

## Chapter 9

# Zooplankton

Luc Brendonck<sup>1,2,\*</sup>, Lizaan de Necker<sup>2</sup>, Trevor Dube<sup>3</sup>, Tatenda Dalu<sup>4,5</sup>, Kay Van Damme<sup>6</sup>, Tom Pinceel<sup>7,8</sup> and Tamuka Nhiwatiwa<sup>9</sup>

<sup>1</sup>Animal Ecology, Global Change and Sustainable Development, KU Leuven, Charles Deberiotstraat, Leuven, Belgium, <sup>2</sup>Water Research Group, Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa, <sup>3</sup>Department of Applied Biotechnology and Biosciences, Midlands State University, Gweru, Zimbabwe, <sup>4</sup>School of Biology and Environmental Sciences, University of Mpumalanga, Nelspruit, South Africa, <sup>5</sup>South African Institute for Aquatic Biodiversity, Makhanda, South Africa, <sup>6</sup>Faculty of Sciences, Ghent University, Ghent, Belgium, <sup>7</sup>Centre for Environmental Management, University of the Free State, Bloemfontein, South Africa, <sup>8</sup>Animal Ecology, Global Change and Sustainable Development, KU Leuven, Leuven, Belgium, <sup>9</sup>Department of Biological Sciences, University of Zimbabwe, Mt. Pleasant, Harare, Zimbabwe

\*[luc.brendonck@kuleuven.be](mailto:luc.brendonck@kuleuven.be)

### 9.1 General introduction

Despite the key ecological role of zooplankton in lentic freshwater ecosystems, current knowledge on their systematics, species richness, and distribution is limited, especially in (sub)tropical biogeographical regions (further mostly indicated as “the tropics” here). Because of their important function in a wide range of both temporary and permanent aquatic ecosystems, ample ecological information is available on selected groups (see Wasserman and Dalu, 2022, Chapter 1). Furthermore, some species (e.g., *Daphnia magna*) became important models in ecological and evolutionary research. Increasing ecological knowledge, however, contrasts with the lack of taxonomic and biogeographical studies, due to which current insights on species richness and distribution are incomplete. This largely obstructs accurate large scale (biogeographical) comparisons. Every exploration in poorly studied regions almost always reveals new zooplankton taxa. This is particularly true for the tropics where taxonomy is a scarce skill, especially of microscopic organisms like zooplankton that often require rather expensive optical and molecular techniques for species identification.

Besides the typical zooplankton groups like the rotifers and the cladoceran and copepods crustaceans, we also include ostracods in this chapter. Although adult ostracods are mainly benthic, they are also caught in plankton samples, together with their early developmental stages. As ostracod communities play

an important role in wetland systems and can be very species rich, they deserve a prominent position in a book on tropical wetlands. Sometimes large branchiopod crustaceans are also considered as zooplankton. However, as the Notostraca and Diplostraca orders are mainly benthic, while the Anostraca are rather good swimmers, they are treated in a separate chapter in this book (Brendonck et al., 2022a, Chapter 10).

With this chapter we aim to review and integrate current knowledge on species richness and distribution patterns of tropical zooplankton. This will be complemented with general information on ecology and life history strategies of each group. Where possible, we compare patterns of species richness and distribution between permanent and temporary wetlands. In line with the focus of this book, we here focus on the Afrotropical, Australasian, Neotropical, and Oriental biogeographical regions. Due to size constraints, this review is necessarily limited and incomplete. However, to the best of our knowledge, this is the first large scale integrative effort combining information from all zooplankton groups.

## 9.2 Cladocerans

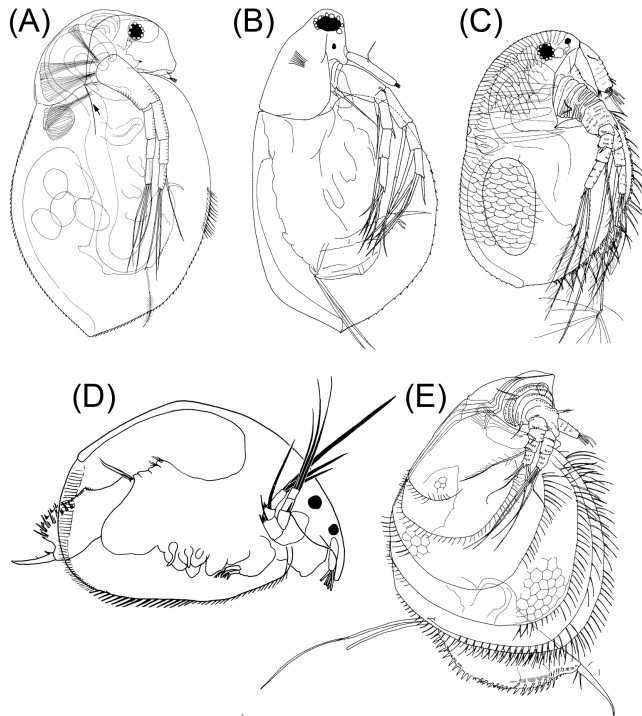
### 9.2.1 Introduction

Cladocerans, also known as water fleas, belong to the Class Branchiopoda, Subphylum Crustacea. The majority are small-sized (0.2–7 mm; some exceptionally larger), primarily freshwater-dwelling organisms, characterized by biramous antennae, four to six limb pairs, and a bivalved carapace not covering the head (Fig. 9.1). These animals thrive in pelagic, littoral, and benthic biotopes, where they occupy key trophic roles as secondary producers, predominantly in lentic waters (Dumont and Negrea, 2002). Members of the Anomopoda, the most speciose cladoceran order, in particular chydorids, daphniids, and moinids often dominate the microcrustacean communities in a wide range of (sub)tropical wetland types. Representatives of the latter families are also particularly well-adapted to temporary waters in the (sub)tropics where they may survive prolonged periods of drought through the production of dormant embryos encased in ephippia.

### 9.2.2 Systematics and general species richness

Cladocerans are grouped into four extant orders, which are systematically well-defined and widely accepted (Fryer, 1987; Kotov, 2013); while several orders are now extinct (Van Damme and Kotov, 2016). The two suspension- and deposit-feeding orders, Anomopoda and Ctenopoda, are the most speciose in tropical wetlands (Chiambeng and Dumont, 2005), while the other (mainly pelagic predatory) orders are virtually absent from these environments.

General cladoceran species richness remains insufficiently known because estimates strongly depend on regional taxonomical efforts. There is especially a general shortage of field data as well as experimental work regarding



**FIGURE 9.1** Selected cladocera from tropical and subtropical wetlands. (A) *Daphnia paggii* (Daphniidae), a high altitude endemic from a sub- to hyposaline temporary lagoon in the Chilean Andes (Kotov et al., 2010). (B) *Moinodaphnia macclaei* (Moinidae), a common pantropical species (after Kotov et al., 2012). (C) *Macrothrix spinosa* (Macrothricidae) from the Pantanal floodplains in Brazil (Hollwedel et al., 2003). (D) *Anthalona acuta* (Chydoridae), a Neotropical endemic from temporary interdunal pools in the Lencois Maranhenses, Brazil; Chydoridae are the most speciose group in most (sub)tropical wetlands (Van Damme et al., 2011). (E) *Ilyocryptus africanus* (Ilyocryptidae) from temporary rockpools, endemic to Cape Point, Republic of South Africa; one of only two species of the family ever found in temporary rockpools (Kotov and Štifter, 2005). Drawings by AA. Kotov (A–C, E) and K. Van Damme (D), reproduced with permission from the copyright holder; not to scale (for scale bars, see original publications).

cladocerans in the tropics (Sarma et al., 2005). This is particularly true for the many taxa residing in shallow macrophyte- and/or detritus-rich lentic habitats that are beyond the scope of most studies that generally focus on the pelagic of deep lakes. Study of zooplankton from such small water bodies requires in-depth systematic knowledge and separate sampling efforts and techniques.

Forró et al. (2008) estimated a global richness of c.620 valid cladoceran species, yet suggested that the realistic number is likely much higher. Since then, a substantial number of new cladoceran genera and species have been described and/or revised (Kotov, 2013; Kotov et al., 2013); the majority from tropical regions.

Up to 50% of cladoceran species are thought to occur exclusively in the (sub)tropics, predominantly in lentic wetlands (Dumont, 1994) with a general and strong increase in diversity around the equator (Forró et al. 2008). From aquatic habitats in tropical rainforests (from flooded forest patches to temporary puddles in tree holes), currently at least 196 cladoceran species are known worldwide (Chiambeng and Dumont, 2005), which is nearly a third of the estimated global diversity. Based on Forró et al. (2008), each of the (sub)tropical regions hosts about half (or a little more) of all cladoceran genera and between a sixth to a quarter of the global species richness, with the Australasian and Neotropical regions having a relatively higher richness and number of endemics (Table 9.1). However, regional diversity estimates are not entirely comparable because they are biased by research intensity. For example, the relatively low diversity in the Afrotropics (Table 9.1) may be partly a natural phenomenon due to historical extinctions (Chiambeng and Dumont, 2005), but lack of taxonomists and limited intensive surveys in the region also play a significant role (Van Damme et al., 2013a; Bird et al., 2019). Similar impediments have been noted for the Oriental region (Korovchinsky, 2013), where nevertheless rainforest areas stand out with the highest richness in the world, matching the Neotropics (Chiambeng and Dumont, 2005).

### 9.2.3 Comparison between wetland types and tropical biogeographical regions

In Table 9.1, numbers of cladoceran genera and species for the considered biogeographical regions are presented, while Table 9.2 summarizes species richness from selected areas and wetland types. Studies on cladoceran zooplankton have been carried out in all tropical regions and in permanent as well as temporary wetland types. An in-depth comparison of species richness in different types of tropical wetlands is limited. This is due to differences in the level of taxonomical research (regional as well as related to the type of habitat), level of habitat description, and sampling approach. Often, wetland types and habitat characteristics are not defined in sufficient detail in cladoceran studies. Studies that cover a wide range of temporary and permanent tropical wetland habitats usually yield a high richness; often with more than half of the known total cladoceran diversity in a region. For example, there are at least 120 cladoceran species known from the Pantanal, counted from 50 permanent and temporary wetland habitats (Brazil; da Silva Brito et al., 2020), which covers 65% of the Neotropical species (known in 2008; Table 9.1). In tropical Africa and India, cladoceran populations have been studied in river pools (Nhiwatiwa et al., 2009), rock pools (Padhye and Victor, 2015), temporary and floodplain pans (Simões et al., 2011; Riato et al., 2014; Nhiwatiwa et al., 2017), and floodplain wetlands (Lindholm et al., 2009; Gogoi et al., 2018; Dube et al., 2017). However, although highly informative, few studies pay attention to a specific wetland type and include a proper (taxonomically accurate) species list (Table 9.2).

**TABLE 9.1** Number of cladoceran genera and species (with endemics between brackets) in the Afrotropical, Australasian, Oriental, and Neotropical regions; numbers from Forró et al. (2008), with the addition of the subtropical Australian Gondwanotrichidae.

	Afrotropical		Australasian		Oriental		Neotropical		Global	
	Genera	Species	Genera	Species	Genera	Species	Genera	Species	Genera	Species
<b>Anomopoda</b>	42(1)	125(24)	48(11)	149(78)	36(1)	89(20)	44(3)	170(89)	76	537
Bosminidae	2(0)	3(0)	2(0)	3(0)	2(0)	4(1)	2(0)	7(3)	2	14
Chydoridae	26(1)	66(17)	33(10)	85(47)	22(1)	48(11)	27(1)	89(51)	49	269
Daphniidae	5(0)	25(1)	4(0)	26(13)	4(0)	17(1)	4(0)	32(13)	5	121
Euryceridae	1(0)	1(0)	0	0	1(0)	1(0)	1(0)	2(1)	1	8
Gondwanotrichidae	0	0	1(1)	1(1)	0	0	0	0	1	1
Ilyocryptidae	1(0)	8(3)	1(0)	5(3)	1(0)	5(3)	1(0)	9(4)	1	28
Macrothricidae	5(0)	12(2)	4(0)	20(9)	4(0)	12(4)	7(2)	21(12)	11	60
Moinidae	2(0)	10(1)	2(0)	7(3)	2(0)	3(0)	2(0)	10(5)	2	29
Neothricidae	0	0	1(1)	3(3)	0	0	0	0	1	3
<b>Ctenopoda</b>	4(0)	9(0)	4(0)	9(5)	6(0)	15(4)	6(0)	16(9)	8	50
Holopediidae	0	0	0	0	0	0	1(0)	1(1)	1	3

(Continued)

**TABLE 9.1 (Continued)**

	Afrotropical		Australasian		Oriental		Neotropical		Global	
	Genera	Species	Genera	Species	Genera	Species	Genera	Species	Genera	Species
Sididae	4(0)	9(0)	4(0)	9(5)	6(0)	15(4)	5(0)	15(8)	7	47
<b>Haplopoda</b>	0	0	0	0	1(0)	1(0)	0	0	1	1
Leptodoridae	0	0	0	0	1(0)	1(0)	0	0	1	1
<b>Onychopoda</b>	0	0	0	0	0	1(0)	0	0	10	32
Polyphemidae	0	0	0	0	1(0)	1(0)	0	0	1	2
<b>Total</b>	<b>46(1)</b>	<b>134(24)</b>	<b>52(11)</b>	<b>158(83)</b>	<b>43(1)</b>	<b>106(24)</b>	<b>50(3)</b>	<b>186(98)</b>	<b>95</b>	<b>620</b>

Only families from tropical wetlands are listed. Estimates are outdated and strongly tied to research intensity per region. A substantial number of new species and genera were described in recent years (Kotov et al., 2013). To put richness of genera and species of the considered biogeographical regions in perspective to those at the global scale, an extra column was added.

**TABLE 9.2** Selected studies on cladoceran diversity and/or ecology in temporary and permanent (sub)tropical wetland types across tropical biogeographical regions.

Region	Area	Wetland type(s)	#spp.	Most speciose group	Remarks	References
<b>Afrotropical</b>	Rwenzori Mountains, Uganda	Temporary pools, permanent swamps, and lakes	11	Chydoridae	29 Water bodies, high altitude; new species	Van Damme and Eggermont (2011)
	Okavango Delta, Botswana	Temporary and permanent habitats (lakes, swamps, floodplains, rain ponds, river)	45	Chydoridae	Highest cladoceran diversity in floodplains (42 spp.) and in swamps (19 spp.), lowest in temporary rain ponds (7 spp.)	Lindholm et al. (2009)
	SE Botswana	Temporary rockpools (on granite)	1	Chydoridae	18 Pools, 1 spp. (undescribed new taxon)	Jocqué et al. (2006)
<b>Australasia</b>	Cameroon	Temporary and permanent habitats (rock pools, ponds, flooded rainforest, lakes)	61	Chydoridae	700 + samples	Chiambeng and Dumont (2005)
	SW Australia	Temporary rockpools	13	Chydoridae	94 Pools, intensively sampled	Jocqué et al. (2007)
	Western Australia	Temporary rockpools (gnammas)	14	Chydoridae	36 Pools on granite	Bayly (1997)

(Continued)

**TABLE 9.2 (Continued)**

Region	Area	Wetland type(s)	#spp.	Most speciose group	Remarks	References
<b>Neotropical</b>	Pantanal, Mato Grosso, Brazil	Temporary and permanent habitats (floodplains, lakes)	120	Chydoridae	50 Localities; general study with different wetland types	da Silva Brito et al. (2020)
	Cochabamba, Bolivia	Temporary (peat-) pools (bofedales)	21	Chydoridae	61 Pools at high altitude; 3–16 spp. per pool; new species	Coronel et al. (2007)
	Andes, Chile	Permanent lakes and temporary saline lagoon	19	Chydoridae	6 Localities at high altitude; new species and new genus	Kotov et al. (2010)
	Pernambuco, Brazil	Temporary pond	22	Chydoridae	1 Pond sampled throughout different periods	Diniz et al. (2013)
	Federal District and Goiás, Brazil	Temporary shallow wetlands (moist grasslands, earth mounds, shallow ponds)	33	Chydoridae	9 Localities; groundwater-fed waters in Cerrado biome	Sousa et al. (2013)
	Lencóis Maranhenses, Maranhão, Brazil	Temporary pools on sand (interdunal, groundwater fed)	34	Chydoridae	5 Localities; 9–17 spp. per pool; Sars' method	Van Damme and Dumont (2010)



<b>Oriental</b>	Western Ghats, India	Temporary rockpools	22	Chydoridae	12 Localities	Padhye and Victor (2015)
	Southern Thailand	Permanent swamps	73	Chydoridae	22 Localities; up to 45 spp. per locality	Van Damme et al. (2013b)
	Thale Noi Wetland, Southern Thailand	Permanent shallow wetland	40	Chydoridae	1 Wetland, sampled using activity traps	Choedchim et al. (2017)

In the Oriental region, up to 85% of the total known cladoceran fauna from Thailand (of which over 60% chydorids) and nearly 70% of the species richness in the region was specifically retrieved from shallow permanent swamps in Southern Thailand (Table 9.1) (Van Damme et al., 2013b). In addition, the focus on swamp habitats led to the discovery of several new species (*Leydigiopsis pulchra*, *Karualona serrulata*, *Notoalona pseudomacronyx*) and the identification of very specific tropical paludal communities with similar species in other continents (Van Damme et al., 2013b; Van Damme and Sinev, 2013). Similar studies were done in each region and for different wetland types, in particular in the increasingly studied Neotropics (Table 9.2). These studies underline that close examination of cladocerans in tropical wetlands is highly valuable, as these habitats continue to harbor a hidden diversity. In the Afrotropics, Lindholm et al. (2009) compared species richness in permanent and temporary habitats in the Okavango Delta, recording a relatively high richness in permanent floodplains (42 spp.), followed by swamps (19 spp.) and lowest values in temporary ponds (7 spp.). The generally lower recorded diversity in tropical temporary ponds and pools in comparison to permanent swamps and floodplains could to some extent depend on the characteristics of the habitat but also on the type and duration of sampling. In the Neotropics, Diniz et al. (2013) monitored a shallow temporary pond in Brazil over several months and counted up to 22 cladoceran species. In contrast, individual tropical temporary pools sampled over shorter periods usually yield lower species numbers (Table 9.2). In a study across 94 temporary rock pools in SW Australia Jocqué et al. (2007) collected 13 species, while only one species was collected from 18 temporary rock pools in SE Botswana (Jocqué et al., 2006). When properly sampled, (sub)tropical shallow temporary pools usually house between 0 and 17 species with on average about 6 species, of which the majority are expected to be chydorids ( ).

Cladoceran communities in lentic (sub)tropical freshwater environments are very similar across the regions at family level, both in temporary and in permanent waters. In each region and in a wide range of (sub)tropical wetlands, communities are dominated by small-bodied and phytophilous/epibenthic Chydoridae (Table 9.2), followed by Daphniidae, Macrothricidae, Sididae, and Bosminidae. At genus-level, *Alona* (*sensu lato*; separated into different genera), *Chydorus*, *Macrothrix*, and *Diaphanosoma* often constitute the most diverse taxa (e.g., rainforests of the world; Chiambeng and Dumont, 2005). The Chydoridae alone easily constitute 60%–70% of the overall richness in both ephemeral (e.g., rockpools in Australia; Bayly, 1997) and permanent (e.g., swamps in Thailand; Van Damme et al., 2013b) tropical waters, a trend which is similar across regions. Moinidae may be locally abundant in temporary and permanent waters, but they are generally represented by only one or two species per locality. Tropical cladoceran communities are usually characterized by a paucity of *Daphnia* species in the lowlands, partially replaced by other filter feeding daphniids (*Ceriodaphnia*, *Simocephalus*, *Scapholeberis*), sidids

(*Latonopsis*, *Pseudosida*, *Diaphanosoma*), moinids (*Moina*, *Moinodaphnia*), and to some extent by bosminids (*Bosmina*). The lower diversity of *Daphnia* is potentially due to the higher predation pressure in the tropics compared to temperate zones (Dumont, 1994), or may result from extinctions (Popova and Kotov, 2013). In contrast, *Daphnia* is sometimes well represented and even abundant in high altitude temporary and permanent tropical wetlands (Van Damme and Eggermont, 2011; Kotov et al., 2010). Suspension-feeding cladocerans thrive in relatively more open biotopes in comparison to chydorids, although shallow (few centimeters) temporary environments can sometimes harbor large populations.

Despite the relatively lower diversity in ephemeral compared to permanent wetlands, they often include peculiar taxa, such as the shallow ephemeral rockpool “specialists,” represented by the genus *Dumontiellus* or *Ilyocryptus africanus* (Fig. 9.1), endemic to Southern Africa (Kotov and Štifter, 2005; Van Damme et al., 2013a); *Coronatella anemae* dominating short-lived pools in arid zones in Northern Africa and Arabia (Van Damme and Dumont, 2008); or *Daphnia jollyi* inhabiting rockpools in Western Australia (Bayly, 1997). Also medium- to high-altitude tropical temporary and permanent waters may harbor peculiar often local endemic species, such as the *Sphagnum*-specialist *Alona sphagnophila* from permanent swamps in the Rwenzori Mountains of Uganda (Van Damme and Eggermont, 2011), the eye-less endemic genus *Spinalona anophtalma* found in a temporary lagoon in Mexico (Ciros-Pérez and Elias-Gutiérrez, 1997), or *Alona boliviana* in temporary pools in the Bolivian Cordillera (Coronel et al., 2007; Sinev and Coronel, 2006). In addition, a surprising number of endemic species such as *Daphnia paggii* (Fig. 9.1) and even an endemic genus (*Geoffreya*), were found in temporary as well as permanent endorheic saline water bodies high in the Chilean Andes (Kotov et al., 2010). With some exceptions, lotic habitats are generally unfavored by cladocerans (Dumont and Negrea, 2002). In tropical floodplains, populations of riverine species may sporadically occur, such as *Nicsmirmovius* (hyporheic) and *Bosminopsis* (rheic), although these species are not typical for lentic environments.

#### 9.2.4 Ecology

Cladocerans in general perform a crucial role in wetland ecosystems by linking primary producers (algae, bacteria) to higher levels of the food web (fish, amphibians, aquatic insects). Functional trait analysis has furthermore revealed that (sub)tropical taxa display some traits that allow survival under conditions with variable food availability as well as predation pressure (Oriental region; Rizo et al., 2017). As one of the most abundant herbivorous zooplankton groups in tropical waters, small-bodied cladocerans may influence the lower trophic levels (microbial loop, phytoplankton), thereby affecting size structure (Pagano, 2008), biomass, and community composition of

phytoplankton, as also confirmed in mesocosm experiments (Silveira et al., 2010). Through their keystone role in tropical aquatic food webs, cladocerans directly or indirectly support ecosystem services such as provisioning (e.g., freshwater fish for human consumption), and regulating services (e.g., clearing water through top-down control of algae and bacteria).

In tropical temporary and therefore usually fishless systems, hydroperiod, macrophytes, and depth play important roles in structuring cladoceran communities (Eitam et al., 2004; Sousa et al., 2013; Eskinazi-Sant'Anna et al., 2020), while in permanent wetlands macrophytes, pH, conductivity, and depth were found to variably determine cladoceran communities (Rossa et al., 2001; Lima et al., 2003; Lansac-Tôha et al., 2009; Van Damme and Eggermont, 2011; Choedchim et al., 2017). In contrast to the biotic environment, the relative importance of abiotic variables to explain cladoceran community composition is poorly studied for tropical temporary shallow wetlands. Some of these variables govern cladoceran communities in a similar way in both temporary and permanent waters. The presence of macrophytes, for example, often results in temporary pond communities that are similar to littoral communities of nearby permanent lakes (e.g., Brazil; Sousa et al., 2013). The presence of macrophytes becomes especially important in shallow wetlands lacking top predators (Scheffer et al., 2006; Thomaz and Cunha, 2010). Overall, the presence of macrophytes and a well-developed detritus layer create ecological niches (van der Valk, 2006) and support typical deposit-feeding phytophagous cladoceran groups in both ephemeral and permanent tropical wetlands (mainly chydorids and macrothricids).

### 9.2.5 Life history

Cladocerans generally alternate asexual with sexual reproduction, producing predominantly populations of female clones, only forming males and sexual females under cues related to stress (Dumont and Negrea, 2002). All cladoceran taxa living in (sub)tropical wetlands (Anomopoda and Ctenopoda) have the ability to sexually produce dormant embryos. Anomopoda hereby generate a thick-walled chitinous envelope called the *ephippium*, which encloses and protects the dormant embryo(s) and which may act as a propagule for dispersal. Deposited in situ, ephippia may contribute to dormant drought-resistant cladoceran “egg banks” in temporary as well as in permanent waters (Brendonck and De Meester, 2003; Santangelo et al., 2015). The production of sexual stages in anomopods can be initiated by food limitation and crowding (Azuraidi et al., 2013). These cues also prevail during the drying phase of (sub)tropical temporary pools and therefore initiate sexual reproduction of propagules that provide a temporal escape from adverse conditions (Stenert et al., 2017). For permanent (sub)tropical wetland systems, the abiotic triggers initiating ephippium production and hatching from the egg bank are well understood and are thought to be initiated by similar cues in tropical as

well as in temperate regions (mainly photoperiod and temperature). Studies on hatching strategies in tropical populations are, however, inhibiting generalizations.

Some tropical daphniids that are very common in both temporary and permanent waters were shown to be highly productive at high temperatures and with abundant food. Tropical populations of *Scapholeberis* and *Simocephalus*, for example, produced no less than 240–250 parthenogenetic eggs during their lifetime (of 20–40 days, respectively) at 28°C–30°C (Murugan and Sivaramakrishnan, 1976). At such elevated temperatures and abundant food conditions, life history traits of tropical cladocerans differ from temperate taxa, with usually a longer and more productive lifespan (Sarma et al., 2005; Han et al., 2011).

### 9.2.6 Feeding biology

Feeding biology of cladocerans in the tropics has been insufficiently studied (Pagano, 2008). Cladocerans are primarily suspension or deposit feeders. A few taxa are specialized predators, but these are virtually absent from tropical wetlands. Suspension-feeding representatives of the Anomopoda and Ctenopoda feed primarily on algae, while members of the most speciose tropical family Chydoridae mainly process periphyton and detritus (Dumont and Negrea, 2002).

### 9.2.7 Threats and conservation

No studies related to cladoceran-specific conservation efforts in the tropics have been carried out, despite the vulnerability of tropical wetlands. In particular, land use change and pollution caused by development form direct pressures on the often peculiar cladoceran biodiversity in ephemeral as well as in permanent habitats. Cladoceran communities are sensitive to eutrophication, chemical pollution, and pH and may therefore have potential as bioindicators for assessing trophic state and human impact (e.g., Neotropical lowlands; Pérez et al., 2013). However, more ecological work is needed to confirm the bioindicator value of cladoceran species from tropical wetlands.

Many currently threatened but unstudied habitats potentially still house new and peculiar cladoceran taxa. This concern is especially illustrated by dystrophic habitats and temporary lagoons in SE Asia, where local sites with high cladoceran diversity have disappeared in recent years (Van Damme et al., 2013b; Van Damme and Maiphae, 2013). Habitat-specific taxa in the Oriental region, such as the endemic genus *Salinalona*, only known from temporary brackish lagoons, or the rare paludal endemics such as *L. pulchra*, are therefore under direct threat. Several rare species in the tropics occur nearly exclusively in protected areas, such as the peculiar chydorids *Ephemeroporus quasimodo* and *Celsinotum candango* inhabiting pristine

shallow waters in the Brazilian Cerrado (Elmoor-Loureiro, 2014). Among the few cladocerans on the IUCN Red List, the West Australian endemic *D. jollyi* has been assessed as vulnerable (Benzie, 1996), herewith emphasizing the conservation value of ephemeral rock pool environments where this species occurs.

Limited experimental studies on some widespread thermophilous species complexes revealed that some may be tropical alternatives to *Daphnia* for applications in aquaculture and/or ecotoxicology, such as *Diaphanosoma* sp., *Moina micrura*, and the *Ceriodaphnia cornuta*-complex (Pagano, 2008; Martinez-Jeronimo and Ventura-Lopez, 2011; Sipaúba-Tavares et al., 2014).

Although cladocerans are not usually considered as a charismatic group for conservation, they do serve as a primary food item for invertebrate and vertebrate predators that are generally more appealing for conservation efforts such as dragonflies, amphibians, and fish (Eitam et al., 2004). Conservation measures for cladocerans in (sub)tropical wetland types should therefore be integrated with the conservation of other groups of concern (Eitam et al., 2004; Jocqué et al., 2007).

## 9.3 Ostracods

### 9.3.1 Introduction

Ostracods, also known as mussel (Martens et al., 2008) or seed shrimp (Brendonck et al., 2016), are a class of microscopic bivalved crustaceans part of the subphylum Crustacea (Smith and Delorme, 2010). Ostracods are found mostly in aquatic (marine and nonmarine) environments although some (semi) terrestrial representatives also exist (Martens et al., 2008; Smith and Delorme, 2010). This section will focus on free-living ostracods present in nonmarine inland tropical and subtropical (both permanent and temporary) wetland ecosystems.

### 9.3.2 Systematics and general species richness

Class Ostracoda is subdivided into the two subclasses Myodocopa and Podocopa (Martens and Horne, 2009). Myodocopa consists of exclusively marine representatives (Martens and Horne, 2009) and will not be dealt with further here. Podocopa originated between 450 and 360 million years ago and consists of three superfamilies (Cytheroidea, Darwinuloidea, and Cypridoidea) (Martens et al., 2008) with both marine and nonmarine representatives. Of these, only Darwinuloidea are fully nonmarine and consist of 1 extant family (Darwinulidae) and 35 extant species. Cypridoidea and Cytheroidea include both marine and nonmarine representatives with the former being the most species rich (4 families and 1760 species) while the latter has the highest family diversity (11 families and 531 species) (Martens et al.,

2008; Meisch et al., 2019). Cyprididae and Candonidae are the two largest known families of Ostracoda with a total of 1681 described species of which Candonidae represent 40.2% (Martens et al., 2008; Meisch et al., 2019).

The first nonmarine ostracods were named and described in 1776 (Müller, 1776) and since then approximately 2330 subjective species of extant nonmarine Ostracoda have been described worldwide (Meisch et al., 2019). The most recent checklist by Meisch et al. (2019) reported that of the eight biogeographical regions (Antarctic, Afrotropical, Australasian, Nearctic, Neotropical, Oriental, Palearctic, and Pacific Oceanic Island), the highest species richness is in the Palearctic region (799 species) and the lowest in the Antarctic (3 species). With the exception of Notodromadidae, most ostracod families are found in all biogeographical regions and are thus considered cosmopolitan. In contrast, at species level approximately 90% of all known nonmarine Ostracoda are endemic, with only 10% having intercontinental distributions (Martens et al., 2008). Approximately 20%–25% of the world's nonmarine ostracods are found in the ancient lakes of which Lake Baikal (Russia) and Tanganyika (East Africa) have the richest diversity and highest endemism of species (Martens, 1994; Martens et al., 2008).

### 9.3.3 Distribution in tropical biogeographical regions

If the 17 extant families of nonmarine ostracods, Cyprididae is by far the most common family found in the tropical regions (i.e., Afrotropical, Australasia, Neotropic, and Oriental) (Meisch et al., 2019). Entocytheridae consists solely of parasitic and commensal species (Martens and Savatnalinton, 2011) and will not be dealt with further here. The number of known species in the tropics is considered grossly underestimated as far less research has been published in these regions compared to areas such as the Palearctic (Cohuo et al., 2017; Martens et al., 2008). While endemism is high at species level, the Neotropic and Oriental regions have the lowest number of endemic genera (Martens et al., 2008). Seasonal and intermittent wetlands or pools that are abundant habitats in many of the tropical regions, often have a rich biodiversity of aquatic biota but remain neglected in research and are thus potential hotspots for ostracod diversity (see Halse and McRae, 2004; Martens et al., 2012; Halse and Martens, 2019) (Table 9.3).

The Afrotropics have the greatest species diversity of nonmarine tropical ostracods with approximately 450 described species of which 382 are endemic to the continent (Martens et al., 2008; Meisch et al., 2019). This may, however, be an underestimation as approximately 50% of the species known to occur in the Afrotropical region were described before 1940, and the taxonomic status has not truly been reviewed since (Martens 1984; Baltanás and Danielopol, 2013). Genetic endemism of ostracods is particularly high in East African ancient lakes with Southwest African temporary pools following close behind (Martens, 1998). The best known ostracod







fauna from wetlands in the African region are from the Western Cape province in South Africa. This is largely due to the work by Sars (1924) who described 40 new species and 10 new genera along with the redescription of 30 species (Martens 2001). In southern Africa, the highest level of endemism is found in temporary wetland habitats, most likely due to the lack of many cosmopolitan species and large predators (Bird et al., 2019; Martens, 1994; Martens et al., 2008).

At present, 328 nonmarine ostracod species have been recorded in Australasia (encompassing Australia, New Zealand, New Guinea, and Melanesian islands) of which 293 are endemic (Meisch et al., 2019). The number of described species for this region has increased significantly with the addition of 180 species in the last half-century. This may still be an underestimation as most of these species were found in the Pilbara region, representing 6.5% of Australia (Karanovic, 2007; Martens and Savatnalinton, 2011; Baltanás and Danielopol, 2013), while much less research has occurred in the rest of Australasia. The athalassic saline aquatic habitats of Australia, including many lakes and wetlands, possess a remarkably high diversity of nonmarine Ostracoda as approximately 37 species have been described in these ecosystems (De Deckker, 1983), several of which are able to tolerate constantly changing salinity and thus well adapted to life in both fresh and saline ecosystems (Campbell, 1995; Martens et al., 2008). Australia is also one of the few locations outside of Africa where “giant” ostracods (>3 mm) occur, with two of the four genera (*Australocypris* sp. and *Mytilocypris* sp.) represented exclusively in wetlands with increased salt concentrations (De Deckker, 1983; Halse and McRae, 2004).

The Neotropics (including the Caribbean, Central, and South America) have approximately 333 recorded species of nonmarine Ostracoda of which 250 are considered endemic (Meisch et al., 2019). The lower species diversity in the Neotropics is primarily a result of fewer speciation-prone ecosystems such as the ancient lakes in Africa (Martens and Behen, 1994). Martens and Behen (1994) reported 260 ostracod species in South America alone of which 96 were from Brazil (Martens, 1998; Higuti et al., 2010) although this has increased to 108 species in recent years (Higuti et al., 2009; Higuti et al., 2010). Approximately 42% of the described species in this region are found in the Neotropic-Caribbean, a geographic region with high habitat heterogeneity including lakes, lagoons, sinkholes, temporary ponds, and wetlands (Cohuo et al., 2017). Further investigation in the region may yield an even greater diversity of ostracods as research is still fairly limited (Karanovic and Datry, 2009).

With approximately 271 species, the Oriental region (including India, Southeast Asia, and southern China) has the lowest number of described nonmarine Ostracoda species of the tropics (Meisch et al., 2019). Of these, 175 species are endemic, with Notodromadidae as the most diverse (nonmarine)

family in this region (Martens et al., 2008). The majority of species described for this region arises from research in the 1960s to 1980s, predominantly from India and Southeast Asia. Hence most areas are still severely underrepresented (Karuthapandi et al., 2014; Savatnalinton and Suttajit, 2016). In the past decade, intensive sampling of various ecosystems in Thailand (including pools, lakes, swamps, reservoirs, springs, canals, rivers, rice-fields, and waterfalls) added a number of new species and genera to the list of nonmarine Ostracoda from the Oriental region (see Savatnalinton et al., 2008; Savatnalinton et al., 2008, 2009a, 2009b, 2010, 2013; Savatnalinton, 2014, 2015). Of the five genera considered endemic to the Orient, namely *Batucyprretta*, *Indiacypris*, *Indocandona*, *Astenocypris*, and *Pseudocyprretta*, the latter two were part of the abovementioned research effort. This is indicative of the need of comprehensive research in this understudied region as many species may still be undiscovered (Savatnalinton and Suttajit, 2016).

#### 9.3.4 Ecology

Whether saline or fresh, ostracods are found in most aquatic habitats ranging from small temporary or permanent pools to larger lakes, streams, and oceans as some species are able to tolerate salinities of up to three times that of seawater (Martens et al., 2008; Smith and Delorme, 2010; Martens, 2001). The ecology of ostracods is affected by a complex interaction of many environmental variables including but not limited to water chemistry, thermal regime, hydrogeology, soil structure, and food availability (Forester, 1991; Smith and Delorme, 2010; Mesquita-Joanes et al., 2012; Williams, 2016).

Most ostracods are free-living, benthic organisms and can be divided into swimming and nonswimming (or true benthic) forms. Swimming capacity is mainly determined by the presence of long, often plumose, setae on the antennulae and antennae (Martens and Horne, 2009; Smith and Delorme, 2010). Swimming forms occur most often between aquatic plants, using the macrophytes as shelter from predators, although some species will swim into the pelagic as well. In contrast, nonswimmers have strong, stout appendages and a more strongly developed carapace for protection from predation, and will crawl and/or burrow into the upper 2 cm of sediments (Martens and Horne, 2009; Smith and Delorme, 2010; Mesquita-Joanes et al., 2012; Li et al., 2010).

Although not considered a “keystone” group, ostracods nonetheless comprise an essential part of the animal biomass and productivity in most freshwater ecosystems (both permanent and temporary) (Mesquita-Joanes et al., 2012). Ostracods are preyed upon by numerous aquatic insects and invertebrates including larvae of Chironomidae, Tanypodinae, and Odonata as well as snails, water mites, other microcrustaceans such as copepods (Smith and Delorme, 2010; Vandekerkhove et al., 2012; Mesquita-Joanes et al., 2012)

and vertebrates including amphibians, waterfowl, and fish (Lopez et al., 2002; Blanco et al., 2004; Smith and Delorme, 2010).

In most aquatic habitats, adult ostracods have a body size typically ranging from 0.3 to 2.0 mm. However, most will not grow larger than 1 mm in the presence of visual predators such as fish, dragonfly larvae, and predatory diving beetles (Martens and Horne, 2009). This relatively small size is an adaptation to avoid predation in larger, permanent habitats while also reducing resource demands and the probability of extinction in smaller, temporary systems (Valentine, 2009; Mesquita-Joanes et al., 2012). In “predator-free” (fishless) habitats, for example temporary ecosystems, gigantism has been recorded in Cyprididae in Australian lakes (Halse and McRae, 2004) and Indian and African temporary pools. Indeed, species as large as 8 mm have been recorded in temporary pools of South Africa (Martens, 2003; Martens and Horne, 2009).

Variations also exist in ostracod shape, color, and valve surface (Martens and Horne, 2009; Smith and Delorme, 2010; Ramos et al., 2017). Shapes may range from spherical, elongated, or compressed while epidermal pigmentation results in numerous color variations (Martens and Horne, 2009; Mesquita-Joanes et al., 2012). Little is known about the function of color variation although it has been suggested that it may offer some form of protection against visual predators and UV radiation (Mesquita-Joanes et al., 2012). On the surface, valves may be smooth or have various muscle scars and ornamentations (Martens and Horne, 2009; Smith and Delorme, 2010; Ramos et al., 2017). Variations occur as a result of differences in growth, environment, genetics, and sexual dimorphism (Van Harten, 1975; Yin et al., 1999; Danielopol et al., 2008; De Deckker and Martens, 2013; Ruiz et al., 2013) and are useful tools that aid in identification of species, but may also serve specific functions (Martens and Horne, 2009; Smith and Delorme, 2010; Karanovic, 2012; Halse and Martens, 2019). In some juvenile stages, ornamentation may be more pronounced than in the adult stage and act as potential deterrents toward (micro-) predators (De Deckker and Martens, 2013) while some adult stages, such as in *Sclerocypris jenkinsae*, have large lateral spines that act as antipredator defences against fish (Van der Meeren et al., 2019). The composition of water may also affect ornamentation as nonmarine ostracods found in humic acid-rich water often have much more delicate ornamentation than their marine counterparts (Carbonel, 1988; Holmes, 2001; De Deckker and Martens, 2013). Stronger calcification and ornament reticulation are also evident in ostracods from slightly saline water (Ramos et al., 2017) or water with higher carbonate ion concentrations (Carbonel and Hoibian, 1988; Carbonel et al., 1990).

### 9.3.5 Life history

Nonmarine ostracods predominantly utilize asexual reproduction (parthenogenesis) such as in Darwinulidae considered an ancient asexual group as

only females have been found for approximately 200 million years (Martens and Horne, 2009). However, some genera may reproduce sexually or use a mixed strategy depending on the habitat and/or geographic location (Martens et al., 2008; Martens and Horne, 2009; Mesquita-Joanes et al., 2012). In a phenomenon known as geographic parthenogenesis, individuals of *Eucypris virens* (Cypridoidea) reproduce asexually in temporary pools in Europe and sexually in circum-Mediterranean populations (Martens and Horne, 2009). Reproduction may also be affected by habitat type as parthenogenesis is more common in unstable habitats, for example temporary ecosystems, while sexual reproduction prevails in established or stable environments such as permanent and ancient lakes (Bell, 1982; Smith and Delorme, 2010; Mesquita-Joanes et al., 2012).

The life cycle of nonmarine ostracods generally consists of nine instars of which eight are juvenile and one adult (Benson, 1981, p 63; Martens and Horne, 2009; Mesquita-Joanes et al., 2012). Lifespan and number of generations vary greatly and depend on species as well as environmental factors and ecosystem type (i.e., permanent or temporary). Genera living in the variable environment of temporary ecosystems live between one to five months and produce only one or two generations before the pond dries. In contrast, genera from more stable permanent habitats, may live as long as four years and produce several generations (Martens and Horne, 2009; Smith and Delorme, 2010; Mesquita-Joanes et al., 2012). In both temporary and permanent habitats, egg hatching and juvenile development occur predominantly in spring and summer with little to no development in autumn and winter, while adults may be present until early winter (Martens and Horne, 2009; Smith and Delorme, 2010). Abiotic variables also affect the lifespan of ostracods. Whereas warm temperatures cause accelerated growth and development, and thus decreased lifespan, low pH, Ca, and bicarbonate ( $\text{HCO}_3$ ) can slow growth and development by reducing shell calcification and molting capabilities (Higuti et al., 2010; De Deckker and Martens, 2013).

Most nonmarine ostracods in both permanent and temporary ecosystems are able to produce dormant propagules or enter a stage of dormancy (Horne and Martens, 1998; Brendonck et al., 2017). Adults and juveniles may enter a state of torpidity (Darwinulidae and some Cytheroidea) or produce desiccation-resistant resting stages, predominantly in the form of eggs (most Cytheroidea and all Cypridoidea), to avoid or tolerate adverse environmental conditions including drought or hypersalinity (Horne and Martens, 1998; Smith and Delorme, 2010; Mesquita-Joanes et al., 2012). These “resting stages” are able to persist for several months to years depending on surrounding conditions and the species involved (Hairston et al., 1995; Horne et al., 2004; Bird et al., 2019). *Cyprideis torosa* is able to survive for at least 30 days in a state of torpor under hypersaline conditions while desiccation-resistant eggs of Cypridoidea remain viable for up to 100 years (Martens, 1994). These resting stages also facilitate passive dispersal between habitats

(Meisch, 2000; Martens, 1994; Mesquita-Joanes et al., 2012) which may occur through wind, or by hitchhiking with mobile animals such as several invertebrates, amphibians, reptiles, and birds, or in mud carried by mammals and even humans (Vanschoenwinkel et al., 2008a,b, 2011; Mesquita-Joanes et al., 2012; Bird et al., 2019).

### 9.3.6 Feeding biology

In nonmarine environments, ostracods are most often considered as generalist deposit feeders, scavengers, or omnivores with a diet consisting largely of algae, detritus, and dead or living plant material (Martens and Horne, 2009; Smith and Delorme, 2010; Karanovic, 2012). As ethological studies on aspects of ostracod feeding activity are scarce (Mesquita-Joanes et al., 2012), this conclusion on feeding mode is based predominantly on the analysis of stomach contents and functional morphology (Cannon, 1933; Vannier et al., 1998; Lawrence et al., 2002). Several studies have, however, revealed that some ostracods may be active predators on not only plant material but animals as well (Mesquita-Joanes et al., 2012). Ostracods have been observed attacking and eating smaller ostracods as well as other zooplankton, insects, and snails (Sohn and Kornicker, 1972; De Deckker, 1983; Campbell, 1995; Meisch, 2000) and vertebrates such as fish (Stepien and Brusca, 1985). Ostracods appear to make use of chemoreception to detect both prey and predators and either move toward or away from them accordingly (Vannier et al., 1998; Mesquita-Joanes et al., 2012).

### 9.3.7 Threats and conservation

Although some ostracods are cosmopolitan in their distribution and/or tolerant to a wide range of environmental variables (Pieri et al., 2009; Meisch et al., 2019), others are highly endemic and sensitive to changes in water quality and anthropogenic inputs (Chial et al., 2003; Klkyliođlu, 2004; Shuhaimi-Othman et al., 2011; Ruiz et al., 2013). Research has illustrated that the diversity and abundance of ostracods is far greater in ecosystems unaffected by human activities (Kiss, 2007; Stark et al., 2003; Klkyliođlu, 2004). The persistence of ostracod populations is threatened by anthropogenic influences, environmental disturbance, habitat destruction, and changes in both water quality and quantity (Reeves et al., 2007; Ruiz et al., 2013).

Ostracods are unable to actively migrate to a new habitat if it becomes unsuitable as they rely on passive modes of dispersal to colonize new ecosystems (Vanschoenwinkel et al., 2008a,b; Brochet et al., 2010; Waterkeyn et al., 2010; Higuti et al., 2017). Alterations to their environment could, therefore, lead to premature death and other long-term effects and eventually even extinction, either locally or globally. One such example is the

introduction of fish into Lake Naivasha, Kenya, which led to the complete disappearance of large ostracod species (Van der Meeren et al., 2019).

Ostracods also have an extensive fossil record as their valves readily fossilize (Park and Martens, 2001; Poquet et al., 2008) making them useful short and long-term bioindicators of, among other things, climate change, habitat loss, and water degradation.

The use of pesticides (e.g., DDT) and herbicides (e.g., dioxin) threatens ostracod populations as these pollutants accumulate in soft tissue and lead to intoxication, immobilization, or even mortality (Matsumura, 1977; Ruiz et al., 2013). Industrial pollution such as by various heavy metals has been found to be even more harmful to ostracod populations than pesticides (Samir, 2000). These harmful effects may have bottom-up cascading effects in the food web through bioaccumulation and biomagnification of these pollutants in biota that feed on ostracods. Climate change and its associated predicted effects on water quality, including increasing temperatures and changes in severe weather conditions such as drought (Woodward et al., 2012), may also affect performance and even persistence of ostracod populations since water temperature and salinity play a significant role in their survival, growth, and reproduction (Mesquita-Joanes et al., 2012; Ruiz et al., 2013). Habitat destruction, often destroying the macrophyte stands, also affects the survival of various biota (Malmqvist et al., 1997), including ostracods, since aquatic macrophytes are important substrates utilized by ostracods for egg deposition and shelter from visual predators (Martens and Horne, 2009; Mormul et al., 2010). Floating vegetation also acts as a source of passive dispersal (Higuti et al., 2017) and the loss of habitat complexity or total habitat destruction could therefore lead to local extinction of ostracod populations.

## 9.4 Copepods

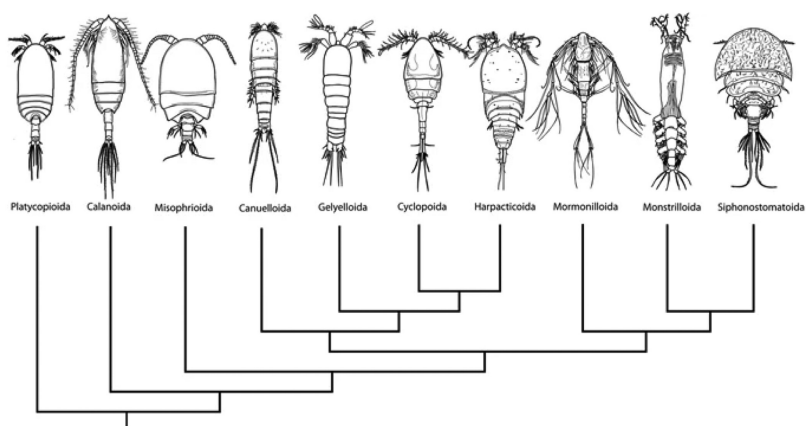
### 9.4.1 Introduction

The Copepoda is one of the most species rich groups of metazoans on Earth (Humes, 1994; Brotskaya, 1963; Kikuchi, 1994). Copepods are capable of invading and surviving successfully in nearly every continental habitat and situation where sufficient moisture and organic matter are present (Reid, 2001). Although both parasitic and free-living copepods exist, this section only deals with the planktonic hence free-living component of the group. Free-living copepods typically range from 0.2 to 5.0 mm.

### 9.4.2 Systematics and general species richness

The phylogenetic position within Arthropoda and the relationships of the major evolutionary lineages within Copepoda is debatable (Khodami et al.,

2017). Huys and Boxshall (1991) listed 10 orders of Copepoda based on homologies in the body plan, segmentation, and setation of copepod appendages. The resulting phylogeny divides Copepoda into three infraclasses: Progymnoplea Lang, 1948 (=Platycopioidea Fosshagen, 1985); Gymnoplea Giesbrecht, 1892 (=Calanoida Sars, 1903); and Podoplea Giesbrecht, 1892. The Podoplea was divided into two main clades, the so-called “MHPSM-clade” containing Mormonilloidea Boxshall, 1979; Harpacticoida Sars, 1903; Poecilostomatoida Thorell, 1859; Siphonostomatoida Burmeister, 1834; Monstrilloidea Sars, 1901; and the “MCG-clade” including the Misophrioida Gurney, 1933; Cyclopoida Burmeister, 1835; and Gelyelloidea Huys, 1988. Recent work based on morphological characteristics has revised the Huys and Boxshall (1991) phylogenetic concept. Martinez (2000) first revealed the paraphyletic status of Cyclopoida and Cyclopinidae Sars, 1913. He rejected the ordinal status of Poecilostomatoida and included all of its families in Cyclopoida. The Polyarthra Lang, 1948, order was considered a separate order with an uncertain phylogenetic position (Dahms, 2004) while Ho et al. (2003) proposed an ordinal level for the family Thaumatopsyllidae Sars, 1913. A molecular phylogenetic relationship among representatives of 10 copepod orders revised their taxonomy (Khodami et al., 2017). It demonstrated for the first time the monophyly of Copepoda (including Platycopioidea Fosshagen, 1985) and rejected the polyphyletic Maxillopoda as a taxonomic unit. The molecular phylogenetic study supported the monophyly of the major subgroups of Copepoda (Fig. 9.2).



**FIGURE 9.2** Most recent phylogram of copepod orders. Adapted from Khodami, S., McArthur, J.V., Blanco-Bercial, L., Martinez Arbizu, P., 2017. Molecular phylogeny and revision of copepod orders (Crustacea: Copepoda). *Scientific Reports* 7, 9164.



### 9.4.3 Comparison between tropical biogeographical regions

In Table 9.4, numbers of copepod genera and species for the considered biogeographical regions are presented. The Neotropical region has the highest copepod richness, with 561 recorded species. The major contributors are the Cyclopidae (31%), especially *Eucyclops*, *Metacyclops*, and *Mesocyclops*, the Canthocamptidae (19%), especially *Elaphoidella*, *Attheyella* (*Chappuisiella*), and *A. (Delachauxiella)*, the Diaptomidae (15%), and Parastenocarididae (12%) (Boxshall and Defaye, 2008). The most speciose genera within the Diaptomidae are *Notodiaptomus* and *Argyrodiaptomus* which are both endemic to the region. The Afrotropical region has the second highest richness with 405 species. The major contributors are the Cyclopidae (41%), especially *Eucyclops* and *Thermocyclops*, and the Diaptomidae (18%), especially *Tropodiaptomus*, followed by the Lernaeidae (10%) (Boxshall and Defaye, 2008). The benthic families Canthocamptidae, particularly *Elaphoidella* and *Echinocamptus*, and Parastenocarididae contribute only 11% and 8% to the total, respectively. The diversity of the Oriental region is relatively low, with only 16 families represented by 381 species. The major contributors are the Cyclopidae (30%), especially *Mesocyclops* and *Thermocyclops*, the Diaptomidae (24%), especially *Tropodiaptomus* and *Heliodiaptomus*, the Canthocamptidae (15%), especially *Elaphoidella*, and the Lernaeidae (12%). The Oriental region is home to seven genera of Lernaeidae, three of which (*Indopeniculus*, *Pillainus*, and *Indolernaea*) are endemic (Boxshall and Defaye, 2008). The Australasian region has the lowest richness with 205 species. The major contributors to the overall species richness are the Cyclopidae (31%), especially *Mesocyclops* and *Eucyclops*, the Canthocamptidae (25%) especially *Canthocamptus*, and the Centropagidae (23%). The paucity of copepod species in the Australasian region is largely due to the aridity of large areas of the Australian continent. However, recent research into the subterranean fauna of arid Western Australia has revealed an unexpectedly high diversity and degree of endemism (Karanovic, 2004). The level of endemism in freshwater copepods is very high in the tropical region: Neotropical (89%), Afrotropical (85%), Australasian (82%), and Oriental (73%). Ancient lakes constitute prime hotspots for freshwater biodiversity. For copepods, Lake Baikal has over 120 species, the majority of which are endemic (Boxshall and Evstigneeva, 1994), and Lake Tanganyika with 69 species, of which 34 (49%) are endemic (Boxshall and Strong, 2006) (Table 9.4).

### 9.4.4 Ecology

Copepods are extremely abundant in freshwaters and comprise a major component of most planktonic, benthic, and groundwater communities. They occupy a variety of habitats including open water impoundments, a wide



Cyclopidae	30	174	25	167	19	115	19	64	364	800
Oithonidae	2	6			1	2			5	7
Ozmanidae	1	2							2	2
Lernaeidae	6	10	7	39	7	47	1	2	90	114
Ergasilidae	16	63	6	19	5	23	3	8	107	173
<b>Total</b>	<b>104</b>	<b>561</b>	<b>60</b>	<b>405</b>	<b>79</b>	<b>380</b>	<b>52</b>	<b>205</b>	<b>1291</b>	<b>2737</b>

range of temporary water bodies, vleis, and floodplain wetlands (Silva, 2008; Waterkeyn et al., 2008; Dube et al., 2017; Nhiwatiwa et al., 2017). Physical habitat factors (e.g., surface area) and water quality (e.g., conductivity and vegetation cover) have been demonstrated as the main factors structuring copepod species composition (Frisch et al., 2006). Ecologically, copepods play a role as a direct and efficient path for the transfer of energy to higher level consumers, which is pivotal to the functioning of tropical wetlands (Park and Marshall, 2000). Furthermore, accurate estimates of copepod abundance are fundamental for proper determination of biomass and productivity, which are crucial for the understanding of energy flow and the trophodynamics of tropical wetlands (Magalhães et al., 2015). Some copepods are predatory and have even been identified as key predators of mosquito larvae (Marten and Reid, 2007) and therefore have potential for natural biocontrol of disease vector mosquitoes (Cuthbert et al., 2018; Buxton et al., 2020).

#### 9.4.5 Life history

Copepods are sexually dimorphic in size, with typically larger females than males. Parthenogenesis occurs when males are rare and has been demonstrated in some harpacticoid species such as *Elaphoidela bidens*, *Epectophanes richardi*, and *Canthocamptus staphylinus* (Dole-Olivier et al., 2000). Dormancy is known exclusively from free-living taxa of the Harpacticoida, Cyclopoida, and Calanoida. Dormant instars may comprise resting eggs, naupliar stages arrested in their development, and free swimming or encysted copepodids and adults (Dahms, 1995). All cyclopoid taxa with a dormancy strategy belong to the Eucyclopinæ (Cyclopidae). The three cyclopoid genera with encysting copepodids are *Cyclops*, *Microcyclops*, and *Metacyclops*. There are 16 species of freshwater Calanoida where there is proof for resting eggs (Dahms, 1995). They belong to the genera *Diaptomus*, *Onychodiptomus*, *Leptodiptomus*, *Aglaodiptomus*, *Acanthodiptomus*, *Scotodiptomus*, *Eurytemora*, *Epischura*, and *Limnocalanus*. Both abiotic (e.g., desiccation, temperature, oxygen availability) and biotic (e.g., food availability, predation) environmental factors can trigger the onset of diapause (Spindler, 1971; Hairston, 1987; Hairston and Brunt, 1994; Johnson, 1979). Copepods inhabiting temporary water bodies produce resting eggs or dormant copepodid stages which allow survival of adverse conditions (Hairston and Brunt, 1994). Juvenile stages of copepods are the earliest zooplankters recolonizing temporary waters after the dry phase (Frisch et al., 2005; Badosa et al., 2010). They furthermore have short developmental times and a quick hatching response after dormancy (Brendonck and De Meester, 2003).

#### 9.4.6 Feeding biology

Freshwater copepods occupy different trophic levels in the food web. Most freshwater copepods are free-living, but they have adopted parasitism in

numerous independent lineages. About 330 species of freshwater copepods are parasitic, most commonly on fish hosts (e.g., *Lernaea cyprinacea*) (Barson et al., 2008; Fryer, 1968), but also on molluscs (Boxshall and Jaume, 2000; Boxshall and Strong, 2006). Copepods also live as commensal epibionts on freshwater invertebrates including crayfish, medusae, and sponges (Boxshall and Strong, 2006). Some calanoids are herbivores feeding on phytoplankton. Several large copepods are predatory eating rotifers, oligochaetes, dipteran larvae, and small crustaceans such as cladocerans (Fryer, 1993; Wasserman et al., 2015). The main food source for harpacticoids consists of particulate organic matter. Predatory behavior has been observed in some species such as *Heterocypros incongruens* (Otonello and Romano, 2011).

#### 9.4.7 Threats and conservation

Freshwater copepods have not attracted much concern from the general conservationist community. The factors threatening copepods are common in tropical regions and include: salinization, draining of wetlands or conversion of temporary to permanent water bodies, mining, pollution, and damming of rivers (Reid et al., 2002; Dalu et al., 2017). For example, salinization of inland waters is a major factor in the disappearance of habitat for Australian freshwater crustaceans, especially in Western Australia (Yencken and Wilkinson, 2000). Draining of swamps may threaten certain species such as the vulnerable calanoids *Boeckella nyoraensis* and *Boeckella propinqua*, for which this type of habitat is important. Many of the wetlands in the Afrotropical region have been drained for agriculture and polluted by mining, industry, and informal settlements (Rayner and Heeg, 1994). Another major threat is the conversion of temporary into permanent wetlands, which is often even aggravated by the introduction of fish. Such drastic hydrological change does not only have a dramatic impact on specialist groups of temporary wetlands such as large branchiopods (Brendonck et al., 2022a,b), but also on specialized zooplankton, including some copepods (Dalu et al., 2017).

### 9.5 Rotifers

#### 9.5.1 Introduction

Rotifers are acoelomate metazoan animals that are microscopic, ranging between 50 and 2000  $\mu\text{m}$  in size, and are widely distributed in freshwater ecosystems (Fernando, 2002; Segers, 2008). Many rotifers have a transparent body, consisting of two specific organs: the rotatory organ (i.e., corona) and a mastax, which is the pharynx (Brain, 2002; Fernando, 2002). The two main freshwater Rotifera classes are Bdelloidea and Monogononta, with the

latter being widely distributed in tropical ecosystems. In general, many rotifer species are benthic, living on the substratum and among submerged vegetation. Wetland habitats are favored by many of the Bdelloidea, as there they can shift from the active to the anhydrobiotic stage (i.e., cryptobiosis), enabling them to live in temporary wetland environments (Brain, 2002).

### 9.5.2 Systematics and general species richness

Reliable information on rotifer species numbers is sparse, but Segers (2008) estimates that there are about 2031 taxa, with many unidentified species. In turn, known distributions reflect more the biased prevalence of rotiferologists in Western Europe where most studies have been conducted rather than the real distribution of rotifers. Little is known about rotifer phylogeny, due to a lack of modern comprehensive studies (Mills et al., 2017), coupled with the lack of a robust fossil record. Recent decades of research have led to the hypothesis that subtropical floodplains are among the world's richest habitats for rotifers (Segers et al., 1993; Segers, 2008). There are several relatively complete surveys of rotifer taxa from different regions of the tropics (e.g., Africa, Amazonia, Australia, Central America and the Caribbean, Neotropics, and the Oriental regions) which are provided in detail by Segers (1996, 2001, 2003, 2007, 2008) and Fernando (2002).

Analysis of planktonic and littoral rotifer fauna from different tropical regions has shown endemism at the species level, however, with most being cosmopolitan. The most diverse rotifer group are the Notommatidae, with *Cephalodella*, monogeneric Lecanidae, and Dicranophoridae being the most speciose. All of these groups contain almost exclusively benthic-littoral or psammon-inhabiting species, with a majority inhabiting oligotrophic to mesotrophic, slightly acidic and soft waters (Segers, 1993; Kutikova and Fernando, 1995). Dumont and Segers (1996) calculated that a nonpolluted lake with developed, weedy littoral would harbor approximately 150 species in temperate, and up to 250 species in tropical regions.

Littoral-periphytic taxon richness of Lecanidae, Lepadellidae, Testudinellidae, and Trichocercidae reflect more the littoral-periphytic assemblages, while Brachionidae and especially *Brachionus* spp. and *Keratella* spp. usually attain a higher abundance and richness in limnetic fish pond environments. Recently, Luo and Segers (2020) reported that the Lepadellidae rotifers collected in the Congo Basin contained eight hitherto unknown species (i.e., *Colurella asymmetrica*, *Lepadella hanneloreae*, *L. jingruae*, *L. weijiai*, *L. wilungulai*, *L. yangambi*, *Squatinella curviseta*, *S. longipila*) among the 33 Lepadellidae taxa. This remarkable result illustrates previously unknown and largely endemic Congo Basin microfauna and refutes the “African anomaly” hypothesis on the purported African rotifer fauna poverty. In another study by Serafim et al. (2003) in the Pantanal Upper Paraná River Floodplain Wetland, 11 genera and 42 species including

new rotifer records were observed. The study showed an increase in rotifer diversity in this particular ecosystem from 184 to 230 species. Thus, 37 species occurred in the littoral floodplain zones and 34 species in the pelagic floodplain zones. The lagoons had the highest richness due to greater stability, low current velocity, and extensive aquatic macrophyte cover in the littoral zones (Serafim et al., 2003).

Green (2003) showed that euplankters dominated in static waters, and also when the flow was very slow in the Okavango Delta. Where water flow was visibly stronger, euplankters were very sparse, and periphytic species dominated such as *Lecane bulla*. A study by Koste and Robertson (1983) in Brazil during the dry season, recorded 33 species and the number of species increased to 138 during the wet season. The sparse, diverse, wet season community may merely reflect rotifer species most easily dislodged during sampling. Thus in stagnant waters, periphytic species may remain among the macrophytes due to their inability to compete with euplankters in open water, or they may be vulnerable to predation by large euplankters such as *Asplanchna* spp. and copepods. Furthermore, the macrophyte diversity and varied architecture of wetlands provide a large number of physical niches, which are preferred by certain rotifers. For example, *Euchlanis dilatata* survives better on *Myriophyllum* spp. than on *Elodea* spp. and/or *Ceratophyllum* spp. when exposed to predation (Green, 2003). Serafim et al. (2003) observed that there were no great differences in rotifer species richness between habitats of the Paraná River Floodplain Wetland environments, with high species richness being observed in the littoral habitats due to the greater influence of shoreline vegetation, which allows for greater habitat diversification. The high rotifer diversity observed in the lagoons compared to river sites was related to some characteristics of these environments such as low stream velocity (Serafim et al., 2003). The Okavango Delta moving waters contained low abundances, but high species diversities of euplankters as compared to samples from stagnant waters (Green, 2003). When euplankters are washed away by water movement, some of the periphytic species are free to leave the macrophytes and free-floating algae and bacteria. Another key factor influencing species richness is the food variety and availability. For example, the complexity of epiphytic algae results in herbivorous rotifers developing foraging patterns which parallel their food distributions.

### 9.5.3 Comparison between tropical biogeographical regions

In Table 9.5, numbers of rotifer genera and species for the considered biogeographical regions are presented. Despite some increasing knowledge on diversity in the last few years, the fauna of tropical Asia, especially the Indian subcontinent, and Afrotropical regions warrant further study as there has been sampling bias. Studies in south-eastern Asia by Segers (2001), Athibai et al. (2013), and Sa-artrit et al. (2017) have shed light on

**TABLE 9.5** The number of genera and species level per rotifer family, per region based on Segers (2008).

	Afrrotropical		Australasian		Oriental		Neotropical		Endemics		Cosmopolitan		Global	
	Genera	Species	Genera	Species	Genera	Species	Genera	Species	Species	Species	Species	Species	Species	Species
<b>Monogononta</b>														<b>1496</b>
Asplanchnidae	2	9	2	9	3	12	3	10	2	2	8	15		
Atrochidae	1	1	2	2	3	3	1	1	0	0	1	4		
Brachionidae	7	51	6	58	7	57	7	71	94	94	36	169		
Collotheidae	1	14	2	12	2	8	2	15	24	24	10	47		
Conochilidae	1	5	2	6	1	5	1	5	1	1	5	7		
Dicranophoridae	5	19	8	24	5	15	6	21	98	98	9	181		
Epiphanidae	4	9	5	8	5	9	3	10	4	4	9	16		
Euchlanidae	4	15	4	18	5	15	4	14	8	8	11	27		
Flosculariidae	6	22	7	30	6	23	7	37	7	7	19	50		
Gastropodiidae	2	8	2	7	2	6	2	8	2	2	6	12		
Hexarthriidae	1	8	1	6	1	4	1	7	7	7	4	18		
Ituridae	1	2	1	5	1	3	1	4	0	0	2	6		
Lecanidae	1	82	1	61	1	99	1	94	81	81	49	200		
Lepadellidae	3	62	3	55	4	59	4	70	89	89	37	168		
Lindliidae	1	2	1	7	1	3	1	4	4	4	3	13		





the diversity of rotifers, and Luo and Segers (2013, 2020) did the same for the Afrotropics. The latter studies described nine new rotifer species within the genera *Colurella*, *Lepadella*, and *Squatinella*, which refuted the African anomaly hypothesis on the purported rotifer species poverty. Within the Australia region, the number of known rotifer species was more than doubled to close to 500 species in the early 1980s by the research efforts of Russell J. Shiel. In the neotropical realm, as exemplified by the Amazon basin, several endemics in the *Brachionus*, *Anuraeopsis*, *Lecane*, and *Lepadella* genera have been characterized (see Serafim et al., 2003; Segers, 2007, 2008). Given the lack of rotifer studies within tropical wetlands, the rotifer diversity in this section is described in general, highlighting the diversity that exists within freshwater ecosystems across different tropical regions.

#### 9.5.4 Ecology

Analysis of rotifer distribution and diversity is seriously hampered by lack of knowledge on the taxonomy and chorology of this group (Luo and Segers, 2020). However, ecological research on rotifers from interstitial waters has been neglected to date. Rotifers living in interstitial water within *Sphagnum* mats and *Sarracenia purpurea* pitchers are capable of regenerating large amounts of nitrogen and phosphorus, that is, ~3%–10% in Europe and 5%–7% in North America, and can be a major source of inorganic phosphorus (Błędzki et al., 2018). Thus a world estimate of rotifer nutrient regeneration is approximately 0.12 and 0.17 million tons of N and P, respectively, to wetlands every year (Błędzki et al., 2018). For example, *Habrotrocha rosa* can live between wet *Sphagnum* litter and is the most frequent rotifer species in wetland peatlands, responsible for about 40%–50% of N and P regeneration by rotifers. Rotifers provide food to many other aquatic animals, that is, adults and eggs may be parasitized by fungi, while some rotifers are symbiotic with, or parasitic on, other organisms. Some rotifers are endoparasitic mainly on invertebrates (e.g., algae, annelids, bacteria, brachiopods, bryozoans, crustaceans, protists, other rotifers) (Segers, 2007). Rotifer diversity is mainly explained by fluctuations in hydrological level (Bonecker and Lansac-Tôha, 1996).

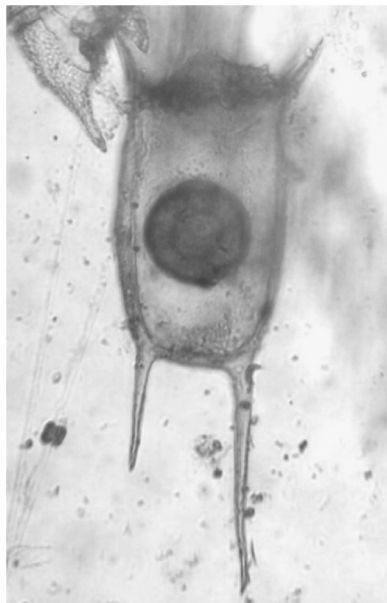
#### 9.5.5 Life history

The Monogononta and Bdelloidea have one and two gonads, respectively, and both reproduce parthenogenetically. In Monogononta, parthenogenetic reproduction periods are interspersed with sexual phases (i.e., heterogony), but in Bdelloidea reproduction is by diploid, mitotic parthenogenesis only,

making them unique and the most diverse group of metazoans (Segers, 2008). The Monogononta propagules consist of single, hard-shelled, and durable encapsulated cysts, while those of Bdelloidea consist of anhydrobiotic individuals (Segers, 2008). The propagules produced are small and drought-resistant, making rotifers perfectly adapted to aerial, passive, and/or phoretic dispersal. The high dispersal capacity and their parthenogenetic reproduction enable them to establish or renew a population starting off from a single resting stage, and to reach viable population sizes relatively quickly, making them superb (re)colonizers (Brain, 2002; Segers, 2008). For these reasons, many rotifer species are cosmopolitan.

### 9.5.6 Feeding biology

In tropical freshwater food webs, rotifers are of particular importance, forming a key link between primary producers (i.e., phytoplankton, bacteria, detritus) and consumers (i.e., carnivorous zooplankton, fish). Nearly all planktonic rotifers are herbivores, feeding on phytoplankton and ingesting cells roughly 4–17  $\mu\text{m}$  in size (see Fig. 9.3). Besides being heterotrophic, planktonic rotifers also consume organic detritus and bacteria. Obertegger et al. (2011) classified rotifers into two functional feeding guilds based on the feeding strategy they employed across genera: (1) *raptorial rotifers*



**FIGURE 9.3** *Keratella* sp. identified from a temporary wetland (Malilangwe Reserve, Zimbabwe) feeding on a centric diatom. Photo by Tatenda Dalu.

(genera, e.g., *Ascomorpha*, *Asplanchna*, *Collotheca*, *Gastropus*, *Ploesoma*, *Polyarthra*, *Synchaeta*, *Trichocerca*), that exhibit active grasping, piercing, and/or pumping action to catch single food items and generally consist of cardate, forcipate, incudate, uncinata, and/or virgate trophi; and (2) *microphagous rotifers* (genera, e.g., *Brachionus*, *Conochilus*, *Euchlanis*, *Filinia*, *Floscularia*, *Kellicottia*, *Keratella*, *Lecane*, *Notholca*, *Testudinella*, *Trichotria*), that collect multiple food items and consist of malleate, malleoramate, and/or ramate trophi.

### 9.5.7 Threats and conservation

Human introduction coupled with inadequate taxonomic expertise/studies in tropical regions precludes accurate biogeographical classifications of zooplankton. This is also the case for rotifers where most taxa are currently classified as cosmopolitan when in effect that might not be the case and some can be considered as cryptogenic species. Rotifers in general are not considered endangered or threatened in any way. As mainly planktonic animals, rotifers are an important food source for many aquatic animals, including some economically important to humans. Indeed, particular environments such as wetlands deserve more intensive sampling across different seasons to uncover more detail about their peculiar microfauna. Due to the large dispersal and colonization capacities of many rotifer species, they are easily transported to new habitats by humans (Segers, 2008). For example, rotifers have been and continue to be introduced to regions where they did not naturally occur before. This phenomenon may have been going on for a long time and is thought to be responsible for isolated records of regionally common species outside their natural range. The same reasons explain why rotifers have hardly been used in biodiversity assessments and conservation, notwithstanding their economic relevance in aquaculture (Segers, 2008). Rotifers are mostly threatened by water quality changes due to anthropogenic influences.

## 9.6 General conclusions and conservation management

It is too early to draw far going conclusions on general patterns in richness and endemism across tropical regions and wetland types (see Irvine et al., 2022, Chapter 19). Current data reflect mainly areas with higher research efforts, rather than natural patterns of species richness and endemism. More studies are required covering large areas and time-integrated sampling as species succession and turnover in relation to environmental changes are typical to zooplankton communities. In addition to more explorative studies, more taxonomical research is needed. Particularly for southern continents, there is an overall lack in trained taxonomists for most aquatic invertebrate groups. Nearly every extensive study on zooplankton from tropical wetlands

reveals new species or even higher order taxa, especially when applying molecular systematics as cryptic species are common.

Many zooplankton groups are widely distributed, can cope with variable environmental conditions, and occur in both permanent and temporary tropical wetlands. Functional feeding groups include detritus feeders, scavengers, predators, and filter feeders. They consequently sustain important ecosystem functions (e.g., nutrient cycling, clearing water) and form crucial components of the food web (Cuthbert et al., 2022, Chapter 17). Zooplankton is the main link of biomass transfer between primary producers and consumers (Setubal et al., 2020). Especially under often high temperature conditions in the tropics, accelerated processing of autochthonous and allochthonous organic matter takes place, which without the activities of zooplankton groups would quickly result in eutrophic systems with frequent (often toxic) algal blooms. An abundant and diverse zooplankton community can maintain the aquatic ecosystem in a clear water phase with ample vegetation and deliver crucial services to human populations (e.g., clean water, fish, recreational area).

Reproduction modes span the whole range in zooplankton, from obligate sexual to parthenogenetic reproduction, with sometimes different modes represented in a single species. In addition, in each of the zooplankton groups covered here, species are known that produce drought-resistant dormant propagules in variable developmental stages that allow persistence in temporary wetlands and facilitate passive dispersal.

Habitat characteristics that tend to impact zooplankton community composition, species richness, and diversity include wetland size, wetland type (permanent vs temporary), the presence of predatory fish (mainly in permanent wetlands) and macrophyte cover as biotic variables, and pH and salinity as for the abiotic environment. Fish predation not only selects for smaller species but also affects size structure and sometimes behavior of populations. The presence of a diverse and vegetated littoral zone offers extra food, shelter, and habitat heterogeneity supporting often high species richness and occurrence of particular plant dwelling species. For conservation of zooplankton diversity in tropical wetlands, it is therefore crucial to focus mainly on the maintenance of a well-vegetated littoral zone (Gebrehiwot et al., 2017). Some zooplankton groups seem to do well under (even hyper) eutrophic conditions in (subtropical) systems, so that indicators based on zooplankton richness sometimes are positively associated with trophic status, in contrast with the impact on macroinvertebrate richness (Azevêdo et al., 2015). In temporary wetlands, the community composition and species richness are mainly determined by the hydroperiod, that indirectly has an impact on water quality and the presence of invertebrate predators. Any change in temporary wetland hydrology due to direct anthropogenic impact and/or by climate change will therefore have a significant impact on community processes and dynamics. This topic is being dealt with in detail in the chapter on large branchiopods (Brendonck et al., 2022a,b, Chapter 10).

Zooplankton groups are usually not prime targets for conservation efforts as they are too small and lack the charism of other wetland invertebrates such as dragonflies. Due to their versatile feeding, reproduction, and life history strategies, they are usually abundant, quite widespread with limited documented cases of species extinctions. However, tropical zooplankton are crucial to maintain ecosystem functions and services, including suppression of harmful algal blooms and provisioning of food for rare insect, amphibian, and fish species.

## References

- Athibai, S., Segers, H., Sanoamuang, L.O., 2013. Diversity and distribution of Brachionidae (Rotifera) in Thailand, with a key to the species. *Journal of Limnology* 72, e17.
- Azevêdo, D.J.S., Barbosa, J.E.L., Gomes, W.I.A., Porto, D.E., Marques, J.C., Molozzi, J., 2015. Diversity measures in macroinvertebrate and zooplankton communities related to the trophic status of subtropical reservoirs: contradictory or complementary responses? *Ecological Indicators* 50, 135–149.
- Azuraidi, O.M., Yusoff, F.M., Shamsudin, M.N., Raha, R.A., Alekseev, V.R., Matias-Peralta, H. M., 2013. Effect of food density on male appearance and ephippia production in a tropical cladoceran, *Moina micrura* Kurz, 1874. *Aquaculture* 412/413 (1), 131–135.
- Badosa, A., Frisch, D., Arechederra, A., Serrano, L., Green, A.J., 2010. Recovery of zooplankton diversity in a restored Mediterranean temporary marsh in Doñana National Park (SW Spain). *Hydrobiologia* 654, 67–82.
- Baltanás, A., Danielopol, D.L., 2013. Body-size distribution and biogeographical patterns in non-marine ostracods (Crustacea: Ostracoda). *Biological Journal of the Linnean Society* 109 (2), 409–423.
- Barson, M., Mulonga, A., Nhiwatiwa, T., 2008. Investigation of a parasitic outbreak of *Lernaea cyprinacea* Linnaeus (Crustacea: Copepoda) in fish from Zimbabwe. *African Zoology* 43, 175–183.
- Bayly, I.A.E., 1997. Invertebrates of temporary waters in gnammas on granite outcrops in Western Australia. *Journal of the Royal Society of Western Australia* 80, 167–172.
- Bell, G., 1982. *The Masterpiece of Nature, the Evolution and Genetics of Sexuality*. University of California Press, California.
- Benson, R.H., 1981. Form, function, and architecture of ostracode shells. *Annual Review of Earth and Planetary Sciences* 9 (1), 59–80.
- Benzie, J., 1996. *Daphnia jollyi*. The IUCN Red List of Threatened Species 1996: e. T6254A12592488 [online]. Available at: <https://doi.org/10.2305/IUCN.UK.1996.RLTS.T6254A12592488.en> (accessed 01.12.20.).
- Bird, M.S., Mlambo, M.C., Wasserman, R.J., Dalu, T., Holland, A.J., Day, J.A., et al., 2019. Deeper knowledge of shallow waters: reviewing the invertebrate fauna of southern African temporary wetlands. *Hydrobiologia* 827, 89–121.
- Blanco, S., Romo, S., Villena, M.J., 2004. Experimental study on the diet of mosquitofish (*Gambusia holbrooki*) under different ecological conditions in a shallow lake. *International Review of Hydrobiology* 89 (3), 250–262.
- Błędzki, L.A., Bubier, J.L., Ellison, A.M., Moore, T.R., 2018. Ecology of rotifers and their unappreciated source of nitrogen and phosphorus in temperate northeastern American bogs. *Fundamental and Applied Limnology/Archiv für Hydrobiologie* 191, 277–287.

- Bonecker, C.C., Lansac-Tôha, F.A., 1996. Community structure of rotifers in two environments of the upper River Paraná floodplain (MS)-Brazil. *Hydrobiologia* 325 (2), pp. 137–150.
- Boxshall, G., Evstigneeva, T., 1994. The evolution of species flocks of copepods in Lake Baikal: a preliminary analysis (With 4 figures and 3 tables in the text). *Ergebnisse der Limnologie* 235–246.
- Boxshall, G., Jaume, D., 2000. Making waves: the repeated colonization of fresh water by copepod crustaceans. *Advances in Ecological Research* 31, 61–79.
- Boxshall, G.A., Defaye, D., 2008. Global diversity of copepods (Crustacea: Copepoda) in freshwater. *Hydrobiologia* 595, 195–207.
- Boxshall, G.A., Strong, E.E., 2006. An extraordinary shift in life habit within a genus of cyclopoid copepods in Lake Tanganyika. *Zoological Journal of the Linnean Society* 146, 275–285.
- Brain, C.K., 2002. Rotifera. In: Day, J.A., de Moor, I.J. (Eds.), *Guides to the Freshwater Invertebrates of Southern Africa. Volume 5: Non-Arthropods. The Protozoans, Porifera, Cnidaria, Platyhelminthes, Nemertea, Rotifera, Nematoda, Nematomorpha, Gastrotrichia, Bryozoa, Tardigrada, Polychaeta, Oligochaeta and Hirudinea*. Water Research Commission (WRC) Report No. TT 167/02, WRC, Pretoria.
- Brendonck, L., De Meester, L., 2003. Egg banks in freshwater zooplankton: evolutionary and ecological archives in the sediment. *Hydrobiologia* 491, 65–84.
- Brendonck, L., Lanfranco, S., Timms, B., Vanschoenwinkel, B., 2016. Chapter 2: invertebrates in rock pools. In: Batzer, D., Boix, D. (Eds.), *Invertebrates in Freshwater Wetlands: An International Perspective on Their Ecology*. Springer, Cham, pp. 25–53.
- Brendonck, L., Pinceel, T., Ortells, R., 2017. Dormancy and dispersal as mediators of zooplankton population and community dynamics along a hydrological disturbance gradient in inland temporary pools. *Hydrobiologia* 796, 201–222.
- Brendonck, L., Rogers, D.C., Vanschoenwinkel, B., Pinceel, T., 2022a. Large branchiopods. In: Dalu, T., Wasserman, R.J. (Eds.), *Fundamentals of Tropical Freshwater Wetlands: From Ecology to Conservation Management*. Academic Press, London.
- Brendonck, L., Rogers, D.C., Vanschoenwinkel, B., Pinceel, T., 2022b. Chapter: tropical large branchiopods. In: Dalu, T., Wasserman, R.J. (Eds.), *Fundamentals of Tropical Freshwater Wetlands: From Ecology to Conservation Management*. Elsevier.
- Brochet, A.L., Gauthier-Clere, M., Guillemain, M., Fritz, H., Waterkeyn, A., Baltanás, A., et al., 2010. Field evidence of dispersal of branchiopods, ostracods and bryozoans by teal (*Anas crecca*) in the Camargue (southern France). *Hydrobiologia* 637 (1), 255–261.
- Brotskaya, V., 1963. A survey of the family Cerviniidae (Crustacea, Copepoda). *Zoologicheskii Zhurnal* 42, 1785–1803.
- Buxton, M., Cuthbert, R.N., Dalu, T., Nyamukondiwa, C., Wasserman, R.J., 2020. Predator density modifies mosquito regulation in increasingly complex environments. *Pest Management Science* 76, 2079–2086.
- Campbell, C.E., 1995. The influence of a predatory ostracod, *Australocypris insularis*, on zooplankton abundance and species composition in a saline lake. *Hydrobiologia* 302 (3), 229–239.
- Cannon, H.G., 1933. On the feeding mechanism of certain marine ostracods. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh* 57 (3), 739–764.
- Carbonel, P., 1988. Ostracods and the transition between fresh and saline waters. In: De Deckker, P., Colin, J.P., Peypouquet, J.P. (Eds.), *Ostracoda in the Earth Sciences*. Elsevier, Amsterdam, pp. 157–173.

- Carbonel, P., Hoibian, T., 1988. The impact of organic matter on ostracods from an Equatorial deltaic area, the Mahakam Delta-Southeastern Kalimantan. *Development in Palaeontology and Stratigraphy* 11, 353–366.
- Carbonel, P., Mourguiart, Ph, Peypouquet, J.-P., 1990. The external mechanisms responsible for morphological variability in recent Ostracoda: seasonality and biotope situation: an example from Lake Titicaca. In: Whatley, R., Maybury, C. (Eds.), *Ostracoda and Global Event*. Chapman and Hall, London, pp. 331–340.
- Chial, B.Z., Persoone, G., Blaise, C., 2003. Cyst-based toxicity tests. XVII. Application of ostracodtoxkit microbiotest in a bioremediation project of oil-contaminated sediments: sensitivity comparison with *Hyalella azteca* solid-phase assay. *Environmental Toxicology* 18 (5), 279–283.
- Chiambeng, G.Y., Dumont, H.J., 2005. The Branchiopoda (Crustacea: Anomopoda, Ctenopoda and Cyclestherida) of the rain forests of Cameroon, West Africa: low abundances, few endemics and a boreal-tropical disjunction. *Journal of Biogeography* 32 (9), 1611–1620.
- Choedchim, W., Van Damme, K., Maiphae, S., 2017. Spatial and temporal variation of Cladocera in a tropical shallow lake. *Annales de Limnologie—International Journal of Limnology* 52, 233–252.
- Ciros-Pérez, J., Elias-Gutiérrez, M., 1997. *Spinalona anophthalma*, n. gen. n. sp. (Anomopoda, Chydoridae) a blind epigean cladoceran from the Neovolcanic Province of Mexico. *Hydrobiologia* 353, 19–28.
- Cohuo, S., Macario-González, L., Pérez, L., Schwalb, A., 2017. Overview of Neotropical-Caribbean freshwater ostracode fauna (Crustacea, Ostracoda): identifying areas of endemism and assessing biogeographical affinities. *Hydrobiologia* 786 (1), 5–21.
- Coronel, J.S., Declerck, S., Brendonck, L., 2007. High-altitude peatland temporary pools in Bolivia house a high cladoceran diversity. *Wetlands* 27 (4), 1166.
- Cuthbert, R.N., Dalu, T., Wasserman, R.J., Callaghan, A., Weyl, O.L.F., Dick, J.T.A., 2018. Calanoid copepods: an overlooked tool in the control of disease vector mosquitoes. *Journal of Medical Entomology* 55, 1656–1658.
- Cuthbert, R.N., Wasserman, R.J., Keates, C., Dalu, T., 2022. Food webs. In: Dalu, T., Wasserman, R.J. (Eds.), *Fundamentals of Tropical Freshwater Wetlands: From Ecology to Conservation Management*. Academic Press, London.
- da Silva Brito, M.T., Diniz, L.P., Pozzobom, U.M., Landeiro, V.L., Sousa, F.D., 2020. Biodiversity of Cladocera (Crustacea: Branchiopoda) from the state of Mato Grosso, Brazil: new records and species richness in hydrographic regions. *Annales de Limnologie—International Journal of Limnology* 2020 (56), 7.
- Dahms, H.-U., 1995. Dormancy in the Copepoda—an overview. *Hydrobiologia* 306, 199–211.
- Dahms, H.-U., 2004. Exclusion of the Polyarthra from Harpacticoida and its reallocation as an underived branch of the Copepoda (Arthropoda, Crustacea). *Invertebrate Zoology* 1, 29–51.
- Dalu, T., Wasserman, R.J., Dalu, M.T.B., 2017. Agricultural intensification and drought frequency increases may have landscape-level consequences for ephemeral ecosystems. *Global Change Biology*. Available from: <https://doi.org/10.1111/gcb.13549>.
- Danielopol, D.L., Baltanás, A., Namiotko, T., Geiger, W., Pichler, M., Reina, M., et al., 2008. Developmental trajectories in geographically separated populations of non-marine ostracods: morphometric applications for palaeoecological studies. *Senckenbergiana lethaea* 88 (1), 183–193.
- De Deckker, P., 1983. Notes on the ecology and distribution of non-marine ostracods in Australia. *Hydrobiologia* 106 (3), 223–234.



- De Deckker, P., Martens, K., 2013. Extraordinary morphological changes in valve morphology during the ontogeny of several species of the Australian ostracod genus *Bennelongia* (Crustacea, Ostracoda). *European Journal of Taxonomy* 36, 1–37.
- Diniz, L.P., Elmoor-Loureiro, L.M.A., dos Santos Almeida, V.L., de Melo Júnior, M., 2013. Cladocera (Crustacea, Branchiopoda) of a temporary shallow pond in the Caatinga of Pernambuco, Brazil. *Nauplius* 21 (1), 65–78.
- Dole-Olivier, M.J., Galassi, D., Marmonier, P., Creuzé Des Châtelliers, M., 2000. The biology and ecology of lotic microcrustaceans. *Freshwater Biology* 44, 63–91.
- Dube, T., Denecker, L., van Vuren, J.H.J., Wepener, V., Smit, N.J., Brendonck, L., 2017. Spatial and temporal variation of invertebrate community structure in flood-controlled tropical floodplain wetlands. *Journal of Freshwater Ecology* 32, 1–15.
- Dumont, H., Segers, H., 1996. Estimating lacustrine zooplankton species richness and complementarity. *Hydrobiologia* 341, 125–132.
- Dumont, H.J., 1994. On the diversity of Cladocera in the tropics. *Hydrobiologia* 272, 27–38.
- Dumont, H.J., Negrea, S.V., 2002. Introduction to the Class Branchiopoda (Guides to the Identification of the Microinvertebrates of the Continental Waters of the World, vol. 19). Backhuys Publishers, Leiden.
- Eitam, A., Blaustein, L., Van Damme, K., Dumont, H.J., Martens, K., 2004. Crustacean species richness in temporary pools: relationship with habitat traits. *Hydrobiologia* 525 (1), 125–130.
- Elmoor-Loureiro, L.M.A., 2014. *Ephemeroporus quasimodo* sp. nov. (Crustacea: Cladocera: Chydoridae), a new species from the Brazilian Cerrado. *Zootaxa* 3821 (1), 88–100.
- Eskinazi-Sant'Anna, E.M., de Souza Santos, G., da Silva Alves, N.J., Brito, L.A.F., Leite, M.G. P., 2020. The relative importance of regional and local factors in shaping zooplankton diversity in high-altitude tropical shallow lakes. *Journal of Freshwater Ecology* 35 (1), 203–221.
- Fernando, C.H., 2002. *A Guide to Tropical Freshwater Zooplankton: Identification, Ecology and Impact on Fisheries*. Backhuys Publishers, Leiden.
- Forró, L., Korovchinsky, N.M., Kotov, A.A., Petrusek, A., 2008. Global diversity of cladocerans (Cladocera; Crustacea) in freshwater. *Hydrobiologia* 595, pp. 177–184.
- Forester, R.M., 1991. Ostracode assemblages from springs in the western United States: implications for paleohydrology. *Memoirs of the Entomological Society of Canada* 123 (S155), 181–201.
- Frisch, D., Libman, B.S., D'surney, S.J., Threlkeld, S.T., 2005. Diversity of floodplain copepods (Crustacea) modified by flooding: species richness, diapause strategies and population genetics. *Archiv Fur Hydrobiologie* 162, 1–17.
- Frisch, D., Moreno-Ostos, E., Green, A.J., 2006. Species richness and distribution of copepods and cladocerans and their relation to hydroperiod and other environmental variables in Doñana, South-west Spain. *Hydrobiologia* 556, 327–340.
- Fryer, G., 1987. Morphology and the classification of the so-called Cladocera. *Hydrobiologia* 145, 19–28.
- Fryer, G., 1968. The parasitic Crustacea of African freshwater fishes; their biology and distribution. *Journal of Zoology* 156, 45–95.
- Fryer, G., 1993. Variation in acid tolerance of certain freshwater crustaceans in different natural waters. *Hydrobiologia* 250, 119–125.
- Gebrehiwot, M., Kifle, D., Triest, L., 2017. Emergent macrophytes support zooplankton in a shallow tropical lake: a basis for wetland conservation. *Environmental Management* 60, 1127–1138.

- Gogoi, B., Sousa, F.D.R., Das, D.N., 2018. Faunal diversity of Cladocera (Crustacea: Branchiopoda) with notes on biogeographically important species in the floodplain wetlands of the Subansiri River basin, India. *Annales de Limnologie—International Journal of Limnology* 2018 (54), 36.
- Green, J., 2003. Associations of planktonic and periphytic rotifers in a tropical swamp, the Okavango Delta, Southern Africa. *Hydrobiologia* 490, 197–209.
- Hairston Jr, N., 1987. Diapause as a predator avoidance adaptation. In: Kerfoot, W.C., Sih, A. (Eds.), *Predation: Direct and Indirect Impacts on Aquatic Communities*. University Press of New England, Hanover, NH, pp. 281–289.
- Hairston Jr, N.G., Van Brunt, R.A., Kearns, C.M., Engstrom, D.R., 1995. Age and survivorship of diapausing eggs in a sediment egg bank. *Ecology* 76 (6), 1706–1711.
- Hairston, N.G., Van Brunt, R.A., 1994. Diapause dynamics of two diaptomid copepod species in a large lake. *Hydrobiologia* 292, 209–218.
- Halse, S.A., Martens, K., 2019. Four new genera and five new species of *Heterocypris* from Western Australia (Crustacea, Ostracoda, Cyprinotinae). *European Journal of Taxonomy* 493, 1–35.
- Halse, S.A., McRae, J.M., 2004. New genera and species of ‘giant’ ostracods (Crustacea: Cyprididae) from Australia. *Hydrobiologia* 524 (1), 1–52.
- Han, B.P., Yin, J., Lin, X., Dumont, H.J., 2011. Why is *Diaphanosoma* (Crustacea: Ctenopoda) so common in the tropics? Influence of temperature and food on the population parameters of *Diaphanosoma dubium*, and a hypothesis on the nature of tropical cladocerans. *Hydrobiologia* 668, 109–115.
- Higuti, J., Conceição, E.D.O.D., Campos, R.D., Ferreira, V.G., Rosa, J.D., Pinto, M.B.D.O., et al., 2017. Periphytic community structure of Ostracoda (Crustacea) in the river-floodplain system of the Upper Paraná River. *Acta Limnologica Brasiliensia* 29 (120).
- Higuti, J., Declerck, S.A.J., Lansac-Tôha, F.A., Velho, L.F.M., Martens, K., 2010. Variation in ostracod (Crustacea, Ostracoda) communities in the alluvial valley of the upper Paraná River (Brazil) in relation to substrate. *Hydrobiologia* 644 (1), 261–278.
- Higuti, J.C., Meisch, C., Martens, K., 2009. On *Paranacypris samambaiensis* gen. nov., sp. nov. (Crustacea, Ostracoda), the first South American psychrodromid, from the alluvial valley of the Upper Paraná River, Brazil. *Journal of Natural History* 43 (13–14), 769–783.
- Ho, J.-S., Dojiri, M., Hendler, G., Deets, G.B., 2003. A new species of Copepoda (Thaumatopsyllidae) symbiotic with a brittle star from California, USA, and designation of a new order Thaumatopsylloida. *Journal of Crustacean Biology* 23, 582–594.
- Hollwedel, W., Kotov, A.A., Brandorff, G.-O., 2003. Cladocera (Crustacea: Branchiopoda) from the Pantanal (Brazil). *Arthropoda Selecta* 12 (2), 67–93.
- Holmes, J.A., 2001. Ostracoda. In: Smol, J.P., Birks, H.J.B., Last, W.M. (Eds.), *Tracking Environmental Change Using Lake Sediments. Volume 4: Zoological Indicators*. Kluwer Academic Publishers, Dordrecht, pp. 125–151.
- Horne, D.J., Martens, K., 1998. Geographical parthenogenesis in European non-marine ostracods: post-glacial invasion or Holoene stability? *Hydrobiologia* 391 (1–3), 1–7.
- Horne, D.J., Smith, R.J., Whittaker, J.E., Murray, J.W., 2004. The first British record and a new species of the Superfamily Terrestrialtheroidea (Crustacea, Ostracoda): morphology, ontogeny, lifestyle and phylogeny. *Zoological Journal of the Linnean Society* 142 (2), 253–288.
- Humes, A.G., 1994. Copepoda associated with Octocorals in Northwestern Madagascar, including *Orecturus sakalavicus* n. sp. from the Telestacean *Coelogorgia palmosa*. *Transactions of the American Microscopical Society* 113, 117–126.
- Huys, R., Boxshall, G.A., 1991. *Copepod Evolution*. Ray Society, London.

- Irvine, K., Dickens, C., Castello, L., Bredin, I., Finlayson, C.M., 2022. Vegetated wetlands: from ecology to conservation management. In: Dalu, T., Wasserman, R.J. (Eds.), *Fundamentals of Tropical Freshwater Wetlands: From Ecology to Conservation Management*. Academic Press, London.
- Jocqué, M., Martens, K., Riddoch, B., Brendonck, L., 2006. Faunistics of ephemeral rock pools in Southeastern Botswana. *Archiv für Hydrobiologie* 165 (3), 415–431.
- Jocqué, M., Timms, B.V., Brendonck, L., 2007. A contribution on the biodiversity and conservation of the freshwater fauna of rocky outcrops in the central Wheatbelt of Western Australia. *Journal of the Royal Society of Western Australia* 90 (3), 137–142.
- Johnson, J., 1979. Effects of temperature and salinity on production and hatching of dormant eggs of *Acartia californiensis* (Copepoda) in an Oregon estuary. *Fishery Bulletin* (United States) 77.
- Karanovic, I., 2007. *Candoninae (Ostracoda) from the Pilbara Region in Western Australia*. Brill Publishers, Leiden.
- Karanovic, I., 2012. *Recent Freshwater Ostracods of the World: Crustacea, Ostracoda, Podocopida*. Springer, Berlin.
- Karanovic, I., Detry, T., 2009. Overview of Candoninae (Crustacea, Ostracoda) of South America and the West Indies, with the description of two new species and one new genus. *Zootaxa* 2267 (1), 1–25.
- Karanovic, T., 2004. *Subterranean Copepoda from Arid Western Australia*. Crustacean Monographs 3. Koninklijke Brill, Leiden, p. 366.
- Karuthapandi, M., Rao, D.V., Innocent, B.X., 2014. Freshwater Ostracoda (Crustacea) of India—a checklist. *Journal of Threatened Taxa* 6 (12), 6576–6581.
- Khodami, S., Mearthur, J.V., Blanco-Bercial, L., Martínez Arbizu, P., 2017. Molecular Phylogeny and revision of copepod orders (Crustacea: Copepoda). *Scientific Reports* 7, 9164.
- Kikuchi, Y., 1994. *Glaciella*, a new genus of freshwater Canthocamptidae (Copepoda, Harpacticoida) from a glacier in Nepal, Himalayas. *Hydrobiologia* 292, 59–66.
- Kiss, A., 2007. Factors affecting spatial and temporal distribution of Ostracoda assemblages in different macrophyte habitats of a shallow lake (Lake Fehér, Hungary). *Hydrobiologia* 585, 89–98.
- Korovchinsky, N.N., 2013. Cladocera (Crustacea: Branchiopoda) of South East Asia: history of exploration, taxon richness and notes on zoogeography. *Journal of Limnology* 72 (s2), 109–124.
- Koste, W., Robertson, B., 1983. Taxonomic studies of the Rotifera (Phylum Aschelminthes) from a Central Amazonian varzea lake, Lago Camaleão (Ilha de Marchantaria, Rio Solimões, Amazonas, Brazil). *Amazoniana: Limnologia et Oecologia Regionalis Systematis Fluminis Amazonas* 8 (2), pp. 225–254
- Kotov, A., Forró, L., Korovchinsky, N.M., Petrusek A., 2013. World Checklist of Freshwater Cladocera Species', Crustacea-Cladocera Checklist FADA [online]. Available at <http://fada.biodiversity.be/group/show/17> (accessed 01.12.20.).
- Kotov, A.A., Štifter, P., 2005. Notes on the genus *Ilyocryptus* Sars, 1862 (Cladocera: Anomopoda: Ilyocryptidae). 7. Two new species from South Africa, with first record of *Ilyocryptus* from rockpools. *Arthropoda Selecta* 14 (3), 219–228.
- Kotov, A.A., 2013. Morphology and Phylogeny of the Anomopoda (Crustacea: Cladocera). KMK, Moscow [in Russian].
- Kotov, A.A., Jeong, H.G., Lee, W., 2012. Cladocera (Crustacea: Branchiopoda) of the south-east of the Korean Peninsula, with twenty new records for Korea. *Zootaxa* 3368, 50–90.

- Kotov, A.A., Sinev, A.Y., Berrios, V.L., 2010. The Cladocera (Crustacea: Branchiopoda) of six high altitude water bodies in the North Chilean Andes, with discussion of Andean endemism. *Zootaxa* 2430 (1), 1–66.
- Külköylüoğlu, O., 2004. On the usage of ostracods (Crustacea) as bioindicator species in different aquatic habitats in the Bolu region, Turkey. *Ecological Indicators* 4 (2), 139–147.
- Kutikova, L.A., Fernando, C.H., 1995. *Brachionus calyciflorus* Pallas (Rotatoria) in inland waters of tropical latitudes *Brachionus calyciflorus* tropical in waters. *Internationale Revue der gesamten Hydrobiologie* 80, 429–441.
- Lansac-Tôha, F.A., Bonecker, C.C., Velho, L.F.M., Simões, N.R., Dias, J.D., Alves, G.M., et al., 2009. Biodiversity of zooplankton communities in the Upper Paraná River floodplain: inter-annual variation from long-term studies. *Acta Limnologica Brasiliensia* 69 (2), 539–549.
- Lawrence, J., Scharf, B., Packroff, G., Neu, T., 2002. Microscale evaluation of the effects of grazing by invertebrates with contrasting feeding modes on river biofilm architecture and composition. *Microbial Ecology* 44 (3), 199–207.
- Li, X., Liu, W., Zhang, L., Sun, Z., 2010. Distribution of recent ostracod species in the Lake Qinghai are in northwestern China and its ecological significance. *Ecological Indicators* 10 (4), 880–890.
- Lima, A.F., Lansac-Tôha, F.A., Velho, L.F.M., Bini, L.M., Takeda, A.M., 2003. Composition and abundance of Cladocera (Crustacea) assemblages associated with *Eichhornia azurea* (Swartz) Kunth stands in the Upper Paraná River floodplain. *Acta Scientific* 25 (1), 41–48.
- Lindholm, M., Hessen, D.O., Ramberg, L., 2009. Diversity, dispersal and disturbance: cladoceran species composition in the Okavango Delta. *African Zoology* 44 (1), 24–35.
- Lopez, L.C.S., Gonçalves, D.A., Mantovani, A., Rios, R.I., 2002. Bromeliad ostracods pass through amphibian (*Scinax perpusillus*) and mammalian guts alive. *Hydrobiologia* 485 (1–3), 209–211.
- Luo, Y., Segers, H., 2013. On *Pulchritia* new genus, with a reappraisal of the genera of Trichotriidae (Rotifera, Monogononta). *ZooKeys* 342, 1–12.
- Luo, Y., Segers, H., 2020. Eight new Lepadellidae (Rotifera, Monogononta) from the Congo bring to level endemism in Africa's rotifers. *Zootaxa* 4731, 371–387.
- Magalhães, A., Pereira, L.C.C., Da Costa, R.M., 2015. Relationships between copepod community structure, rainfall regimes, and hydrological variables in a tropical mangrove estuary (Amazon coast, Brazil). *Helgoland Marine Research* 69, 123–136.
- Malmqvist, B., Meisch, C., Nilsson, A., 1997. Distribution patterns of freshwater Ostracoda (Crustacea) in the Canary Islands with regards to habitat use and biogeography. *Hydrobiologia* 347 (1–3), 159–170.
- Marten, G.G., Reid, J.W., 2007. Cyclopoid copepods. *Journal of the American Mosquito Control Association* 23, 65–92. 28.
- Martens, K., Halse, S., Schön, I., 2012. Nine new species of Bennelongia De Deckker & McKenzie, 1981 (Crustacea, Ostracoda) from Western Australia, with the description of a new subfamily. *European Journal of Taxonomy* 8, 1–56.
- Martens, K., 1984. Annotated checklist of non-marine ostracods (Crustacea, Ostracoda) from African inland waters. *Zoologische Dokumentatie-Koninklijk Museum voor Midden-Afrika, Tervuren-België* 20, 1–51.
- Martens, K., 1994. Ostracod speciation in ancient lakes: a review. *Ergebnisse der Limnologie* 44, 203.
- Martens, K., 2001. Chapter 1: Ostracoda. In: Day, J.A., De Moor, I.J., Stewart, B.A., Louw, A. E. (Eds.), *Guides to the Freshwater Invertebrates of Southern Africa. Volume 3: Crustacea*

- II (Ostracoda, Copepoda and Branchiura). Water Research Commission Report No. TT 148/01. WRC, Pretoria, South Africa.
- Martens, K., Behen, F., 1994. A Checklist of the Recent Non-marine Ostracods (Crustacea, Ostracoda) from the Inland Waters of South America and Adjacent Islands. Volume 22. Ministère des affaires culturelles, Musée national d'histoire naturelle.
- Martens, K., 2003. On the evolution of Gomphocythere (Crustacea, Ostracoda) in Lake Nyassa/Malawi (East Africa), with the description of five new species. *Hydrobiologia* 497, pp. 121–144.
- Martens, K., Horne, D.J., 2009. Ostracoda. In: Likkens, G. (Ed.), *Encyclopedia of Inland Waters*. Elsevier, Amsterdam.
- Martens, K., Savatentalinton, S., 2011. A subjective checklist of the recent, free-living, non-marine Ostracoda (Crustacea). *Zootaxa* 2855 (1), 1–79.
- Martens, K., 1998. Diversity and endemism of recent non-marine ostracods (Crustacea, Ostracoda) from Africa and South America: a faunal comparison. *Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen* 26 (4), 2093–2097.
- Martinez Arbizu, P., 2000. The Paraphyly of Cyclopinidae Sars, 1913, and the Phylogenetic Position of Poecilostome Families Within Cyclopoida Burmeister, 1835 (Copepoda: Crustacea). PhD Thesis, University of Oldenburg.
- Martens, K., Schön, I., Meisch, C., Horne, D.J., 2008. Global diversity of ostracods (Ostracoda, Crustacea) in freshwater. *Hydrobiologia* 595, 185–193.
- Martinez-Jeronimo, F., Ventura-Lopez, C., 2011. Population dynamics of the tropical cladoceran *Ceriodaphnia rigaudi* Richard, 1894 (Crustacea: Anomopoda). Effect of food type and temperature. *Journal of Environmental Biology* 32 (4), p513–p521.
- Matsumura, F., 1977. Adsorption, accumulation, and elimination of pesticides by aquatic organisms. In: Khan, M.A.A. (Ed.), *Pesticides in Aquatic Environments*. Springer, Boston, pp. 77–105.
- Meisch, C., 2000. *Freshwater Ostracoda of Western and Central Europe*. Spektrum Akademischer Verlag GmbH, Heidelberg.
- Meisch, C., Smith, R.J., Martens, K., 2019. A subjective global checklist of the extant non-marine Ostracoda (Crustacea). *European Journal of Taxonomy* 492, 1–135.
- Mesquita-Joanes, F., Smith, A.J., Viehberg, F.A., 2012. Chapter 2: The ecology of Ostracoda across levels of biological organisation from individual to ecosystem: a review of recent developments and future potential. In: Horne, D.J., Holmes, J.A., Rodriguez-Lazaro, J., Viehberg, F.A. (Eds.), *Developments in Quaternary Sciences*, 17. Elsevier, Amsterdam, pp. 15–35.
- Mills, S., Alcántara-Rodríguez, J.A., Ciroso-Pérez, J., Gómez, A., Hagiwara, A., Galindo, K.H., et al., 2017. Fifteen species in one: deciphering the *Brachionus plicatilis* species complex (Rotifera, Monogononta) through DNA taxonomy. *Hydrobiologia* 796, 39–58.
- Mormul, R.P., Thomaz, S.M., Higuiri, J., Martens, K., 2010. Ostracod (Crustacea) colonization of a native and a non-native macrophyte species of Hydrocharitaceae in the Upper Paraná floodplain (Brazil): an experimental evaluation. *Hydrobiologia* 644 (1), 185–193.
- Murugan, N., Sivaramakrishnan, K.G., 1976. Laboratory studies on the longevity, instar duration, growth, reproduction and embryonic development in *Scapholeberis kingi* Sars (1903) (Cladocera: Daphnidae). *Hydrobiologia* 50, 75–80.
- Nhiwatiwa, T., Brendonck, L., Dalu, T., 2017. Understanding factors structuring zooplankton and macroinvertebrate assemblages in ephemeral pans. *Limnologica-Ecology and Management of Inland Waters* 64, 11–19.

- Nhiwatiwa, T., De Bie, T., Vervaeke, B., Barson, M., Stevens, M., Vanhove, M.P., et al., 2009. Invertebrate communities in dry-season pools of a large subtropical river: patterns and processes. *Hydrobiologia* 630 (1), 169–186.
- Obertegger, U., Smith, H.A., Flaim, G., Wallace, R.L., 2011. Using the guild ratio to characterize pelagic rotifer communities. *Hydrobiologia* 662, 157–162.
- Otonello, D., Romano, A., 2011. Ostracoda and Amphibia in temporary ponds: who is the prey? Unexpected trophic relation in a mediterranean freshwater habitat. *Aquatic Ecology* 45, 55–62.
- Padhye, S.M., Victor, R., 2015. Diversity and distribution of Cladocera (Crustacea: Branchiopoda) in the rock pools of Western Ghats, Maharashtra, India. *Annales de Limnologie-International Journal of Limnology* 51 (4), 315–322.
- Pagano, M., 2008. Feeding of tropical cladocerans (*Moina micrura*, *Diaphanosoma excisum*) and rotifer (*Brachionus calyciflorus*) on natural phytoplankton: effect of phytoplankton size–structure. *Journal of Plankton Research* 30 (4), 401–414.
- Park, G.S., Marshall, H.G., 2000. Estuarine relationships between zooplankton community structure and trophic gradients. *Journal of Plankton Research* 22, 121–136.
- Park, L.E., Martens, K., 2001. Four new species of *Gomphocythere* (Crustacea, Ostracoda) from Lake Tanganyika, East Africa. *Hydrobiologia* 450 (1–3), 129–147.
- Pérez, L., Lorenschat, J., Massaferro, J., Pailles, C., Sylvestre, F., Hollwedel, W., et al., 2013. Bioindicators of climate and tropic state in lowland and highland aquatic ecosystems of the Northern Neotropics. *Revista de Biología Tropical* 61 (2), 603–644.
- Pieri, V., Martens, K., Stoch, F., Rossetti, G., 2009. Distribution and ecology of non-marine ostracods (Crustacea, Ostracoda) from Friuli Venezia Giulia (NE Italy). *Journal of Limnology* 68 (1), 1–15.
- Popova, E.Y., Kotov, A.A., 2013. Latitudinal patterns in the diversity of two subgenera of the genus *Daphnia* O.F. Müller (Crustacea: Cladocera: Daphniidae). *Zootaxa* 3736 (2), 159–174.
- Poquet, J.M., Mezquita, F., Rueda, J., Miracle, M.R., 2008. Loss of Ostracoda biodiversity in Western Mediterranean wetlands. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18 (3), 280–296.
- Ramos, L., Cusminsky, G., Schwalb, A., Alperin, M., 2017. Morphotypes of the lacustrine ostracod *Limnocythere rionegroensis* Cusminsky & Whatley from Patagonia, Argentina, shaped by aquatic environments. *Hydrobiologia* 786 (1), 137–148.
- Rayner, N.A., Heeg, J., 1994. Distribution patterns of the Diaptomidae (Calanoida: Copepoda) in southern Africa. *Hydrobiologia* 272, 47–75.
- Reeves, J.M., De Deckker, P., Halse, S.A., 2007. Groundwater ostracods from the arid Pilbara region of northwestern Australia: distribution and water chemistry. *Hydrobiologia* 585, 99–118.
- Reid, J.W., Bayly, I.A., Pesce, G.L., Rayner, N.A., Reddy, Y.R., Rocha, C.E., et al., 2002. Conservation of Continental Copepod Crustaceans. *Modern Approaches to the Study of Crustacea*. Springer.
- Reid, J.W., 2001. A human challenge: discovering and understanding continental copepod habitats. In: Lopes, R.M., Reid, J.W., Rocha, C.E.F. (Eds.), *Copepoda: Developments in Ecology, Biology and Systematics: Proceedings of the Seventh International Conference on Copepoda, held in Curitiba, Brazil, 25–31 July 1999*, Springer, Dordrecht, The Netherlands.
- Riati, L., Van Ginkel, C., Taylor, J.C., 2014. Zooplankton and diatoms of temporary and permanent freshwater pans in the Mpumalanga Highveld region, South Africa. *African Zoology* 49 (1), 113–127.

- Rizo, E.Z.C., Gu, Y., Papa, R.D.S., Dumont, H.J., Han, B., 2017. Identifying functional groups and ecological roles of tropical and subtropical freshwater Cladocera in Asia. *Hydrobiologia* 799, 83–99.
- Rossa, D.C., Lansac-Tôha, F.A., Bonecker, C.C., Velho, L.F.M., 2001. Abundance of cladocerans in the littoral regions in two environments of the Upper Paraná River Floodplain, MatoGrosso do Sul, Brazil. *Brazilian Journal of Biology* 61 (1), 45–53.
- Ruiz, F., Abad, M., Bodergat, A.M., Carbonel, P., Rodríguez-Lázaro, J., González-Regalado, M. L., et al., 2013. Freshwater ostracods as environmental tracers. *International Journal of Environmental Science and Technology* 10 (5), 1115–1128.
- Sa-artrit, P., Pholpunthin, P., Segers, H., Fontaneto, D., 2017. The influence of environmental variables on freshwater rotifers of the family Brachionidae and Lecanidae in Thailand. *Tropical Zoology* 30, 28–48.
- Samir, A.M., 2000. The response of benthic foraminifera and ostracods to various pollution sources: a study from two lagoons in Egypt. *The Journal of Foraminiferal Research* 30 (2), 83–98.
- Santangelo, J.M., Lopes, P.M., Nascimento, M.O., et al., 2015. Community structure of resting egg banks and concordance patterns between dormant and active zooplankters in tropical lakes. *Hydrobiologia* 758, 183–195.
- Sarma, S.S.S., Nandini, S., Gulati, R.D., 2005. Life history strategies of cladocerans: comparisons of tropical and temperate taxa. *Hydrobiologia* 542, 315–333.
- Sars, G.O., 1924. The freshwater Entomostraca of the Cape Province (Union of South Africa). Ostracoda. *Annals of the South African Museum* 20, 105–193.
- Savatnalinton, S., 2014. Ostracods (Crustacea: Ostracoda) from the floodplain of the Chi River, Maharakham Province, Northeast Thailand, with the first record of male *Tanycypris siamensis* Savatnalinton & Martens, 2009. *Zootaxa* 3838 (2), 195–206.
- Savatnalinton, S., 2015. On three new species of non-marine ostracods (Crustacea: Ostracoda) from Northeast Thailand. *Zootaxa* 3914 (3), 275–300.
- Savatnalinton, S., Martens, K., 2009a. On a freshwater species of the genus *Sanyuania* Zhao and Han, 1980 (Crustacea, Ostracoda, Loxoconchidae) from Thailand, with a discussion on morphological evolution of the freshwater Loxoconchidae. *Journal of Natural History* 43 (5–6), 259–285.
- Savatnalinton, S., Martens, K., 2009b. Redescription of the type species of *Strandesia* (Stuhlmann, 1888) and *Cypricercus* Sars, 1895 (Crustacea, Ostracoda, Cypricercinae), with a description of a new species of *Cypricercus* from South Africa. *Zootaxa* 2007 (1), 1–42.
- Savatnalinton, S., Martens, K., 2010. On the subfamily Cypricercinae McKenzie, 1971 (Crustacea, Ostracoda) from Thailand, with the description of six new species. *Zootaxa* 2379 (1), 1–77.
- Savatnalinton, S., Martens, K., 2013. On *Callistocypris thailandensis* sp. nov. (Ostracoda, Crustacea) from Thailand. *Zootaxa* 3686 (5), 578–586.
- Savatnalinton, S., Suttajit, M., 2016. A checklist of recent non-marine ostracods (Crustacea: Ostracoda) from Thailand, including descriptions of two new species. *Zootaxa* 4067 (1), 1–34.
- Savatnalinton, S., Borgonie, G., Martens, K., 2008. On *Thaicythere srisumona* n. gen., n. sp. (Ostracoda) from Thailand, with notes on the phylogeny of the subfamily Timiriaseviinae Mandelstam, 1960. *Crustaceana* 81 (4), 411–432.
- Scheffer, M., Zimmer, K., Jepsen, E., Søndegaard, M., Butler, M.G., Hanson, M.A., et al., 2006. Small habitat size and isolation can promote species richness: second-order effects on biodiversity in shallow lakes and ponds. *Oikos* 121, 227–231.

- Segers, H., 1993. Rotifera of some lakes in the floodplain of the river Niger (Imo State, Nigeria), 1: new species and other taxonomic considerations. *Hydrobiologia* 250, 39–61.
- Segers, H., 1996. The biogeography of littoral *Lecane* Rotifera. *Hydrobiologia* 323, 169–197.
- Segers, H., 2001. Zoogeography of the Southeast Asian Rotifera. *Hydrobiologia* 446/447, 233–246.
- Segers, H., 2003. A biogeographical analysis of rotifers of the genus *Trichocerca* Lamarck, 1801 (Trichocercidae, Monogononta, Rotifera), with notes on taxonomy. *Hydrobiologia* 500, 113–114.
- Segers, H., 2007. A global checklist of the rotifers (Phylum Rotifera). *Zootaxa* 1564, 1–104.
- Segers, H., 2008. Global diversity of rotifers (Rotifera) in freshwater. *Hydrobiologia* 595, 49–59.
- Segers, H., Nwadiro, C.S., Dumont, H.J., 1993. Rotifera of some lakes in the floodplain of the river Niger (Imo State, Nigeria). II faunal composition and diversity. *Hydrobiologia* 255/256, 475–480.
- Serafim Jr, M., Bonecker, C.C., Rossa, D.C., Lansac-Tôha, F.A., Costa, C.L., 2003. Rotifers of the upper Paraná River floodplain: additions to the checklist. *Brazilian Journal of Biology* 63, 207–212.
- Setubal, R.B., Araújo do Nascimento, R., Bozelli, R.L., 2020. Zooplankton secondary production: main methods, overview and perspectives from Brazilian studies. *International Aquatic Research* 12, 85–99.
- Shuhaimi-Othman, M., Yakub, N., Ramle, N., Abad, A., 2011. Toxicity of metal to a freshwater ostracod: *Stenocypris major*. *Journal of Toxicology* 2011, 1–8.
- Silva, W., 2008. Diversity and distribution of the free-living freshwater Cyclopoida (Copepoda: Crustacea) in the Neotropics. *Brazilian Journal of Biology* 68, 1099–1106.
- Silveira, R.D.M.L., de Paiva, L.L.A.R., Camargo, J.C., 2010. Top-down control in a tropical shallow lake of Northern Pantanal, Brazil. *Acta Limnologica Brasiliensia* 22 (4), 455–465.
- Simões, N.R., Ribeiro, S.M., Sonoda, S.L., 2011. Diversity and structure of microcrustacean assemblages (Cladocera and Copepoda) and limnological variability in perennial and intermittent pools in a semi-arid region, Bahia, Brazil. *Iheringia, Série Zoologia* 101 (4), 317–324.
- Sinev, A.Y., Coronel, J.S., 2006. A new species of genus *Alona* Baird, 1843 (Cladocera: Anomopoda: Chydoridae) from the Bolivian Andes. *Archiv für Hydrobiologie, Supplement* 15114, 395–408.
- Sipaúba-Tavares, L., Truzzi, B., Berchielli-Morais, F., 2014. Growth and development time of subtropical Cladocera *Diaphanosoma birgei* Korinek, 1981 fed with different microalgal diets. *Brazilian Journal of Biology* 74 (2), 464–471.
- Smith, A.J., Delorme, L.D., 2010. Chapter 19: Ostracoda. In: Thorp, J.H., Covich, A.P. (Eds.), *Ecology and Classification of North American Freshwater Invertebrates*. Academic Press, London, pp. 725–771.
- Sohn, I.G., Kornicker, L.S., 1972. Predation of schistosomiasis vector snails by Ostracoda (Crustacea). *Science* 175 (4027), 1258–1259.
- Sousa, F.D.R., Elmoor-Loureiro, L.M.A., Mendonça-Galvão, L., 2013. Cladocerans (Crustacea, Anomopoda and Ctenopoda) from Cerrado of Central Brazil: inventory of phytophilous community in natural wetlands. *Biota Neotropica* 13 (3), 222–229.
- Spindler, K., 1971. Dormanzauslösung und Dormanzcharakteristika beim Süßwassercopepoden *Cyclops vicinus*. *Zoologische Jahrbücher Physiologie* 76, 139–151.



- Stark, J.S., Riddle, M.J., Simpson, R.D., 2003. Human impacts in soft-sediment assemblages at Casey Station, East Antarctica: spatial variation, taxonomic resolution and data transformation. *Austral Ecology* 28 (3), 287–304.
- Stenert, C., Wüsth, R., Pires, M.M., Freiry, R.F., Nielsen, D., Maltchik, L., 2017. Composition of cladoceran dormant stages in intermittent ponds with different hydroperiod lengths. *Ecological Research* 32 (6), 921–930.
- Stepien, C.A., Brusca, R.C., 1985. Nocturnal attacks on nearshore fishes in southern California by crustacean zooplankton. *Marine Ecology, Progress Series* 25, 91–105.
- Thomaz, S.M., Cunha, E.R., 2010. The role of macrophytes in habitat structuring in aquatic ecosystems: methods of measurement, causes and consequences on animal assemblages' composition and biodiversity. *Acta Limnologica Brasiliensia* 22 (2), 218–236.
- Valentine, J.W., 2009. Overview of marine biodiversity. In: Witman, J.D., Roy, K. (Eds.), *Marine Macroecology*. The University of Chicago Press, Chicago, pp. 3–28.
- Van Damme, K., Dumont, H.J., 2010. Cladocera of the Lençóis Maranhenses (NE - Brazil): faunal composition and a reappraisal of Sars' method. *Brazilian Journal of Biology* 70, 755–779.
- Van Damme, K., Eggermont, H., 2011. The Afromontane Cladocera (Crustacea: Branchiopoda) of the Rwenzori (Uganda–D. R. Congo): taxonomy, ecology and biogeography. *Hydrobiologia* 676, 57–100.
- Van Damme, K., Sinev, A.Y., 2013. Tropical Amphi-Pacific disjunctions in the Cladocera (Crustacea: Branchiopoda). *Journal of Limnology* 72 (s2), pp. 209–244.
- Van Damme, K., Kotov, A.A., 2016. The fossil record of the Cladocera (Crustacea: Branchiopoda): evidence and hypotheses. *Earth-Science Reviews* 163, 162–189.
- Van Damme, K., Maiphae, S., 2013. *Salinalona* gen. nov., an euryhaline chydorid lineage (Crustacea: Branchiopoda: Cladocera: Anomopoda) from the Oriental Region. *Journal of Limnology* 72 (s2), 142–173.
- Van Damme, K., Bekker, E., Kotov, A.A., 2013. Endemism in the Cladocera (Crustacea: Branchiopoda) of Southern Africa. *Journal of Limnology* 72 (3), 440–463.
- Van Damme, K., Dumont, H.J., 2008. Further division of *Alona* Baird, 1843: separation and position of *Coronatella* Dybowski & Grochowski and *Ovalona* gen. n. (Crustacea: Cladocera). *Zootaxa* 1960, 1–44.
- Van Damme, K., Maiphae, S., Sa-artrit, P., 2013. Inland swamps in South East Asia harbour hidden cladoceran diversities: species richness and the description of new paludal Chydoridae (Crustacea: Branchiopoda: Cladocera) from Southern Thailand. *Journal of Limnology* 72 (s2), 174–208.
- Van der Meeren, T., Ito, E., Laird, K.R., Cumming, B.F., Verschuren, D., 2019. Ecohydrological evolution of Lake Naivasha (central Rift Valley, Kenya) during the past 1650 years, as recorded by ostracod assemblages and stable-isotope geochemistry. *Quaternary Science Reviews* 223, 105906.
- van der Valk, A.G. (Ed.), 2006. *The Biology of Freshwater Wetlands*. Oxford University Press, New York.
- Van Harten, D., 1975. Size and environmental salinity in the modern euryhaline ostracod *Cyprideis torosa* (Jones, 1850), a biometrical study. *Palaeogeography, Palaeoclimatology, Palaeoecology* 17 (1), 35–48.
- Vandekerckhove, J., Namiotko, T., Hallmann, E., Martens, K., 2012. Predation by macroinvertebrates on *Heterocypris incongruens* (Ostracoda) in temporary ponds: impacts and responses. *Fundamental and Applied Limnology/Archiv für Hydrobiologie* 181 (1), 39–47.

- Vannier, J., Abe, K., Ikuta, K., 1998. Feeding in myodocopid ostracods: functional morphology and laboratory observations from videos. *Marine Biology* 132 (3), 391–408.
- Vanschoenwinkel, B., Gielen, S., Seaman, M., Brendonck, L., 2008a. Any way the wind blows—frequent wind dispersal drives species sorting in ephemeral aquatic communities. *Oikos* 117 (1), 125–134.
- Vanschoenwinkel, B., Gielen, S., Vandewaerde, H., Seaman, M., Brendonck, L., 2008b. Relative importance of different dispersal vectors for small aquatic invertebrates in a rock pool meta-community. *Ecography* 31, 567–577.
- Vanschoenwinkel, B., Waterkeyn, A., Nhiwatiwa, T., Pinceel, T., Spooren, E., Geerts, A., et al., 2011. Passive external transport of freshwater invertebrates by elephant and other mud-wallowing mammals in an African savannah habitat. *Freshwater Biology* 56 (8), 1606–1619.
- Wasserman, R.J., Alexander, M.E., Barrios-O’Neill, D., Weyl, O.L.F., Dalu, T., 2015. Using functional responses to assess predator hatching phenology implications for pioneering prey in arid temporary pools. *Journal of Plankton Research* 38, 154–158.
- Wasserman, R.J., Dalu, T., 2022. Tropical freshwater wetlands: an introduction. In: Dalu, T., Wasserman, R.J. (Eds.), *Fundamentals of Tropical Freshwater Wetlands: From Ecology to Conservation Management*. Academic Press, London.
- Waterkeyn, A., Grillas, P., Vanschoenwinkel, B., Brendonck, L., 2008. Invertebrate community patterns in Mediterranean temporary wetlands along hydroperiod and salinity gradients. *Freshwater Biology* 53, 1808–1822.
- Waterkeyn, A., Vanschoenwinkel, B., Grillas, P., Brendonck, L., 2010. Effect of salinity on seasonal community patterns of Mediterranean temporary wetland crustaceans: a mesocosm study. *Limnology and Oceanography* 55, pp. 1712–1722.
- Williams, D., 2016. Chapter 11: Invertebrates in groundwater springs and seeps. In: Batzer, D., Boix, D. (Eds.), *Invertebrates in Freshwater Wetlands: An International Perspective on Their Ecology*. Springer International Publishing, Switzerland, pp. 357–409.
- Woodward, G., Brown, L.E., Edwards, F.K., Hudson, L.N., Milner, A.M., Reuman, D.C., et al., 2012. Climate change impacts in multispecies systems: drought alters food web size structure in a field experiment. *Philosophical Transactions of the Royal Society B: Biological Sciences* 367 (1605), 2990–2997.
- Yencken, D., Wilkinson, D., 2000. *Resetting the Compass: Australia’s Journey Towards Sustainability*. CSIRO Publishing, Melbourne.
- Yin, Y., Geiger, W., Martens, K., 1999. Effects of genotype and environment on phenotypic variability in *Limnocythere inopinata* (Crustacea: Ostracoda). *Hydrobiologia* 400, 85–114.

## Further reading

- Blindow, I., Hargeby, A., Wagner, B.M.A., Andersson, G., 2000. How important is the crustacean plankton for the maintenance of water clarity in shallow lakes with abundant submerged vegetation. *Freshwater Biology* 44, 185–197.
- Bonecker, C.C., Da Costa, C.L., Velho, L.F.M., Lansac-Tôha, F.A., 2005. Diversity and abundance of the planktonic rotifers in different environments of the Upper Paraná River floodplain (Paraná State—Mato Grosso do Sul State, Brazil). *Hydrobiologia* 546, 405–414.
- Dumont, H.J., 1983. Biogeography of rotifers. *Hydrobiologia* 104, 19–30.
- Fonseca, B.M., de Mendonça-Galvão, L., Sousa, F.D.R., Elmoor-Loureiro, L.M.A., Gomes-e-Souza, M.B., Pinto, R.L., et al., 2017. Biodiversity in pristine wetlands of Central Brazil: a multi-taxonomic approach. *Wetlands* 38, 145–156.

- Hay, W.W., DeConto, R.M., Wold, C.N., Wilson, K.M., Voigt, S., Schulz, M., et al., 1999. Alternative global cretaceous paleogeography. In: Barrera, E., Johnson, C.C. (Eds.), Evolution of the Cretaceous Ocean-climate System. Geological Society of America Special Paper 332, pp. 1–47.
- Segers, H., 1992. Taxonomy and zoogeography of the rotifer fauna of Madagascar and the Comoros. *Revue de Zoologie Africaine* 106, 351–361.
- Van Damme, K., Sinev, A.Y., Dumont, H.J., 2011. Separation of *Anthalona* gen.n. from *Alona* Baird, 1843 (Branchiopoda: Cladocera: Anomopoda): morphology and evolution of scraping stenothermic alonines. *Zootaxa* 2875, 1–64.

