Life cycles of the two freshwater copepods *Cyclops strenuus* Fischer and *Cyclops insignis* Claus (Cyclopoida, Copepoda) in an amphibious floodplain habitat

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Abstract

Life cycles of the freshwater cyclopoids *Cyclops strenuus* Fischer and *Cyclops insignis* Claus are described from populations of one permanent and two temporary waters in a floodplain area. The abundance of these two species was studied in detail, with special regard to instars surviving summer drought. Both species coexist in two locations during the flood period in the cold season. *Cyclops insignis* is strictly univoltine, whereas *Cyclops strenuus* may produce two generations. Differences in timing of egg production, mortality of juvenile instars at four different temperatures, and survival of resting stages in terrestrial conditions are discussed as possible characteristics facilitating the coexistence of the two species.

Introduction

In permanent habitats, the life cycle of *Cyclops strenuus* Fischer varies from types with reproduction throughout the year without diapause (Elgmork, 1955; Elbourn, 1966) to types with one or two generations with diapause in the fourth copepodid instar (Elgmork, 1955; Einsle, 1967). Even the adult stage was reported to undergo diapause in an oligotrophic lake (Næs & Nilssen, 1991). In temporary habitats, *C. strenuus* survives the dry period by resting stages in the fourth copepodid instar (Einsle, 1967). Even the adult stage was reported to undergo diapause in an oligotrophic lake (Næs & Nilssen, 1991). In temporary habitats, *C. strenuus* survives the dry period by resting stages in the fourth copepodid instar (Einsle, 1993). So far, the life cycle of *Cyclops insignis* Claus has not been described in detail. Einsle (1993) mentioned its occurrence during the cold season, populations starting with late copepodid instars that presumably have emerged from diapause. Schmeil (1892) found *C. insignis* in small ponds during the cold months. Einsle (1996) stated that it lives in ephemeral pools, with diapause during the dry period. However, the diapausing stage has not been determined. *Cyclops strenuus* and *C. insignis* are abundant during winter and spring in the floodplain waters of the Lower Oder Valley (Frisch, 2000).

The different types of water bodies on the floodplain offer a good opportunity to study life cycles of the two species coexisting in neighbouring permanent and temporary waters. The amphibious character of floodplains is based on regular or irregular flood cycles with aquatic (flooded) and terrestrial (dry) phases. With rising water levels during the aquatic phase, backwaters may connect to flooded areas, thus facilitating inhabitants of permanent waters to colonise the newly formed habitat (Frisch, 1999). Aquatic organisms survive terrestrial phases by realising different strategies, including migration and passive dispersal from permanent waters and aestivation in the dried sediments of temporary waters (Wiggins et al., 1980; Wyngaard et al., 1991; Junk & Robertson, 1997).

The present study gives a description of the life cycles of *C. strenuus* and *C. insignis* in permanent and temporary waters, including summer drought surviving instars. It aims to account for different strategies realised by the two species which enable survival in ephemeral water bodies and coexistence in this complex amphibious habitat.
Study site

The Lower Oder Valley is situated near the mouth of the River Oder in the north-east of Germany, and stretches about 60 km along the German–Polish border. It is one of Central-Europe’s last semi-natural lowland floodplains, characterised by periodic floods in winter and spring. Samples were taken at three locations situated on a periodically flooded grassland area (Fig. 1) from the end of the flood period in spring 1997 throughout the flood period of 1997/1998. The locations differ in their hydroperiods, which are listed along with other characteristics in Table 1. During the inundation period, the permanent pond Mariensee connects with FP (=flooded temporary pool), which fills by rising groundwater levels at the beginning of the flood, whereas TP (=isolated temporary pool) is usually separate from the flooded area, exclusively filling by rising groundwater.

Field data

Samples were taken weekly during the flood at all locations, and monthly after the inundation period in Mariensee. To allow for comparison between the abundance of populations in the shallow temporary pools and the permanent pond, sampling in Mariensee was carried out in the littoral zone at a maximal depth of 50 cm. The use of a bottle sampler proved to be ineffective due to abundant macrophytes and filamentous algae obstructing the closing mechanism. Instead, a plastic beaker (volume 11) was used. To reduce the effect of patchiness, ten single samples were taken from various parts of each location. These were integrated to a total volume of 101. Samples were filtered through a 64-μm nylon gauze and preserved in a 5% formalin solution. Unfortunately, sampling was impossible in August 1997, since the area was closed to the public because of a very high summer flood.

*Cyclops strenuus* and *C. insignis* were determined according to Einsle (1989, 1993). Copepodid stages II–V (CII–CV) and adults were counted separately. Because of high numbers of individuals in samples collected in spring 1997, only a fraction of those samples was counted (usually 30% of the total

<table>
<thead>
<tr>
<th>Location</th>
<th>Hydroperiods</th>
<th>Connection</th>
<th>Max. depth after flood</th>
<th>Approx. size after flood</th>
<th>Mean water temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mariensee</td>
<td>Permanent</td>
<td>18/12/1997 to FP</td>
<td>1.80 m</td>
<td>25 x 60 m</td>
<td>7.2 °C</td>
</tr>
<tr>
<td>FP (flooded temporary pool)</td>
<td>December 1997–May 1998</td>
<td>18/12/1997 to Mariensee</td>
<td>0.20 m</td>
<td>1 x 10 m</td>
<td>7.3 °C</td>
</tr>
<tr>
<td>TP (isolated temporary pool)</td>
<td>(no data) — April 1997</td>
<td>December 1997–May 1998</td>
<td>No (filled by rising groundwater)</td>
<td>0.58 m</td>
<td>4 x 10 m</td>
</tr>
</tbody>
</table>

*Table 1. Hydroperiod of sample stations and connection to other water bodies, maximum depth, and size of the locations studied during 1997 and 1998 (December 1997–May 1998). The water temperatures represent means calculated from all measurements made on the sampling dates from September 1997 through May 1998.*

*Figure 1. Schematic view of the floodplain area, showing approximate sizes of the study locations Mariensee, FP (flooded temporary pool) and TP (isolated temporary pool). The dotted area indicates the connection of Mariensee and FP as part of the flooded area and the boundary of TP as an isolated pool during the aquatic phase. The outline of the permanent pond Mariensee during the terrestrial phase and of the temporary pools before they dry, is marked in black. The white area shows the part of the floodplain that is usually not flooded during the aquatic phase.*