Spatio-temporal distribution of ostracod species in saline inland lakes (Mansfeld lake area; Central Germany)

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Ostracods are a diverse group of microcrustaceans with a ubiquitous distribution in a wide array of aquatic habitats and are common constituents of lake sediments. Inferences on temporal-spatial distribution of ostracod species is the prerequisite for reconstructions of palaeoenvironmental conditions. This requires a precise knowledge not only about ecological preferences and specific life histories, but also the understanding how (local) ecological parameters affect ostracod species assemblages (abundance and composition). Generally, these studies are rare and often characterized by an insufficient differentiation of living specimens from the total amount of valves of the modern population leading to uncertainties in species occurrences and diversity data. Modern ostracod populations were sampled from 12 water bodies within a relatively small study area (Mansfeld lake area, Central Germany). Physico-chemical parameters (temperature, oxygen content, salinity, pH) were measured *in situ* and the uppermost 2 cm of sediment were collected in different seasons (April, June, September). Relative abundances of ostracods (soft parts and valves), differentiated for adults and juveniles were used for statistical analyses (Spearman`s rank correlation, Canonical correspondence analysis, Cluster analyses, Fisher´s α), to investigate relationships between species distribution and environmental factors as well as to identify habitat similarities and ostracod species assemblages. In total, 27 ostracod species (20 living species) were identified. Majority of them are considered as very common (cosmopolitan) freshwater species. Only two species are usually known from brackish water. The relative abundances of ostracods show strong fluctuations during the study period and differences in composition of the ostracod species assemblages between and within the water bodies. There are also strong differences between bio- and taphocoenoses. The measured physico-chemical parameters which are usually considered as most important drivers on ostracod species distribution do not contribute to explain the observed temporal-spatial distribution of the ostracod species. Differences in taphocoenoses show, that taphonomic processes can be very local and the sampling site,

as well as the sampling time, is crucial. Biodiversity of ostracods is biased by sampling time, the variability of the ostracod assemblages between sampling month and that the relationship between abundance of valves and living ostracods is not straightforward. Therefore, without precise knowledge of the ecological requirements of a species at a local scale, uncertainties may for the palaeoecological indication of a species.

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35   **Abstract**

36   Ostracods are a diverse group of microcrustaceans with a ubiquitous distribution in a wide
37   array of aquatic habitats and are common constituents of lake sediments. Inferences on
38   temporal-spatial distribution of ostracod species is the prerequisite for reconstructions of
39   palaeoenvironmental conditions. This requires a precise knowledge not only about ecological
40   preferences and specific life histories, but also the understanding how (local) ecological
41   parameters affect ostracod species assemblages (abundance and composition). Generally,
42   these studies are rare and often characterized by an insufficient differentiation of living
43   specimens from the total amount of valves of the modern population leading to uncertainties
44   in species occurrences and diversity data.
45   Modern ostracod populations were sampled from 12 water bodies within a relatively small
46   study area (Mansfeld lake area, Central Germany). Physico-chemical parameters
47   (temperature, oxygen content, salinity, pH) were measured *in situ* and the uppermost 2 cm of
48   sediment were collected in different seasons (April, June, September). Relative abundances
49   of ostracods (soft parts and valves), differentiated for adults and juveniles were used for
50   statistical analyses (Spearman`s rank correlation, Canonical correspondence analysis, Cluster
51   analyses, Fisher´s α), to investigate relationships between species distribution and
52   environmental factors as well as to identify habitat similarities and ostracod species
53   assemblages.
54   In total, 27 ostracod species (20 living species) were identified. Majority of them are
55   considered as very common (cosmopolitan) freshwater species. Only two species are usually
56   known from brackish water. The relative abundances of ostracods show strong fluctuations
57   during the study period and differences in composition of the ostracod species assemblages
58   between and within the water bodies. There are also strong differences between bio- and
59   taphocoenoses.
60   The measured physico-chemical parameters which are usually considered as most important
61   drivers on ostracod species distribution do not contribute to explain the observed temporal-
62   spatial distribution of the ostracod species. Differences in taphocoenoses show, that
63   taphonomic processes can be very local and the sampling site, as well as the sampling time,
64   is crucial.
65   Biodiversity of ostracods is biased by sampling time, the variability of the ostracod
66   assemblages between sampling month and that the relationship between abundance of valves
67   and living ostracods is not straightforward. Therefore, without precise knowledge of the
68   ecological requirements of a species at a local scale, uncertainties may for the
69   palaeoecological indication of a species.

1. Introduction

70

71 Global climate change and predictions of its consequences for future distribution and

72 diversity of the Earth´s biota is distinctly biased to the terrestrial megafauna and

73 megaflora (Baillie *et al.*, 2008). Despite their high diversity, vast array of ecosystem

74 services, and their importance for the human wellbeing, invertebrates are often neglected in

75 biodiversity conservation policies due to the unawareness of the general public to invertebrates.

76 Moreover, basic science on invertebrates is scarce and underfunded which contributes to that

77 most species remain undescribed and the spatial and temporal distribution of species as well as

78 their ecological preferences is mostly unknown (Cardoso *et al.*, 2011).

79 Ostracods (bivalved microcrustaceans), are one of the most diverse groups of living benthic

80 invertebrates (Horne, Meisch & Martens, 2019), inhabit almost all types of aquatic

81 environments: marine, freshwater and even some semi-terrestrial (Horne, Cohen & Martens,

82 2002). In particular, freshwater ostracods are of great interest in a variety of ecological and

83 evolutionary studies because they are partially found *en masse* in aquatic environments and their

84 calcified valves are common and well preserved in lake sediments (Martens *et al.*, 2008).

85 Although ostracods have generally very broad ecological tolerances, distribution is mainly

86 determined by a variety of physico-chemical (biotic) factors (temperature, pH, salinity, oxygen

87 content, substrate type and depth) (Mezquita *et al.*, 2005), as well as abiotic factors (competition,

88 predation, commensalism) (Guisan, Thuiller & Zimmermann, 2010) and each species has

89 specific tolerances and preferences to these factors (Kiss, 2007). The short life-cycles

90 (sometimes <1 year) and high population rates allow ostracod assemblages to respond quickly to

91 local environmental changes (De Bie *et al.*, 2012).

92   Given this backdrop, ostracods have established as proxies for manifold palaeoenvironmental

93   studies in recent decades (Boomer, Horne & Slipper, 2003). Precise autecological inferences

94   based on fossil material depends on extensive knowledge about the ecological requirements and

95   life-cycle information of the different species, as well as additionally (local) influences on these.

96   Nonetheless, comprehensive studies on these are still rare (Viehberg, 2005; Külköylüoğlu,

97   Yılmaz & Yavuzatmaca, 2017). However, life cycle (or seasonal distribution), ecology, and

98   transfer into the geologic record (taphonomic processes) have rarely been considered together.

99   This, in turn, is problematic, as sometimes incorrect diversity estimates are obtained and, most

100 importantly, imprecise assumptions are made about ecological preferences or (subtle) responses

101 to environmental changes are overlooked, which leads to a discrepancy between Recent and

102 fossil data. Also problematic is the, often, insufficient differentiation between living ostracods

103 (biocoenoses) and valves (taphocoenoses). Diversity and ecology of species are usually

104 evaluated on the basis of Recent material (but usually only valves). Species or entire

105 assemblages are, thus, assigned to incorrect environmental conditions. In addition, studies are

106 mostly based on large-scale trends, which are transferred to local scales (e.g., Pint *et al.*, 2017).

107 The Mansfeld lake area offers several water bodies all differing slightly with respect to

108 hydrochemistry, hydro(geo)logy or degree of pollution settled within a relatively small

109 geographical area. These water bodies offer as `natural laboratories´ ideal conditions to study the

110 effects of regional and local environmental parameters and their seasonal fluctuations on the

111 distribution of individual ostracod species, but also on the entire community. The region is

112 located 25 km west of Halle (Saale) a city of Saxony-Anhalt, in the centre of the central German

113 dry region. It is characterized by low precipitation (428 mm/a), a negative water balance, as well

114 as short and pronounced extreme rainfall events (Wennrich, 2005). Another peculiarity of the

115   region is the natural salinity of the water bodies, which is caused by saline inflows of salt

116   deposits of Permian age from the underground (Wennrich, Meng & Schmiedl, 2007).

117   Temperature and salinity are thought to be major controlling factors for distribution of

118   freshwater ostracod species (Ruiz *et al.*, 2013).

119   Accordingly, spatial ostracod species distribution, abundance, and diversity in the Mansfeld lake

120   area should reflect differences in salinity levels. By repeated sampling, we also wanted to

121   investigate if there is a seasonal effect on the distribution and abundance of the ostracod species

122   related to the specific life-cycle of the species.

123

124   **2.   Materials and methods**

125   Three sampling campaigns were carried out in 2019 (April 16, June 7 and September 12) in the

126   Mansfeld lake area. During each sampling campaign, 10-12 water bodies (ponds, small lakes,

127   ditch) were investigated. An overview about the sampling localities is provided in Table 1.

128   Generally, we tried to visit the same sampling site at each water body as far as possible.

129   Exceptions were made at the lakes TE and ST due to limited access due to dense vegetation of

130   the first sampling site. The sampling localities differed ~80 m north and 120 m east, respectively,

131   from the first site.

132   Most of the investigated water bodies (KS, BS, TE, TE2, QW and MG) lie within the area of the

133   former lake `Salziger See´. `Süßer See´ is located north of the former `Salziger See´, outside the

134   lake basin, but is directly connected by ditches with KS, BS and MG. Both (`Süßer See´ and

135   former `Salziger See´) are located in the deepest part of a large depression (Teutschenthal

136   Anticline) (Wennrich *et al.*, 2007). The remaining water bodies (OT, OT2, WL, TA, ST) are

137   located outside this area, topographically higher and with a maximum distance of 3 km, but

138   mostly located at the marginal area of the former `Salziger See´ (Fig 1). Although the water

139   bodies presumably all have the same catchment, they have different sub-catchments, and the

140   water bodies outside the anticline have different hydrological conditions (e.g., saline inflows).

141   Physico-chemical variables (water temperature, electrical conductivity, pH and oxygen content)

142   were measured *in situ* using probes of the company WTW. Sediment samples were collected

143   from the uppermost few (approx.1-2) centimetres of sediment in the littoral zone using a hand

144   net.

145   The samples were fixed with 70% Ethanol to preserve living specimens. The sediment samples

146   were washed with tap water through standard sieves sizes (1000 µm, 500 µm, 250 µm and 125

147   µm). The sieve residues from mesh sizes 500 µm and 250 µm were transferred to sample bags

148   using 70% ethanol. Ostracods were separated from sediment and species were sorted under a

149   binocular microscope. Ostracods with soft parts were preserved in ethanol for further

150   investigations, empty carapaces and valves were dried at room temperature and stored in micro

151   cells. Empty carapaces and valves were sorted by juveniles and adults. Different juvenile stages

152   were not distinguished.

153   Species identification was based in most cases on valve morphology according to Meisch (2000),

154   Fuhrmann (2012), and Wennrich (2005). For some unidentified species soft part analysis was

155   performed. All ostracod valves were counted (carapace = two valves) and relative abundances

156   were calculated.

157

158   ***Data analyses***

159   Spearman`s rank correlation test was applied to identify relation among abundances of living

160   species and physico-chemical parameters.

161   Canonical correspondence analysis (CCA) was used to investigate the relationships between the

162   distribution of living ostracod species and physical and chemical environmental parameters.

163   Relative abundances of species were used for CCA analyses. Four environmental variables

164   including water temperature, electrical conductivity, oxygen content and pH, were selected for

165   the CCA.

166   To calculate Fisher´s α diversity and richness of the water bodies, the absolute numbers of

167   taphocoenoses of all three months were summed for each species. Additionally, to reveal

168   ostracod assemblages and determine habitat similarities a cluster analysis was carried out.

169   Cluster analyses were performed based on relative abundances of the species, separately for

170   biocoenoses and taphocoenoses in two ways (for water bodies and species). As clustering

171   algorithm, Ward´s method to a Euclidian distance matrix was used. In all analyses, samples

172   (water bodies) containing less than 100 individuals were excluded. Furthermore, all species with

173   overall abundances ≤5% and occurring only in one site were also excluded from the analyses.

174   All statistical analyses were conducted using PAST version 3.25 (2019).

175
176   **3.   Results**

177   ***Physico-chemical variables and habitat characteristics***
178
179   Water temperature shows the strongest seasonal fluctuations ranging between 8.6 in April and

180   26.5°C in June (Fig 2 A). Temperature ranges and fluctuations are similar for all water bodies.

181   Generally, higher water temperatures were measured in smaller water bodies (e.g., WL). The

182   lowest temperatures are provided by a spring (QW). This locality provided the strongest

183   difference of the water temperature compared to other water bodies in June.

184   Conductivity values range between 1.3 mS/cm (OT2) and 26.7 mS/cm (Fig 2 B).

185   The water bodies within the area of the former lake `Salziger See´ (KS, BS, TE, TE2 and QW)

186   have highest conductivity values in April and lowest in September. They provide generally

187   higher values than localities outside this area. The spring QW exhibits the strongest seasonal

188   fluctuations from 14.5 to 26.7 MS/cm. The other localities display relatively constant values

189   during the sampling period.

190   Dissolved oxygen (DO) concentrations vary between 2.77 mg/l (OT2) and 19.4 mg/l (BS) and is

191   in April in most localities higher than in the following months (Fig 2 C). Although temperatures

192   were markedly lower in September, the oxygen content of the water bodies is similar to the

193   values measured in June. In contrast to temperature ranges, is the oxygen content more

194   specifically for the localities. For instance, contrary to the general trend displays OT highest

195   oxygen value in June.

196   In all sites, pH values were ≥ 7 at each sampling site and reach a maximum of 8.9 in BS (Fig 2

197   D). The lowest value 7 was measured in the spring QW in September. Mean pH values are

198   higher in April (8.3), than those in June (8.0) and September (7.7). Generally, values in June and

199   September are relatively similar, except OT where the June value reflects the April value.

200   Substrate texture is dominated by sandy (e.g., BS and KS) and muddy substrate (e.g., TE, TA).

201   Some localities are characterised by algae (SS), detritus (e.g., BS) or aquatic macrophytes (OT).

202   Detailed information is summarised in Table 1.

203
204   ***Ostracod communities***
205
206   *General observations*

207

208 Ostracods were found in all localities (and all samples). Living ostracods were found in 8 out of

209 10 water bodies in April, 10 out of 11 in June, and 9 out of 10 in September. The abundance of

210 valves and living ostracods vary extremely between the localities, within the habitats, and

211 between the months. Compared to the previous months, number of valves and living ostracods

212 were significantly lower in September. An extreme case was documented in a small pond (WS)

213 where number of living ostracods decreased from several hundred (April 794, June 989) to only

214 one specimen in September (Fig 3). Other localities provide a lower variation in living ostracod

215 numbers (e.g., KS).

216
217 *Species list*
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219 In total, 27 podocopid ostracod species were identified based on valve morphology according to

220 Meisch (2000) and Fuhrmann (2012). Twenty species of them were also found living. In some

221 cases, soft parts were analysed, too, in order to identify individuals on species level, e.g., *F.*

222 *fabaeformis, F. holzkampfi, H. incongruens* and *I. gibba*.

223 The following ostracod species were found:

224 Superfamily: Darwinuloidea Brady & Norman, 1889
225   Family: Darwinulidae Brady & Norman, 1889
226   Genus: *Darwinula* Brady & Robertson,1885
227   *Darwinula stevensoni* (Brady & Robertson, 1870)

228 Superfamily: Cypridoidea Baird, 1845
229   Family: Candonidae Kaufmann, 1900
230   Subfamily: Candoninae Kaufmann, 1900
231   Genus: *Candona* Baird, 1845
232   *Candona candida* (O.F. Müller, 1776)
233   *Candona neglecta* Sars, 1887
234   Genus: *Fabaeformiscandona* Krstić, 1972
235   *Fabaeformiscandona fabaeformis* (Fischer, 1851)
236   *Fabaeformiscandona holzkampfi* (Hartwig, 1900)
237   Genus: *Pseudocandona* Kaufmann, 1900
238   *Pseudocandona compressa* (Koch, 1838)
239   *Pseudocandona marchica* (Hartwig, 1899

240   Genus: *Candonopsis* Vavra, 1891
241   *Candonopsis kingsleii* (Brady & Robertson, 1870)
242   Subfamily: Cyclocypridinae Kaufmann, 1900
243   Genus: *Physocypria* Vavra, 1897
244   *Physocypria kraepelini* G.W. Müller, 1903

245   Family: Ilyocyprididae Kaufmann, 1900
246   Subfamily: Ilyocypridinae Kaufmann, 1900
247   Genus: *Ilyocypris* Brady & Norman, 1889
248   *Ilyocypris bradyi* Sars, 1890
249   *Ilyocypris gibba* (Ramdohr, 1808)
250   *Ilyocypris monstrifica* (Norman, 1862)

251   Family: Notodromatidae Kaufmann, 1900
252   Subfamily: Notodromatinae Kaufmann, 1900
253   Genus: *Notodromas* Lilljeborg, 1853
254   *Notodromas monacha* (O.F. Müller, 1776)

255   Family: Cyprididae Baird, 1845
256   Subfamily: Eucypridinae Bronstein, 1947
257   Genus: *Eucypris* Vavra, 1891
258   *Eucypris virens* (Jurine, 1820)
259   *Eucypris sp?*
260   Genus: *Prionocypris* Brady & Norman, 1896
261   *Prionocypris zenkeri* (Chyzer & Toth, 1858)

262   Subfamily: Herpetocypridinae Kaufmann, 1900
263   Genus: *Herpetocypris* Brady & Norman, 1889
264   *Herpetocypris chevreuxi* (Sars, 1896)

265   Subfamily: Cyprinotinae Bronstein, 1947
266   Genus: *Heterocypris* Claus, 1892
267   *Heterocypris incongruens* (Ramdohr, 1808)
268   *Heterocypris salina* (Brady, 1868)

269   Subfamily: Cypridopsinae Kaufmann, 1900
270   Genus: *Cypridopsis* Brady, 1867
271   *Cypridopsis vidua* (O.F. Müller, 1776)
272   Genus: *Plesiocypridopsis* Rome, 1965
273   *Plesiocypridopsis newtoni* (Brady & Robertson, 1870)
274   Genus: *Sarscypridopsis* McKenzie, 1977
275   *Sarscypridopsis aculeata* (Costa, 1847)
276   Genus: *Potamocypris* Brady, 1870
277   *Potamocypris arcuata* (Sars, 1903)
278   *Potamocypris smaragdina* (Vavra, 1891)

279 Superfamily: Cytheroidea Baird, 1850
280   Family: Limnocytheridae Klie, 1938
281   Subfamily: Limnocytherinae Klie, 1938
282   Genus: *Limnocythere* Brady, 1867

283   *Limnocythere inopinata* (Baird, 1843)

284   Family: Cytherididae Sars, 1925
285   Genus: *Cyprideis* Jones, 1857
286   *Cyprideis torosa* (Jones, 1850)

287   Family: Loxoconchidae Sars, 1925
288   Genus: *Cytheromorpha* Hirschmann, 1909
289   *Cytheromorpha fuscata* (Brady, 1869)

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298   ***Spatial and seasonal distribution***

299   *General remarks*

300   Seasonal distribution of the ostracod species of the Mansfeld lake area is displayed at Fig 3. The

301   species list is sorted by maximum salinity tolerance values according to Frenzel et al. (2010).

302   This results in 5 groups, each for the ranges of ≤5 PSU, ≤10 PSU, ≤15 PSU, ≤20 PSU, and ≤25

303   PSU, whereby group I refers to the lowest salinity values and group V to the highest. Within this

304   groups, species are also sorted by increasing salinity tolerance. Water bodies were also classified

305   in ascending order according to salinity values. Category a includes water bodies outside the

306   former `Salziger See´ area. These water bodies have lower salinity values (0.7 to 4 PSU) and are

307   comparatively small. Category b consist of the water bodies within the former `Salziger See´

308   with higher salinity values (4.4 to 20.7 PSU), and are larger than the water bodies in category a

309   (except QW). Category c comprises SS, the largest lake in the study area, and MG, a section of a

310   ditch that encircles the former `Salziger See´. Both water bodies have low salinity values (0.9 to

311   1.3 PSU). All of the species are freshwater species (except *C. torosa* and *C. fuscata*), most of

312   them are found in group I (lowest salinity tolerance) and the lowest number of species is found in

313   groups with higher salinity tolerances (Group IV and V).

314   In water bodies of category a are on average significantly smaller number of species than in

315   water bodies of category b.

316   The water bodies display significant differences in terms of their species composition in bio- and

317   taphocoenoses between the sampling months.

318

319   *April*

320   Even if the number of species that belong to group I is highest, in April almost all species of this

321   group occur only very sporadically and in very low abundances (mostly ≤5%). This is

322   particularly clear in biocoenoses and slightly less pronounced in taphocoenoses (Fig 3).

323   In group II there is a distinct increase in species number and abundances. Especially in section II

324   a, more species in higher numbers occur, notably for three species (*C. candida, C. vidua, L.*

325   *inopinata*) with a lower salinity tolerance in this group. In category b the increase can also be

326   observed, but less significant. Here, species are more common, but abundances are still rather

327   low (mostly ≤5%), especially in taphocoenoses, and also but much less pronounced, in

328   biocoenoses. This development is mainly due to higher appearances of *H. salina*.

329   Although group III (≤15 PSU) includes only half as many species as group II, the species are

330   equally common and abundant. Here, as well, abundances in bio- and taphocoenoses are

331   significantly higher in III a than in III b, where abundances especially in taphocoenoses are

332   rather low (≤5%). In biocoenoses, species richness is the same than in group II b, but the

333   abundances are slightly higher.

334   Higher abundances in group II and III in category a are mainly explained by three species (*C.*

335   *vidua, L. inopinata* and *P. kraepelini*), which often and plentiful occur in both, bio- and

336   taphocoenoses. Species belongs to group IV were not found living in April, although *S. aculeata*

337   is the most abundant species in TE and TE2 in taphocoenoses.

338   In group V category a, occurrences and abundances are very low, but approximately highest in

339   category b, which is cause by *C. torosa*.

340   In general, in category a) the most common and abundant species in taphocoenoses are the same

341   as in biocoenoses. For instance, *C. vidua* and*, P. kraepelini* are common and abundant, *L.*

342   *inopinata* occurs locally but with high abundances, and *C. candida* is common but with low

343   abundances and never found alive). In category b, *C. torosa* is the only common and abundant

344   species in bio- and taphocoenoses. Generally, most of the common species are not very abundant

345   (e.g., *C. candida, L. inopinata, H. salina*). Abundant species in taphocoenoses are not abundant

346   in biocoenoses (*H. salina, I. gibba, S. aculeate*) and common and abundant species in

347   biocoenoses are not in taphocoenoses (e.g., *H. salina, C. neglecta, D. stevensoni*).

348

349   *June*

350   In June the distribution of the species is much more inconsistent compared to April. In Group I

351   (i.e., low salinity tolerant-species) comparatively few species (e.g., in comparison to group II)

352   can be found again. Nevertheless, there are significantly more species than in April. Species with

353   lowest salinity tolerances (uppermost species of group I) are particularly widespread. This

354   applies to all three categories. Overall, in this group species are not only more common, there is

355   also an increase in abundances, both in bio- and taphocoenoses. In group II, in all water bodies

356   species are more common, and abundance of some species increase significantly.

357   In category a, the species distribution mainly relies on the species with comparatively low

358   salinity tolerances (uppermost). The water bodies are nearly similar in their species composition.

359   In category b, on the other hand, the differences between the water bodies are larger. Almost all

360   species occur in KS and BS, while species are basically not apparent in the other water bodies.

361   An exception represents *H. salina*, which is common and abundant in all water bodies of

362   category b. Abundances also increase slightly in category c, but a comparison is difficult as this

363   category only includes one water body.

364   In group III are only two of the four species of category a (*D. stevensoni* and *P. kraepelini*). But

365   these are very common and abundant in bio- and taphocoenoses. In category b the occurrence is

366   more dispersed and species in bio- and taphocoenoses are not very abundant. In category c also

367   two species occur (same like in category a). Abundances in taphocoenosis of *D. stevensoni* are

368   low but in biocoenoses it is relatively high (≤40%). In group IV a, species are very rare (one

369   species ≤4%). In category b two species occur with low abundances. In category c no species

370   was found. Group V is dominated by *C. torosa*, in category a in very low numbers, but in

371   category b and c it is the most common and abundant species in bio- and taphocoenoses.

372   In general, in all of the three categories abundant species in biocoenoses are also abundant in

373   taphocoenoses (with few exceptions e.g., *C. vidua* in ST and *H. salina* in TE2).

374

375   *September*

376   In September, species from group I, were found sporadically in the water bodies and only in very

377   low abundances. Except *P. marchica*, which occurs in category a alive and is also very abundant

378   in taphocoenoses.

379   In category b and c species are slightly more common and more often alive. Also in group II a,

380   the species occur only very sporadically, but the abundances in biocoenoses increase slightly

381   (due to *C. vidua*). In taphocoenoses the abundance also increases due to the mass occurrence of

382   *C. vidua* and *L. inopinata*. In category b, species are more common in both bio- and

383   taphocoenoses with a slight increase in abundances in taphocoenoses, even if most of the species

384   occur in low abundances (≤5%). In particular, living species are common but occur with low

385   abundances in this group and category. In category c, just a few species occur and with low

386   abundances, except of *C. vidua* which is the most common and abundant species. Group III a is

387   the category with highest abundances for these water bodies, although absolute numbers of

388   specimens are generally very low. Taphocoenoses are characterized by *P. kraepelini*, which is

389   very common and abundant. In taphocoenoses of category b, all species occur in KS but are

390   nearly absent in the other water bodies and abundances are very low (all ≤5%). In biocoenoses

391   the abundances increase (two species between 40-70%). In bio- and taphocoenoses of category c

392   abundances are low (≤4 in biocoenoses and ≤5% in taphocoenoses) and species are not very

393   common. In group IV and V, category a just two species (*S. aculeate* and *C. torosa*) occur in one

394   water body (OT2). They are not very common and abundance is low (≤5%) except for adult *S.*

395   *aculeate* (≤40%). In category b and c, the same two species occur. *S. aculeata*, however, is more

396   abundant and was also found alive. *C. torosa* on the other hand is the most abundant species in

397   bio- and taphocoenoses and was nearly found in all water bodies.

398   Samples from September are characterized by lowest number of species, as *P. zenkeri, C.*

399   *kingsleii, E. virens, F. fabaeformis, H. incongruens* and *P. newtoni* not occurred.

400   It should also be noted, that in September a relatively large number of species (in comparison to

401   the previous month), not occurring in taphocoenoses are found in biocoenoses (e.g*., C. vidua, D.*

402   *stevensoni, C. neglecta*). However, occurrences in the water bodies are similar to previous

403   samplings.

404   In general, in all categories most of the species that are abundant in taphocoenoses are also

405   abundant in biocoenoses. But there are more exceptions in September than in the previous

406   month. *C. vidua* for example is the second most species in OT2, but is not present in

407   taphocoenoses, *L. inopinata* is the most abundant species in taphocoenoses in WL, but living

408   specimens not occurred, instead *D. stevensoni* is dominant (but just with one living specimen) in

409   biocoenoses, but is not present in taphocoenoses.

410   In category b most of the species that are abundant in biocoenoses are less abundant in

411   taphocoenoses (≤4%), except *C. torosa* which is abundant in both.

412   In category c abundances of bio- and taphocoenoses correspond most closely.

413

414   *In summary*

415   Comparing the ostracod species of categories a and b (i.e., low vs higher salinities), two patterns

416   stand out. First, two species (*P. marchica* and *N. monacha*) occur exclusively in (bio- and

417   taphocoenoses) category a (low salinity), and two species (*P. compressa, I. gibba*) appear only in

418   category b (higher salinity). But these species are recorded with low specimen numbers. The

419   second point relates to the abundances of species. Some species occur in both water body

420   categories, but are common and abundant only in one category, while they occur sporadically

421   and with low numbers (and mostly only in taphocoenoses) in the other category. Although there

422   are fluctuations in the abundances of the water bodies between the months (especially in the

423   absolute values), it is noticeable that two species of the biocoenoses (*C. vidua* and *P. kraepelini*)

424   are common and mostly dominant in the water bodies with lower salinities in all months. The

425   same applies for the water bodies with higher salinity, the species here are *H. salina* and *C.*

426   *torosa*. The same pattern can be observed in taphocoenoses.

427 Despite the lower salinity values the ostracod assemblages of category c differ from category a.

428 Peculiarly, the ostracod assemblages of category c represent a combination of category a and b,

429 due to the occurrence of the most abundant species *C. vidua* and *C. torosa*.

430 There is another aspect, differentiating the water bodies from each other. First, there are a lower

431 number of species in smaller water bodies, dominated by one species while other species provide

432 only small numbers (e.g., in OT2, *P. kraepelini* exaggerates with 85% the other two species *F.*

433 *holzkampfi*; 9% and *C. vidua*; 6% by far). This becomes particularly obvious in biocoenoses and

434 is very stable during all months.

435 Contrary, in larger water bodies, there are significantly more living specimens while no species

436 is clearly dominant. Rather, species distribution is much more balanced and varies during the

437 months. The ambiguous distribution of species can be also seen in the Cluster analyses of water

438 bodies and species (Fig 4). The Cluster analysis of the biocoenoses reveals that the similarity of

439 the water bodies depends on the seasonal distribution of the species. Each sampling (i.e., month)

440 provides slightly different species composition contributing to distinct species assemblages.

441 Thus, taken all together there are neither distinct types of water bodies (and related

442 environmental conditions) nor specific ostracod species assemblages.

443 The picture is somewhat clearer in taphocoenoses of the five water body groups. More or less the

444 three samplings of a water body form a group, mostly together with spatially close (or

445 connected) water bodies (ex. KS, BS, MG, SS are one group). Only WL and TA form separate

446 groups, but are also more spatially distant from the other water bodies, and thus are more

447 isolated. Cluster analysis of the species revealed only two groups that can be associated with an

448 environmental parameter. These are *P. kraepelini* and *C. vidua* occurring in lower saline water

449 bodies as well as *I. gibba* and *H. salina* occurring in water bodies with higher salinities.

450   However, again, most species (the remaining 16) are in one group showing no species-specific

451   preferences.

452
453   ***Seasonal population structure***
454
455   There is no generalized pattern in taphocoenoses distribution of adult and juvenile valves (Fig 5).

456   Very different ratios were found between water bodies and between the sampling month. Some

457   localities show relatively constant ratios through the sampling period (e.g., KS, WL), while

458   others vary greatly (e.g., BS, TE2). Some water bodies, provided significantly more adults than

459   juveniles (e.g., KS, WL) while juveniles exaggerate adults in other water bodies (e.g., QW, TA).

460   The same applies to biocoenoses which are also characterized by very variable adult/juvenile

461   ratios.

462   However, there is a generally upwards trend of juvenile ostracod from April to September.

463

464   ***Species Diversity***

465   For the Fisher´s α diversity and richness data, taphocoenoses for all three months were

466   considered together (Fig 6). Diversity and richness show the same trend, whereby the richness

467   shows partially lower values. Richness and Fisher´s α diversity also do not show a clear trend or

468   pattern in relation to salinity. Up to 4 PSU, species richness and diversity decrease with

469   increasing salinity, following the pattern from Frenzel (2009). From 4 PSU, however, richness

470   increase, and has its maximum at 6 PSU. After that, the richness and diversity of species

471   decrease again.

472

473   ***Inferences on species life cycle***

474   Although only three samplings were made, covering only half a year, the species show clear

475   differences in their abundance patterns. The strongest fluctuations of the biocoenoses are *L.*

476   *inopinata* with a clear maximum in June. *D. stevensoni* and *H. salina* also have a maximum in

477   summer, although the differences between the months are much smaller, and the number of

478   individuals is generally significantly lower than that of *L. inopinata*. While *C. vidua* has its

479   minimum in summer but occurs in very low numbers in both April and September and shows no

480   clear maximum, *C. torosa* has its maximum in September. *P. kraepelini* shows a clear maximum

481   in April. This trend can be seen in the relative as well as in the absolute numbers. Almost all

482   species show the same pattern between adults and juveniles in the biocoenoses. For example,

483   adult *D. stevensoni* are most abundant in summer, juveniles as well. In addition, there are always

484   significantly more adult individuals of a species than juveniles.

485   The values of the taphocoenoses are (partly) significantly higher than those of the biocoenoses

486   (except for *D. stevensoni*, here the biocoenoses is significantly higher). Again, significant

487   differences can be seen between the samplings. *H. salina* shows the same pattern as in the

488   biocoenoses (max. in June), in all other species the trends are not synchronous. For *P. kraepelini*,

489   for example, the maximum of the taphocoenoses is above the minimum of the biocoenoses and

490   thus temporally shifted from the maximum of the biocoenoses in April, while for *L. inopinata*

491   the maximum of the taphocoenoses is in April. In contrast, in *C. torosa* and *C. vidua*, a

492   continuous decrease in the number of valves is observed over the months.

493

494   ***Species distribution and environmental conditions***

495   Living ostracods occur in the Mansfeld lakes at salinity range between 0.7 and 11.5 PSU (Fig 8).

496   Most species are associated with values between 1 to 6 PSU. Only three species (*H. incongruens,*

497   *H. salina* and *I. gibba*) occur at values up to 11.5 PSU. *H. salina* shows the highest tolerance to

498   salinity (1.4-11.5 PSU).

499   Living Ostracods were found in a temperature range between 9.4 up to 26.5°C. On average, most

500   species were found between temperatures from 10 to 24 °C. Five species (*C. candida, F.*

501   *fabaeformis, I. monstrifica, L. inopinata, N. monacha* and *S. aculeata*) occur in warmer water

502   bodies (>18°C). The dissolved oxygen values, at which living ostracods were found, range

503   between 4.3 mg/l and 19.4 mg/l. Majority of species occur between 5 and 16 mg/l. Although the

504   range of most species is high there are more species associated with lower dissolved oxygen

505   values. Just three species (*C. neglecta, C. torosa* and *H. salina*) were found at values over 19

506   mg/l.

507   The pH range which corresponds to the occurrence of living ostracods is between 7.2 and 8.9.

508   Most species are present between 7.5 and 8.6. Three species (*C. neglecta, C. torosa* and *H.*

509   *salina*) occur in the entire pH range. Only *C. candida* were found in water bodies with higher pH

510   values (8.2 to 8.6).

511   The Canonical correspondence analysis plot (Fig 9) shows the relationships between physico-

512   chemical parameters, ostracod species and localities. The first axis explains with 60% most of

513   the variation and can be correlated with the parameters pH, temperature and dissolved oxygen.

514   The second axis explains 22.5% of the variation and can be correlated with conductivity.

515   However, only a few species show a significant correlation with the measured parameters (S1).

516   *D. stevensoni* correlates with pH (r=0.56, p=0.02) and dissolved oxygen (r=0.57, p=0.02)*, L.*

517   *inopinata* with temperature (r=0.53, p=0.03) and *P. marchica* (r=0.54, p=0.02) with dissolved

518   oxygen. Two species correlate with salinity, *H. salina* (r=0.51, p=0.03) and *S. aculeata* (r=0.57,

519   p=0.02). Nevertheless, no (habitat specific) groups can be distinguished in the CCA.

520
521
522 **4. Discussion**
523
524 ***General aspects on ostracod species distribution***
525
526 All ostracod species found are reported as cosmopolitan, euryoecious freshwater species, and are

527 typical for central Germany (Meisch, 2000; Fuhrmann, 2012), and in particular for the region

528 Mansfeld (Wennrich, 2005; Pint *et al.*, 2015). Due to the natural salinity of the lakes the

529 occurrence of the two brackish water species *C. fuscata* and *C. torosa* are not uncommon and

530 already previously documented (Pint et al., 2012; Wennrich, 2005). So far, no findings of living

531 *C. torosa* from (saline) inland occurrences in Germany are known, although valves of *C. torosa*

532 have been found in higher saline water bodies in central Germany (Pint *et al.*, 2012; Scharf,

533 Herzog & Pint, 2017). The disappearance of *C. torosa* in Mansfeld area was explained by the

534 draining of the `Salziger See´ in 1892 (Fuhrmann, 2012; Scharf *et al.*, 2017) and also Pint et al.

535 (2012; 2015) were not able to find living *C. torosa* in the region. Therefore, the high numbers of

536 living individuals of *C. torosa* found, especially in lower saline water bodies, are somewhat

537 surprising.

538 With 27 species found in the Mansfeld area, with a maximum of 17 species in one site (and

539 maximum of 9 living), the number of species is relatively high with regard to the size of the

540 study area and the small size of the water bodies. Size of the region (and number of water

541 bodies) is decisive for the number of species found (Altınsaçlı, 2001; Rossetti, Bartoli &

542 Martens, 2004; Külköylüoğlu, Sari & Akdemir, 2012). The number of species found within a

543 water body depends, among other things, on size of the water body (Rossetti *et al.*, 2006; Valls *et*

544 *al.*, 2016; Marchegiano *et al.*, 2017), type of habitat and related environmental conditions

545 (Külköylüoğlu & Vinyard, 2000; Altınsaçlı, 2001; Külköylüoglu *et al.*, 2018).

546   In particular, the species richness and diversity of a water body results from an interplay of

547   different factors, such as substrate type, vegetation, food availability, season and water depth

548   (Smith & Delorme, 2010). The more ecological niches a water body has, the more species can be

549   found (Iglikowska & Namiotko, 2012). High species richness usually indicates undisturbed

550   habitats and stable environmental conditions (Carbonel *et al.*, 1988; Valls *et al.*, 2016). In

551   literature, diversity changes in relation to salinity show a species minimum between 5-6 PSU,

552   which is explained by the low tolerance of freshwater species to salinity (Remane, 1934; Frenzel,

553   2009). In contrast, the investigated water bodies show a maximum around 6 PSU. This supports

554   the high tolerance of the species present with respect to salinity.

555   For an evaluation, however, species composition must also be considered. As previously

556   mentioned, are most of the species occurring in the Mansfeld lake area considered as widespread

557   generalists with regard to their ecological preferences (in particular the common and abundant

558   species). Actually, it is stated that cosmopolitan species often occur in disturbed and destroyed

559   habitats (Külköylüoğlu, 2013; Ghaouaci *et al.*, 2017). Külköylüoğlu (2013) describes this case as

560   so-called `pseudo-richness´. Our data confirm this hypothesis, especially at the `Süßer See´, and

561   at the residual lakes of the former `Salziger See´. Due to mining activities in the region during

562   the last 800 years, soil and waters are exposed to high levels of pollutants from geological

563   sources, but also anthropogenic pollutants from mine tailings and smelting products of copper

564   shale mining (Frühauf, 1999; Becker *et al.*, 2001). In particular, `Süßer See´ is considered as a

565   sink for heavy metals (Becker *et al.*, 2001). In addition, there are also considerable nitrogen and

566   phosphate inputs from intensively agricultural use of the region (Lewandowski, Schauser &

567   Hupfer, 2003; Schmidt, Frühauf & Dammann, 2010).

568

569   *Spatial distribution of ostracod species*

570   Although the occurring ostracod species are reported to have wide and rather unspecific

571   ecological preferences, each water body is characterised by specific ostracod species

572   assemblages. Despite some water bodies are more similar (e.g., water bodies of former `Salziger

573   See´) in their assemblages than others (e.g., water bodies without former `Salziger See´), each

574   water body shows specific species composition (and species richness) and abundances during the

575   sampling period. These differences can be explained by different biotic and abiotic conditions

576   (Smith & Delorme, 2010) and cluster analysis of the taphocoenoses revealed that similarities

577   could originate from the hydrological connection of some water bodies (SS,KS,BS and MG).

578   The differentiation between living ostracods and valves shows that species abundance and

579   richness is much higher in valves which is reported by other studies, too (e.g. Akita et al., 2016;

580   Valls et al., 2016). This might be due to the different temporal scales integrated by these two

581   associations. Biocoenoses represent short-term population dynamics and associated

582   environmental conditions at the time the sample was taken and are therefore strongly influenced

583   by the seasonality or life-cycle, respectively, of the species (Winegardner *et al.*, 2015).

584   Taphocoenoses, on the other hand, integrate, through accumulation and time average, several

585   generations over seasons and years and, thus, a larger range of environmental fluctuations

586   (Poquet *et al.*, 2007). In addition, some species, which are present in taphocoenoses, are rare or

587   absent in biocoenoses, due to the fact that variations between seasons and years are captured

588   (Levi *et al.*, 2014). Also, substrate type and sedimentation rate are important to be considered for

589   the number of specimens and species composition. According to Hellmund et al., (2011) and

590   Wennrich (2005) a sedimentation rate of approx. 1cm/y can be assumed for the `Süßer See´ and

591   former `Salziger See´. The sediment volume available at site depends on the underground

592   surface. On gravel considerably lower amounts of samples could be taken than on muddy

593   substrate. Thus, the sampled sediment is estimated to represent about 1-2 years. Taphocoenoses

594   not only contain ostracods through time, but also valves relocated from other areas within a lake

595   or other water bodies (e.g. transported by waterfowls) and may be included to the sample (spatial

596   factor) (Mezquita *et al.*, 2005; Winegardner *et al.*, 2015). This can lead to a distortion of the

597   results (Dieffenbacher-Krall, 2013). An indication of valve transportation is the extremely high

598   number of adult valves compared to juvenile valves in most water bodies. Another indication for

599   taphonomic processes is the occurrence of some living species that were not found in the

600   taphocoenoses of the respective water bodies (e.g., *C. vidua* and *D. stevensoni*). This is

601   especially true for *D. stevensoni*, because here, in sum, significantly more living than valves

602   were found. These may have been relocated or destroyed. The latter aspect is favoured by the

603   fact, that valves of *D. stevensoni* are very thin and fragile (Meisch, 2000). The preservability of

604   the valves therefore also plays a role in which valves (and in which abundances) are found.

605   The strong differences of species abundances demonstrate that the location of sampling within a

606   water body is crucial. Sampling positions only a few meters away from each other can provide

607   significantly different live and dead species assemblages which might be caused by differences

608   in microhabitat conditions (Decrouy, 2009) or very local currents. This could be a reason why no

609   living *C. torosa* has been found in the past few decades. The occurrence of single ostracod

610   species or populations in a water body can be, therefore, very local (Smith & Delorme, 2010;

611   Marchegiano *et al.*, 2017) and is not mandatorily related to changes in water chemistry (i.e.,

612   salinity) as it is often assumed as in the case of *C. torosa*. In order to obtain a comprehensive

613   picture of the ostracod fauna, multiple sampling should therefore ideally carry out. If only one

614 sampling can take place at a site, this site should be carefully selected in order to better classify

615 the results.

616

617   *Seasonal distribution of ostracod species*

618 The differences in abundances and occurrences of species in the samples show, that not only

619 sampling site but also the time (i.e., specific month) of sampling have an important influence on

620 the distribution and abundance of living species due to their specific life-cycles (Decrouy, 2009;

621 Altınsaçlı, Perçin-Paçal & Altınsaçlı, 2015) and also contributes to significant differences in

622 taphocoenoses. Although the taphocoenoses usually integrates several years and should therefore

623 not show any inter-annual variations, sometimes strong differences occur in the number of

624 species (Poquet *et al.*, 2007), the number of valves and the ratio of adult and juvenile valves of a

625 species (Decrouy, 2009). Some species are represented by valves only (and with very low

626 abundances) during the sampling period, which raises the question where these valves originate

627 from. One explanation could be also very local distribution patterns of the species within a water

628 body (Poquet & Mesquita-Joanes, 2011). The species could live elsewhere in the water body and

629 the valves have been relocated (Mezquita *et al.*, 2005). Another explanation could be the

630 occasional entry of single specimens through passive dispersal by water fowls or mammals

631 (Dieffenbacher-Krall, 2013). The Mansfeld lake area is not only a bird sanctuary with numerous

632 water fowl species, it is also a staging and wintering site. Migratory birds pass this area in spring

633 and late autumn (Al Hussein *et al.*, 2000). Some ostracod species could be transported from other

634 regions in this way, but cannot prevail due to unfavorable ecological conditions and/or

635 competition, food supply, etc. This is supported by the fact that some species occur only in April

636 (*C. kingsleii*) and June (*P. newtony, P. zenkeri*) but completely disappeared in September. An

637   air-born colonization by migratory birds is also assumed for the foraminifer genus *Ammonia* and

638   the ostracod species *C. fuscata* (Wennrich *et al.*, 2007). Birds will not only play an important

639   role in the dispersal of species from other regions, but also in the distribution of species between

640   and within the water bodies in this area.

641   Furthermore, it is possible that a species may no longer occur in a water body because one or

642   more environmental conditions have changed (Poquet *et al.*, 2007). Thus, the temporary

643   occurrence of some species cannot be explained by the life-cycle alone. All these aspects (e.g.,

644   single/few valves from a species in one month only, higher adult: juvenile ratio in valves) rather

645   indicate strongly dynamic conditions in the sampling sites (i.e., littoral) of the water bodies due

646   to high seasonal variations. These variations include daily, seasonal as well as inter-annual

647   fluctuation, like temperature or water level fluctuation (flooding increase habitat availability,

648   drawdown decrease habitat availability (observed in WL and SS for example)) (Gasith & Gafny,

649   1990) and higher wave motion (Peters & Lodge, 2009). In addition, the littoral is most affected

650   by terrestrial run-off (detritus, sediment and nutrient input from terrestrial sources) and transient

651   species from the surrounding ecosystem (Peters & Lodge, 2009). Due to the location in the

652   central German dry region, the water bodies are highly affected by long dry periods (with low

653   water levels) and short extreme precipitation events (and high run-offs with high nutrient inputs)

654   (Schmidt *et al.*, 2010). These factors indicate a disturbed habitat and could be stressors for the

655   species (Padisák, 1993).

656

657   ***Ecological inferences***

658   According to Fuhrmann (2012) and Meisch (2000), most of the species prefer warm stagnant or

659   cool stagnant water bodies. However, this is not applicable in order to explain the spatial

660   distribution of the species in this study. The area is spatially very limited, deviations of abiotic

661   parameters of the water bodies are relatively small and almost all species are assumed to have

662   large tolerance ranges for (measurable) physico-chemical parameters. Thus, all species

663   occurrences reflect the known range of physico-chemical parameters (Frenzel *et al.*, 2010; Ruiz

664   *et al.*, 2013). Only *I. bradyi* was found in higher saline waterbodies (up to 7.9 PSU) than the

665   known range from literature (4.5 PSU). The higher range of *Potamocypris* is probably due to the

666   merging of two species because of the difficulty in distinguishing them from each other.

667   Due to this the question arises, why not all species were found in all water bodies. As explained

668   above, sampling of the water bodies may not cover the entire ostracod fauna of a water body

669   (Poquet & Mesquita-Joanes, 2011). Hints for this could be provided by the higher number of

670   species in the taphocoenoses and the deviations of species composition and abundances in bio-

671   and taphocoenoses.

672   Furthermore, the water bodies could provide, e.g. due to different hydro(geo)logical condition,

673   such as residence time, inflow and/or run off, different hydrochemical compositions, like major

674   ion concentrations (Mezquita *et al.*, 2001; Smith & Delorme, 2010) that could have a undetected

675   control on the species distribution. Also, other not-measured (micro)habitat specific factors are

676   possible, like substrate type, presence and coverage of vegetation, food supply and flow energy

677   (Mezquita *et al.*, 2005; Kiss, 2007; Marchegiano *et al.*, 2017).

678   However, not only habitat conditions, but also metacommunity dynamics, e.g. source-sink

679   effects, dispersal rates, mass and rescue effects, are important drivers in the distribution,

680   abundance and life-cycle of species and can contract the structuring role of environmental

681   parameters, especially in cosmopolitan species (Leibold *et al.*, 2004; Guisan *et al.*, 2010).

682   Studies revealed that species move, for example, to other microhabitats when the optimal niche

683   is occupied or competing species develop contrary life-cycles to avoid competition (Carbonel *et*

684   *al.*, 1988).

685   Nonetheless, this implies that the species might be not controlled by the most commonly

686   considered environmental parameters but it also implies that they are not as euryoecious or

687   generalistic as assumed.

688   The two species that occur exclusively in low saline (*P. marchica* and *N. monacha*) and higher

689   saline (P. compressa and *I. gibba*) water bodies occur (except for *P. marchica*) in such low

690   abundances (<4%) that their occurrence is not significant enough to distinguish water bodies

691   with respect to salinity. *P. marchica* is more abundant but shows no (negative) correlation with

692   salinity in CCA. Two species, *C. vidua* and P. *kraepelini*, occur in higher abundances in lower

693   salinity water bodies (category a) and also form a group in the cluster analysis. However, they

694   also show no correlation with salinity or other parameters in the CCA. In water bodies with

695   higher salinities (category b), *H. salina* and *C. torosa* are particularly abundant, and the CCA

696   also shows a correlation between *H. salina* and salinity. In the cluster analysis, *H. salina* forms a

697   group with *I. gibba*. However, *H. salina* shows higher abundances only in one water body (TE),

698   and *I. gibba* also generally occurs only in two water bodies (TE2 and QW). Moreover, both *C.*

699   *vidua*, *P. kraepelini*, and *H. salina* also occur in other water bodies and show only slight

700   differences in abundance in some cases, especially in the taphocoenoses. This highlights the

701   differences between bio- and taphocoenoses.

702   Considering correlations of the species with the measured parameters (CCA), together with the

703   species abundances of the species, it emerges that only few species correlate with certain

704   parameters (e.g., *L. inopinata* with temperature). However, the indifferent pattern of the species

705   in the CCA implies that species composition is water body specific and not directly controlled by

706   the measured parameters. For instance, a species does not occur in water bodies with the same or

707   better conditions (e.g., slightly higher temperatures). Although the measured physico-chemical

708   parameters salinity, pH, temperature and oxygen content cannot explain the species distribution,

709   the parameters probably influence the population dynamics. Studies show, for example, that the

710   lifespan of *D. stevensoni* can range from <1 to 4 years depending on the temperature (Van

711   Doninck *et al.*, 2003), while *L. inopinata* develops different abundances and overwintering

712   strategies depending on whether they live in freshwater or saline water bodies and these

713   populations never co-occur. Freshwater populations appear in April/May and disappear in

714   October/November, while saline population overwinter (Geiger 1998). Variations in the temporal

715   occurrence of *L. inopinata* in different water bodies (BS & WL) were also observed in the

716   Mansfeld area. Whether these are caused by the different salinities (BS: 6.4 PSU, WL: 2.1 PSU)

717   of the water bodies is uncertain.

718   In the Mansfeld area, not only the occurrence of *C. torosa* is surprising, but also its distribution.

719   Although *C. torosa* is known as a widespread and ecological opportunistic species, it is

720   considered as an indicator species for brackish water and is often used as index fossil to

721   reconstruct palaeosalinity and -temperature (Pint *et al.*, 2012; Scharf *et al.*, 2017). In the

722   Mansfeld area, however, *C. torosa* occurs only between 0.9 to 7.9 PSU, having the highest

723   population density at lower saline water bodies (0.9 and 1.3 PSU), and thus cannot be used as a

724   salinity indicator in this area. The position of *C. torosa* in the CCA near coordinate origin

725   indicates that it is not affected by measured physico-chemical parameters and also in the cluster

726   analyses *C. torosa* shows no similarities with other species. This implies other or at least further

727   environmental controls beside salinity and temperature. It is also important to consider possible

728   autecological differences between marine and terrestrial populations.

729   Wang *et al.* (2021) figure out that populations from different regions are adapt to local aquatic

730   environments and therefore develop specific preferences. Thus, the actual preference range of a

731   species may be locally very narrow. The above-mentioned examples show, this assumption is not

732   only restricted to a large spatial scale, but can also be valid on a local scale for spatially close

733   water bodies with different conditions, such as the Mansfeld area. So, each water body provides

734   a specific combination of biotic and abiotic conditions providing differing habitat conditions for

735   the ostracods. As a result, species seems to develop their specific population dynamics/different

736   life-cycles, depending on the conditions they encounter (Leibold *et al.*, 2004). Thus, no habitat

737   specific species assemblages related to physico-chemical parameters can be distinguished in this

738   study.

739

740   **5. Conclusion**

741   This actualistic-autecological survey focuses on the spatial and temporal distribution of ostracod

742   assemblages in 12 saline inland water bodies with special emphasis to differences between bio-

743   and taphocoenoses.

744   It can be shown that not only the place, but also the time of sampling, can provide very different

745   results with regard to inferences of ostracod species distribution (and the associated conclusions

746   regarding the environment). Furthermore, it is important to consider differences between

747   biocoenoses and taphocoenoses and related mechanisms: the biocoenoses is always only a

748   snapshot and the sampling season has a large influence, the taphocoenoses on the other hand

749   integrate often longer but difficult to estimate temporal scales. Biases due to taphonomic

750   processes can be very local including transport and relocation (e.g., species loss, dispersal).

751   Thus, the relationship between abundance and species composition of living ostracods and

752   related taphocoenoses is, however, not straightforward. Partially, strong deviations of species

753   numbers and/or occurrences in bio- or taphocoenoses between the months highlighting the

754   relevance of post-mortem processes even on short time scales (i.e., month). This must be taken

755   into account when fossil material is interpreted.

756   There is no simple pattern in species distribution and abundances although all species are

757   considered as common freshwater species and known for wide ecological tolerances. The water

758   bodies show differences in ostracod species assemblage composition which cannot explained by

759   measured ecological parameters. Especially, salinity has a comparably small influence on the

760   ostracod species distribution. For species considered as cosmopolitan and/or euryoecious it can

761   be assumed that community dynamics (inter/intraspecific competition, sink-source dynamic,

762   mass effect, dispersal rates) counteracts the structuring role of environmental parameters.

763   However, not all ostracod species are found in all water bodies. This highlights, that current

764   assumptions on autecological inferences on 'common' species are not sufficient to explain

765   distribution of these species. Other factors that have received little attention (e.g., vegetation

766   types, composition or texture of substrate, nutrient input, hydrologic conditions) could provide

767   further clues and thus increase the indicator potential of these generalists. The distribution of

768   species and the waterbody specific life-cycles of species suggest that each species has adapted to

769   its aquatic environment, not only on a large spatial scale, but also on a local scale. In particular,

770   the occurrence of *C. torosa* in slightly saline inland waterbodies questions this species as a proxy

771   for (palaeo-) salinity. This indicates that caution is required when interpreting fossil records in

772   terms of biodiversity, (palaeo-) limnological and (palaeo-) ecological conditions. The Mansfeld

773   lake area represents an example region, as here, in a narrowly defined area with a relative

774   homogeneity in the assumed control variables (pH, salinity, temperature, oxygen content), these

775   variables do not contribute to the explanation of the species distribution pattern. Future studies

776   must therefore consider other environmental factors (biotic and abiotic) for the identification of

777   major controls on species occurrence.

778   Therefore, in order to obtain reliable and conclusive data, several samples should ideally always

779   be carried out and a distinction made between living specimens and valves. This provides a

780   better understanding of the spatial and temporal distribution and a better assessment of

781   variability and possible taphonomic processes, as well as precise ecological inferences.

782

788

789   **References**

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Figure 1

Geographical location in Germany and sampling sites in the Mansfeld lake area (modified after Wennrich 2005).
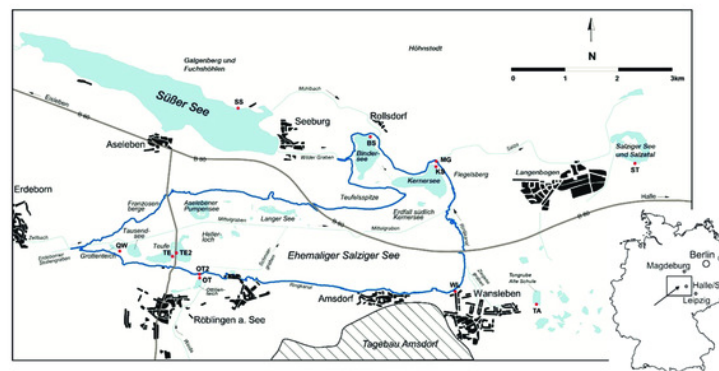
Figure 2

Physico-chemical parameters of the investigated water bodies in the Mansfeld lake area in terms of temperature, conductivity, DO (dissolved oxygen) and pH.

Symbols represent: ◆ =lake, + = temporary source fed ditch section, ● =pond, ▲ = ditch.
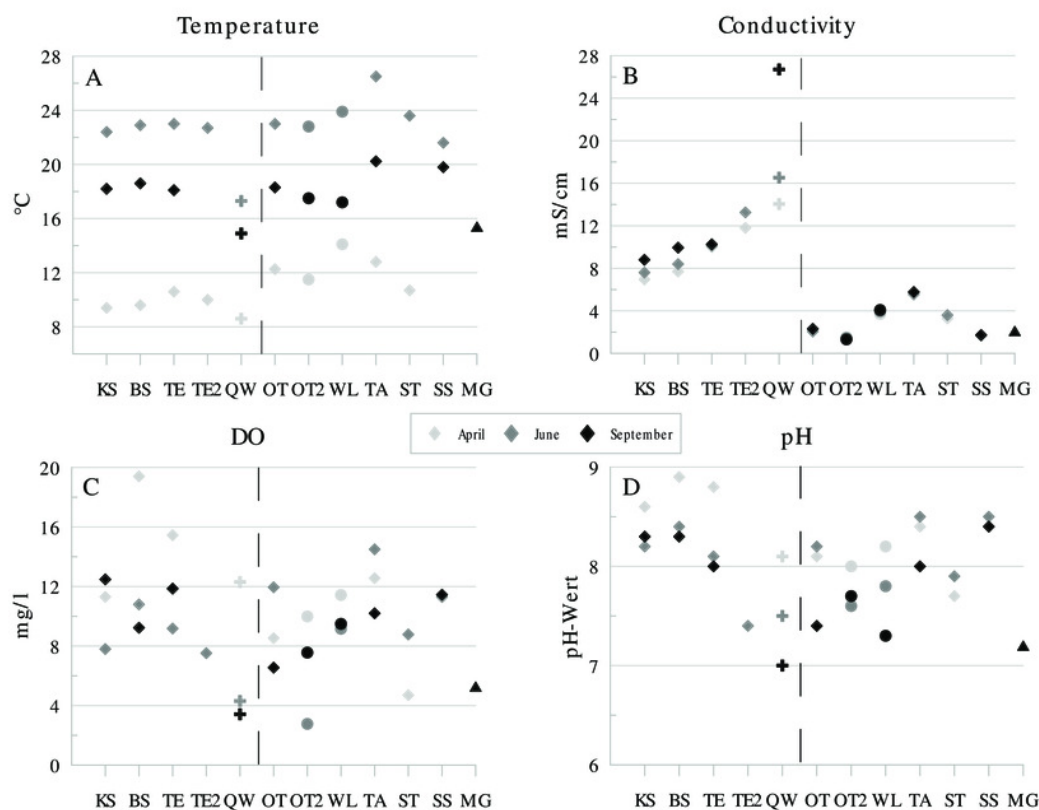
Figure 3(on next page)

Relative abundance of valves and living ostracod species in April, June, and September.

Cc=*Candona candida*, Cn= *Candona neglecta*, Cf= *Cytheromorpha fuscata*. Ck= *Candonopsis kingsleii*, Ct=*Cyprideis torosa*. Cv= *Cypridopsis vidua*, Ds= *Darwinula stevensoni*, E sp?= *Eucypris* sp?, Ev= *Eucypris virens*, Ff= *Fabaeformiscandona fabaeformis*, Fh= *Fabaeformiscandonda holzkampfi*, Hc= *Herpetocypris chevreuxi*, Hi= *Heterocypris incongruens*, Hs= *Heterocypris salina*, Ib= *Ilyocypris bradyi*, Ig= *Ilyocypris gibba*, Im=*Ilyocypris monstrifica*, Li= *Limnocythere inopinata*, Nm= *Notodromas monacha*, Pk= *Physocypria kraepelini*, Pn= *Plesiocypridopsis newtoni*, Pa= *Potamocypris arcuate*, Ps= *Potamocypris smaragdina*, Pz= *Prionocypris zenkeri*, Psc= *Pseudocandona compressa*, Psm= *Pseudocandona marchica*, Sa= *Sarscypridopsis aculeata*.

April	category	0,9 psu 4 (a)					5,5 psu 12,1 (b)				
Group	Sample ID	OT2	OT	ST	WL	TA	KS	BS	TE	TE2	QW
	Species	a j	a j	a j	a j	a j	a j	a j	a j	a j	a j
I (≤5 psu)	Hc										
	Ib										
	Pa										
	Ps										
	Pz										
	Ck										
	Ev										
	Ig										
	Im										
	Psm										
II (≤10 psu)	Cc										
	Nm										
	Cv										
	Li										
	Psc										
	Ff										
	Fh										
	Hs										
III (≤15 psu)	Cn										
	Ds										
	Pk										
	Cf										
IV (≤20 psu)	Hi										
	Sa										
V (≤25 psu)	Pn										
	Ct										
total	valves	647	1.494	828	1.756	531	2.315	1.279	1.430	860	458
	living ostr.	550	84	469	795	158	222	37	231	0	0

June	category	0,7 psu 3 (a)					4,4 psu 11,5 (b)					0,9 (c)
Group	Sample ID	OT2	OT	ST	WL	TA	KS	BS	TE	TE2	QW	SS
	Species	a j	a j	a j	a j	a j	a j	a j	a j	a j	a j	a j
I (≤5 psu)	Hc											
	Ib											
	Pa											
	Ps											
	Pz											
	Ck											
	Ev											
	Ig											
	Im											
	Psm											
II (≤10 psu)	Cc											
	Nm											
	Cv											
	Li											
	Psc											
	Ff											
	Fh											
	Hs											
III (≤15 psu)	Cn											
	Ds											
	Pk											
	Cf											
IV (≤20 psu)	Hi											
	Sa											
V (≤25 psu)	Pn											
	Ct											
total	valves	1.019	1.452	1.263	1.082	409	2.128	905	1.568	551	258	671
	living ostr.	45	28	12	989	303	531	621	116	0	13	680

September	category	0,7			psu		3,4	5,7			psu			20,7	0,9		1,3	
					a						b						c	
Group	Sample ID	OT2		OT		ST	WL		TA	KS		BS		TE	TE2	QW	SS		MG
	Species	a	j	a	j			a	j	a	j	a	j	a	j		a	j	a	j
	Hc					x		○								x					◔
	Ib					x	◔	○		○	○		○		○	x		○			◔
	Pa	○		○		x	○			○	○	○	○		○	x		○ ○			
	Ps					x				○	○			○		x		◔ ○			
	Pz					x										x					
I	Ck					x										x					
(≤5 psu)	Ev					x										x					
	Ig					x										x	◑ ◔				
	Im					x				○ ○						x				○	
	Psm					x		◕ ◔								x		○ ○		○ ○	
	Cc	○		○		x		○ ○		○ ○		○ ○				x		○ ○			
	Nm		○			x		○								x					
II	Cv	◔ ◔		◑ ◑		x				◑ ○		◔				x		◔ ◔	◑ ◑		
(≤10 psu)	Li					x	● ○			◔ ○		◔ ○				x		○ ○	○ ○		
	Psc					x				○ ○						x					
	Ff					x										x					
	Fh					x				○ ○						x					
	Hs	○ ○ ○				x			○	◔		○ ○		○ ◔		x	○ ◔	○ ○		○ ○	
III	Cn					x				○ ○		◑ ○				x					
(≤15 psu)	Ds					x	■	◔ ○		○						x		○ ○			
	Pk	◑ ◔ ○		○		x	◔ ○ ○			○ ○		○				x		○		○	
	Cf					x				○						x					
IV	Hi					x										x					
(≤20 psu)	Sa	◑ ○				x				◑ ○				◑ ◔		x				○ ○	
V	Pn					x										x					
(≤25 psu)	Ct	○ ○				x				◔ ◔		◔		◑ ○ ○		x		◔ ◔	◔ ○		
total	valves	214		594			384		66	1.536		102		783		313	595		352	
	living ostr.	409		3			1		10	300		731		19		0	636		1.037	

● >70% ◑ ≤40 ○ ≤5   ▮ ≤4% ▮ ≤40% ▮ >70%   ▮ ≤4% ▮ ≤40% ▮ >70%
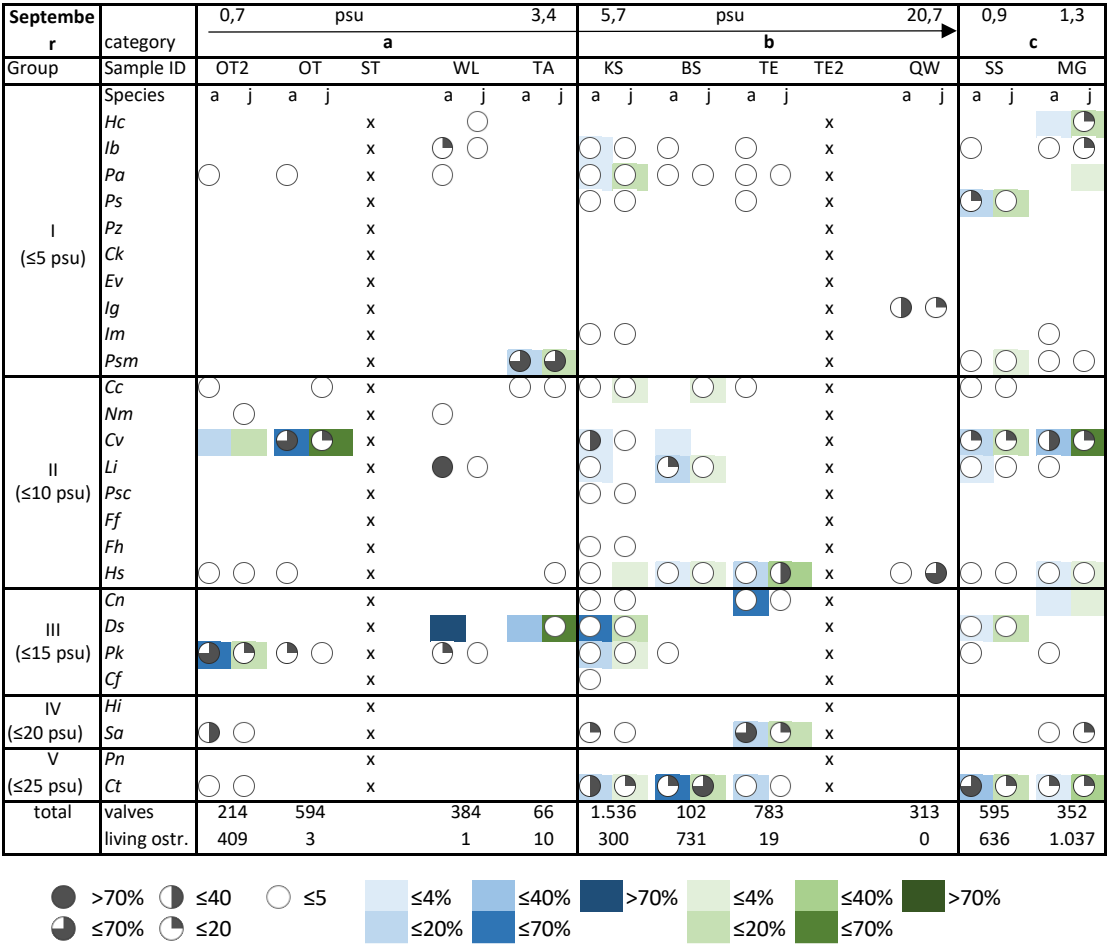◕ ≤70% ◔ ≤20   ▮ ≤20% ▮ ≤70%   ▮ ≤20% ▮ ≤70%

Figure 4

Cluster analyses of water bodies (left side) and species (right side) for thaphocoenoses (upper side) and biocoenoses (lower side).
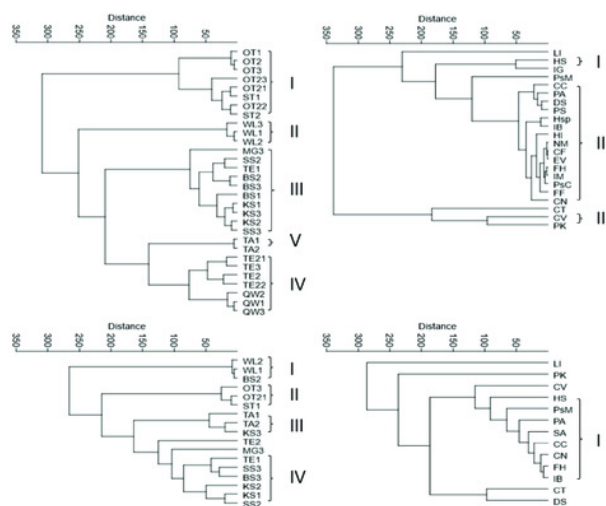
Figure 5

Ratios of adult and juvenile ostracod species in the water bodies. Left columns refer to taphocoenoses, right columns biocoenoses. Abbreviations of the water bodies as in Table 1.
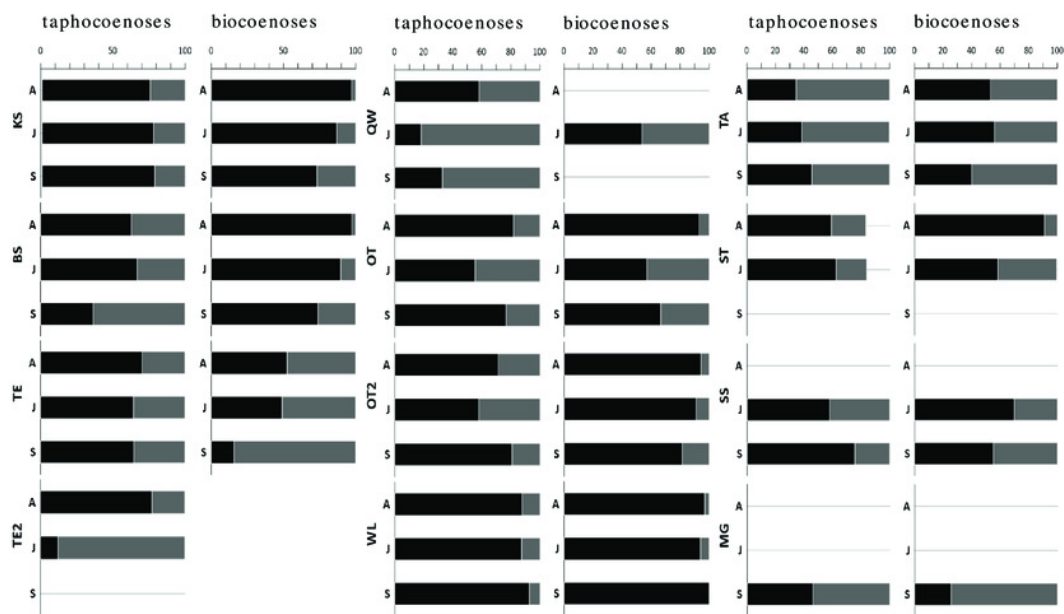
Figure 6

Fisher´s α diversity and richness of cumulated taphocoenoses of the water bodies at Mansfeld in comparison with richness of freshwater species in waterbodies in the catchment of the Baltic sea Frenzel (2009).
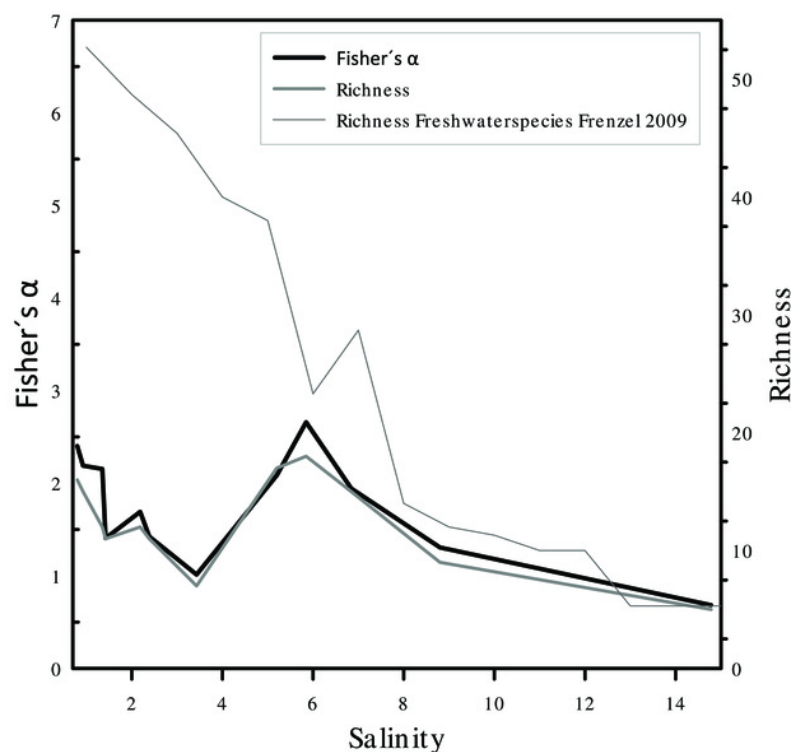
Figure 7

Seasonal distribution of common and abundant species in the study area differentiated for adult and juveniles and distribution of living specimens and valves. Absolute and relative abundances summarized for all water bodies.
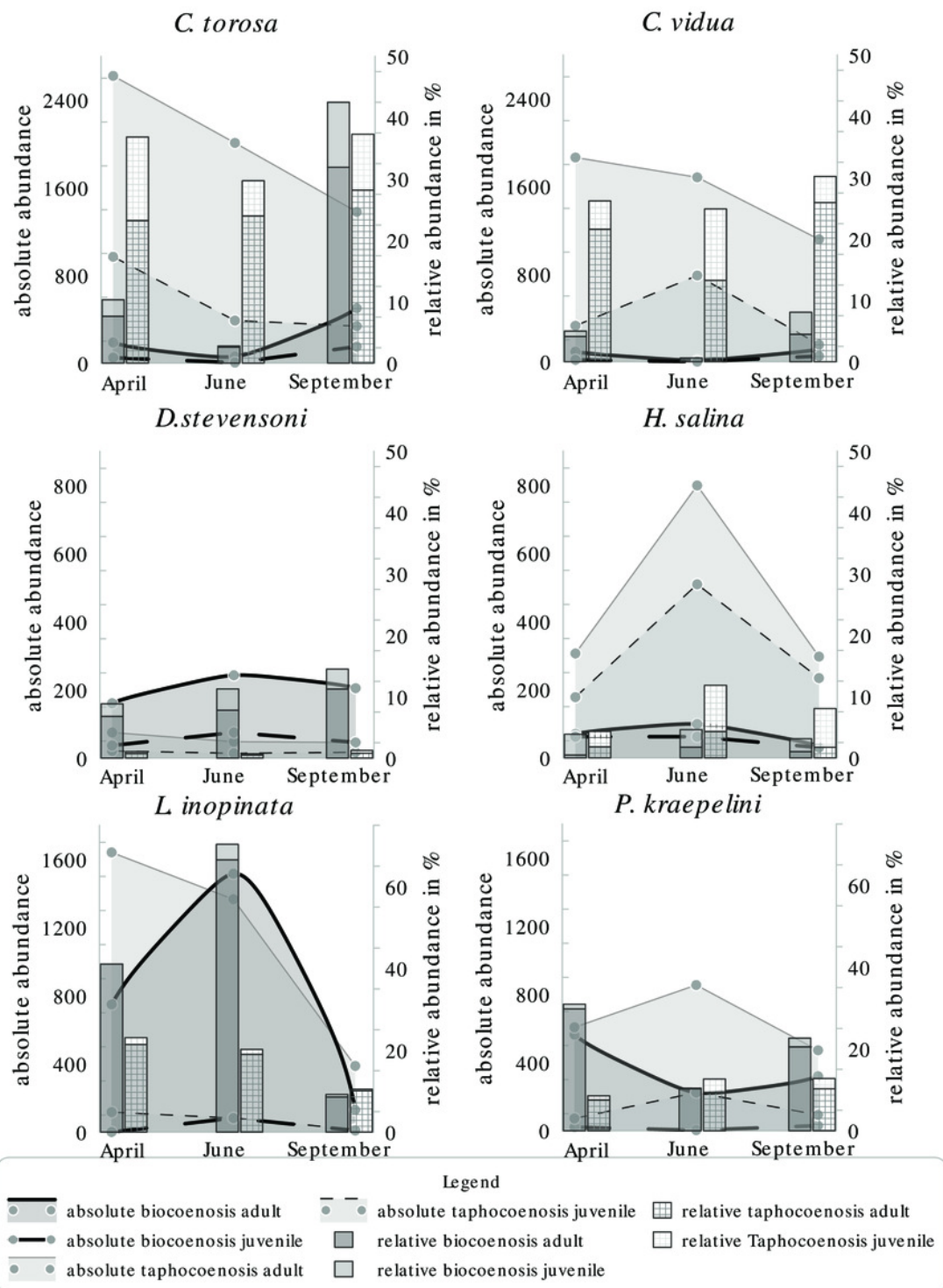
Figure 8

Occurrence of ostracod species in relation to fluctuations in salinity, temperature, dissolved oxygen and pH related to all samplings and localities compared to the study of Frenzel et al 2010.
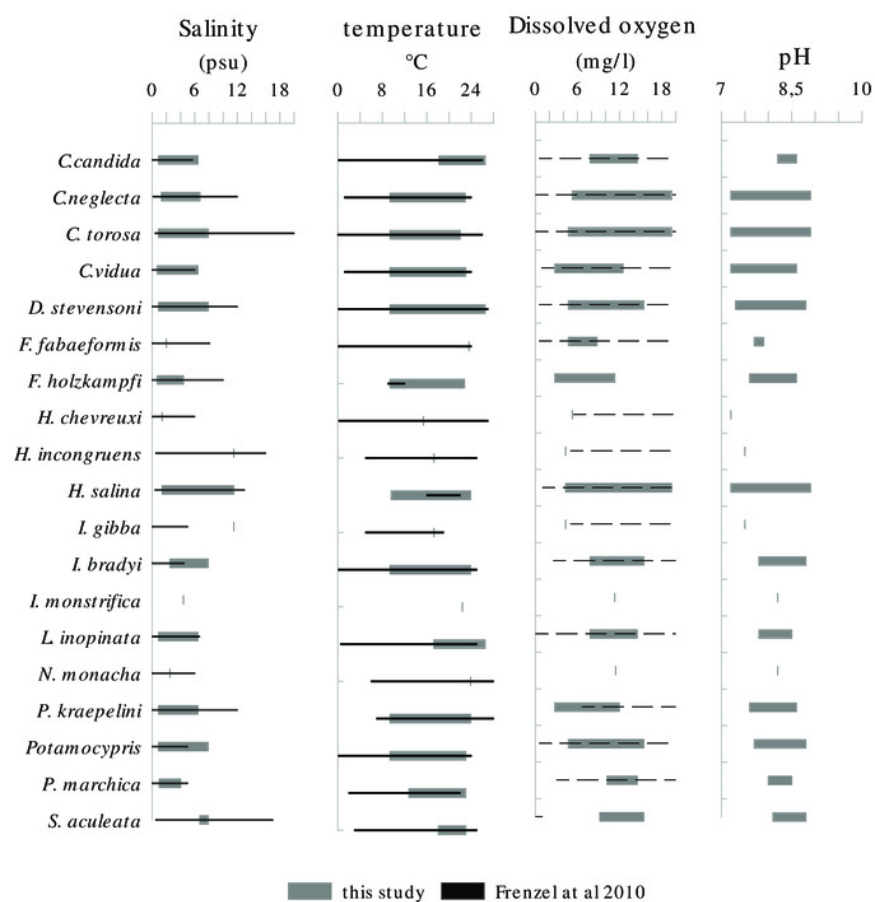
Figure 9

First two axes of Canonical correspondence analysis (CCA) ordination plot of ostracods, environmental variables and water bodies (Sample-ID Table 1 and month with 1=April, 2=June and 3= September).

Species code similar to Fig. 3, cond= conductivity, do=dissolved oxygen, temp= temperature and pH.
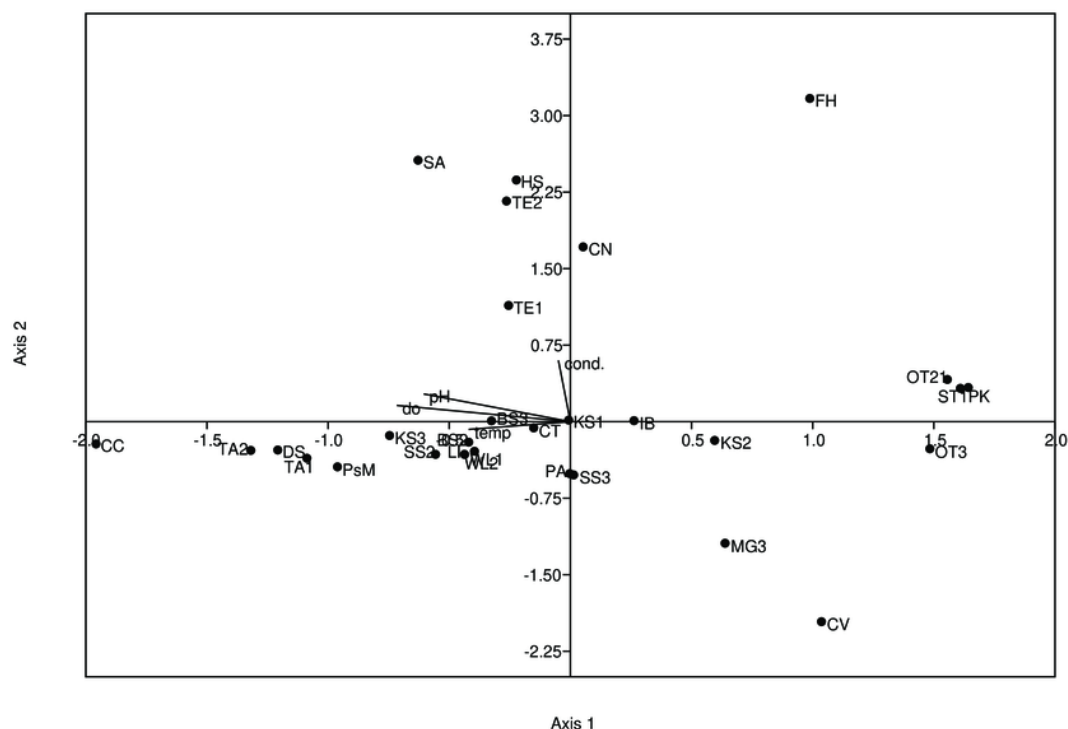
Table 1(on next page)

Overview of sampling sites in terms of name and sample-ID, coordinates, habitat type, substrate, vegetation and sample month.

Information on substrate and macrophytes are classified as following: substrate: 1=sand, 2=mud; vegetation: 0=none, 1=algae, 2=aquatic macrophytes, sample month: A=April, J=June, S=September

Name	Sample-Id	Latitude (N)	Longitude (E)	habitat type	substrate	vegetation	sample month
Kernersee	KS	51.485102	11.740385	lake	1	0	A/J/S
Bindersee	BS	51.489583	11.724183	lake	1	1	A/J/S
Teufe	TE	51.470694	11.675120	lake	2	1	A/J/S
Teufe 2	TE2	51.471072	11.676226	lake	2	1	A/J
Quelle im Wald	QW	51.470166	11.668428	temporary source fed ditch section	2	1	A/J/S
Ottilienteich	OT	51.467471	11.682365	lake	2	2	A/J/S
Ottilienteich 2	OT2	51.468329	11.682151	pond	1	0	A/J/S
Wannsleben	WL	51.465623	11.744928	pond	2	0	A/J/S
Tongrube Alte Schule	TA	51.463703	11.764960	lake	2	1	A/J/S
Salzatal	ST	51.485483	11.790107	lake	1	0	A/J
Süßer See	SS	51.498387	11.676360	lake	1	1	J/S
Mittelgraben	MG	51.485583	11.741115	ditch	1	2	S

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