings were done by sight

Date	B. *affinis*	T. *numidicus*	Remarks
19.08.2007	0	0	
20.08.2007	1	1	*B. affinis*: Nauplius; young *Triops* ~1 mm
21.08.2007	0	0	
22.08.2007	3	0	Young *B. affinis*:
25.08.2007	1	0	Young *B. affinis*: (0,5 cm)
27.08.2007	5	0	4 *B. affinis* with adult size. 1 *B. affinis* ~4mm
29.08.2007	2	0	Fertile *B. affinis* ♀♀
04.09.2007	4	0	Fertile *B. affinis* ♀♀
06.09.2007	0	0	
14.09.2007	Observation of *B. affinis, E. davidi* and *Daphnia*.		
16.09.2007	Observation of *B. affinis, E. davidi* and *Daphnia*.		
18.09.2007	Observation of *B. affinis* and *Daphnia*.		
19.09.2007	Observation of *B. affinis, E. davidi* and *Daphnia*.		

Discussion

Crustacean habitats

Predatory Insects, and especially their larva, are able to prevent large Branchiopods from colonising certain waters. BRENDONCK et al. (2002) showed that even a single dragonfly larva is able to wipe out an entire *Branchipodopsis wolfi* population in Botswana. Thus the phenomenon that *L. dauricus* is present in some ponds in *Khonin Nuga*, despite the presence of predators, must be discussed. *L. dauricus* is significantly smaller than the other Mongolian Branchiopod species and has a bivalved carapace for protection. DUMONT & NEGREA (2002) report on Diplostraca species from Yenissei and Danube River, so can probably be said, that for Diplostraca coexistence with predators isn't that impossible as it is for the unsheltered Anostraca or Notostraca.

As long as predation pressure is absent, factors such as soil conditions or edge vegetation do not seem to influence the presence of large Branchiopods. Species of the MSBC can be found throughout the entire sampling region, stretch their occurrence over all the different ecozones of Mongolia. We found them in highly eutrophed ponds in the steppe (fig. 4) as well as amid of towns and settlements (fig. 5), even in the centre of Ulaanbaatar we recognized a puddle inhabited by *E. davidi* and *T. numidicus*. Only the highly vegetated forest areas were no suitable habitats for large Branchiopods, in the Khentey Mountains they only occur at artificial desert habitats like the roads (fig. 6). Their dispersal may include the transport of cysts on vehicle tires as an important factor.

Despite the threatening of many large branchiopods throughout the world, due to an increasingly lost of wetlands (BRENDONCK et al. 2008), there are some examples for human related changes in ecosystems which are able to benefit large branchiopods. Many forested regions in Europe were modified to "cultural steppe zones", creating biotopes for formerly more eastern-related species (BRTEK & THIÉRY 1995). In Khentey Mountains, the gravel roads form thin, but long stretched habitats, which remain with their solid ground and the lack of vegetation at conditions in Gobi-desert, in South Mongolia.

Fig. 4: Small pond in Dorno-Gov – Aimag. Highly eutrophed due to cattle. Colonized by the MSBC. (photo: S. HEIDELBERGER).

Fig. 5: Waterpond in the town of Baganuur. Inhabited by a multitude of individuals out of the MSBC. (photo: J. KROBBACH).

Fig. 6: Typical MSBC – Puddle in the western Khentey-Mountains. Roads and vehicle tracks form an artificial desert habitat which is suitable for the occurence of branchiopod crustaceans in the Taiga. (photo: Authors).

Predation pressure

It has to be assumed that *Triops numidicus* poses a certain threat, but the present study did not confirm that Notostraca prey on other large Branchiopods.

Predation pressure from outside the puddle is predominantly by birds. It was observed that a single *Tringa ochropus* pair depleted a whole *T. numidicus* population by selective feeding. In such a case muddy water can have a positive effect on large Branchiopod populations. ZIMMERMANN (1986) reports on flood pools along the Tuul River close to Ulaanbaatar, inhabited by the Anostraca-species *Chirocephalus longicornis*, those constitute an important food source for migrating waders.

Crustacean species composition

In Mongolia temporary water bodies are only filled for 3-4 months per year during which time water levels fluctuate and puddles dry up. Short rain periods favour ephemeral, fast-developing species such as *Branchipodopsis* (SEAMAN et al., 1995). The brief rain season of Mongolia and the limited extent of most of the water bodies in time and space also limit the potential number of inhabitants and force these to coexist. It's conspicuous that the MSBC consists of up to four species from each of the four main groups of large Branchiopods (Anostraca, Notostraca, Spinicaudata, Laevicaudata). Inter-specific competition is limited because only one species of each Branchiopoda group is found in the same water body at any one time. The omnivorous Notostraca, the free-swimming, filter feeding Anostraca and the substrate-living Spinicaudata all occupy different ecological niches. From for 16 days existing puddles in South Africa, SEAMAN et al. (1991) describe a very similar species composition like the MSBC: *Branchipodopsis tridens*, *Triops numidicus* and the Spinicaudata – species *Leptestheria spec*.

Population development

In *Khonin Nuga* the first *B. affinis* and *T. numidicus* individuals hatch immediately after rewetting. Two to three days after this the first nauplii and metanauplii stages are present. *E. davidi* seemed to have a slower development more typical for Spinicaudata (THIÉRY, 1991). One week after rewetting the soil, only very small *E. davidi* individuals were present (carapace of 2–3 mm). Little is known about the development of *Lynceus dauricus* and observations in *Khonin Nuga* could not elucidate this further.

An important factor for cyst hatching is temperature. The most Anostraca and Notostraca develop in temperatures above 10 °C (BRENDONCK 1996). In puddle J, after artificial rewetting on September 12th, no Branchiopoda development took place. Most likely this was due to the decreasing water temperatures after the beginning of that month.

Due to our observations in the aquarium, we suggest at least for *B. affinis*, that desiccation is essential for successful hatching. According to BRENDONCK (1996), many Anostraca – species have a required dry – phase or hatching get stimulated by desiccation. The development of *T. numidicus* is described as drought resistant and conditionally drought-stimulate (BRENDONCK 1996), we couldn't observe *T. numidicus* development without previous desiccation.

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Addresses:

Ansgar Poloczek*
Humboldt-University Berlin
Institute of Biology, Comparative Zoology
Phillippstr. 13, Haus 2, D-10115 Berlin
e-mail: poloczea@student.hu-berlin.de

* Corresponding author

Michael Mühlenberg
Georg-August University Goettingen,
Centre for Nature Conservation

Ingo W. Stürmer
Association for interdisciplinary Biology –
Research, Exploration and Consulting (IDBio) e.V.,
Goettingen, Germany