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LABORATORY STUDIES OF DESICCATION RESISTANCE IN *MESOCYCLOPS* (COPEPODA: CYCLOPOIDA)

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ABSTRACT. The desiccation resistance of 4 species of *Mesocyclops* from varied geographical locations was tested against water content in sediment, temperature, and photoperiod. Trays containing sediment were inoculated with copepods and allowed to dry out for a period of 2 months and then reflooded. Both copepodids and adults of all species tested displayed desiccation resistance, with water content having greatest effect on survival.

Rivière et al. (1987) demonstrated the potential of *Mesocyclops* copepods for controlling *Aedes* mosquito larvae in both artificial and natural containers. As some of these containers are prone to dry out, desiccation resistance would be a positive characteristic for a prospective biological control agent. *Mesocyclops* spp. burrow up to 30 cm into the sediment where they remain unencysted but resistant to desiccation (Elgmork 1955; Marten 1989a, 1989b). Little is known about specific abilities to withstand desiccation but it appears to vary greatly and occurs in either the late copepodid or adult stages (Elgmork 1955, Marten 1989a, Wyngaard et al. 1991).

This present study examines the effects of moisture level, temperature, and photoperiod on the desiccation resistance of *Mesocyclops aspericornis* (Daday) collected from Brazil, *Mesocyclops guangxiensis* Reid and Kay collected from China, *Mesocyclops darwini* Dussart collected from north Queensland, and *Mesocyclops australiensis* (Sars) collected from southeast Queensland. All of these species have been evaluated for their potential as biological control agents in laboratory trials (Lin et al. 1990, Brown et al. 1991, Kay et al. 1992).

Containers measuring 18 × 12 × 6.5 cm were half-filled with the same mixture of mud, sand, and leaf litter, and then filled to the top with distilled water. There was no pretreatment of the sediment and no extra food was added. One set of containers was kept at 28°C with a 14:10-h light : dark (LD) cycle (simulating summer drought conditions) and the other was maintained at 15°C with a 10:14-h light : dark cycle (simulating winter drought conditions). Fifteen containers were kept filled with water throughout the trial to act as controls. Each trial was replicated 15 times.

Ten days later, known numbers of copepodid and adult copepods (between 50 and 150) from established cultures of each species were counted and placed into separate containers and left uncovered for 1 month to allow the water to evaporate. Water content in the sediment was measured at this stage. Sediment was moist but there was no free water in the containers. A sample of sediment was taken from each container and weighed. After drying at 60°C for 12 h, the samples were weighed again. The percentage of water in each sample was calculated using the following equation: ([wet weight − dry weight]/wet weight)100. The containers were then covered with clear plastic to prevent further evaporation and left for a further month, after which time they were reflooded with distilled water.

Sediment samples were also taken from Yorks Hollow, Brisbane, south-eastern Queensland (27° 30′S, 153°30′E) to compare moisture levels in the containers with that in the natural environment. Yorks Hollow is a known habitat of *M. australiensis* and was almost dry at the time of sampling. Data were analyzed by *t*-test, ANOVA, or regression. Significantly different means were compared with Tukey's test using the SAS statistical package (SAS Institute 1988). All percentage data were transformed using arcsin transformations.

Four hours after the containers were flooded *M. aspericornis, M. darwini, M. australiensis,* and *M. guangxiensis* populations were 18.1 ± 5.7%, 16.4 ± 4.3%, 17.7 ± 7.2%, and 15.4 ± 5.1%, respectively, of their original inoculation levels. There were no significant differences between the survival rates of these 4 species ($F = 1.68$, df = 3,100, $P = 0.18$).

The average moisture level in the 15°C, 10:14 LD containers, was 31.3 ± 9.6%, whereas in the 28°C 14:10 LD containers, the average was 27.4 ± 14.7%. There was no significant difference between the moisture levels in these containers ($t = 1.24$, $P = 0.27$). Water content in sediment from containers was comparable to the averages for Yorks Hollow, where moisture content 30 cm below the surface and 1, 10, 20, and 40 meters from the water's edge was 45.7 ± 3.5%, 28.6%

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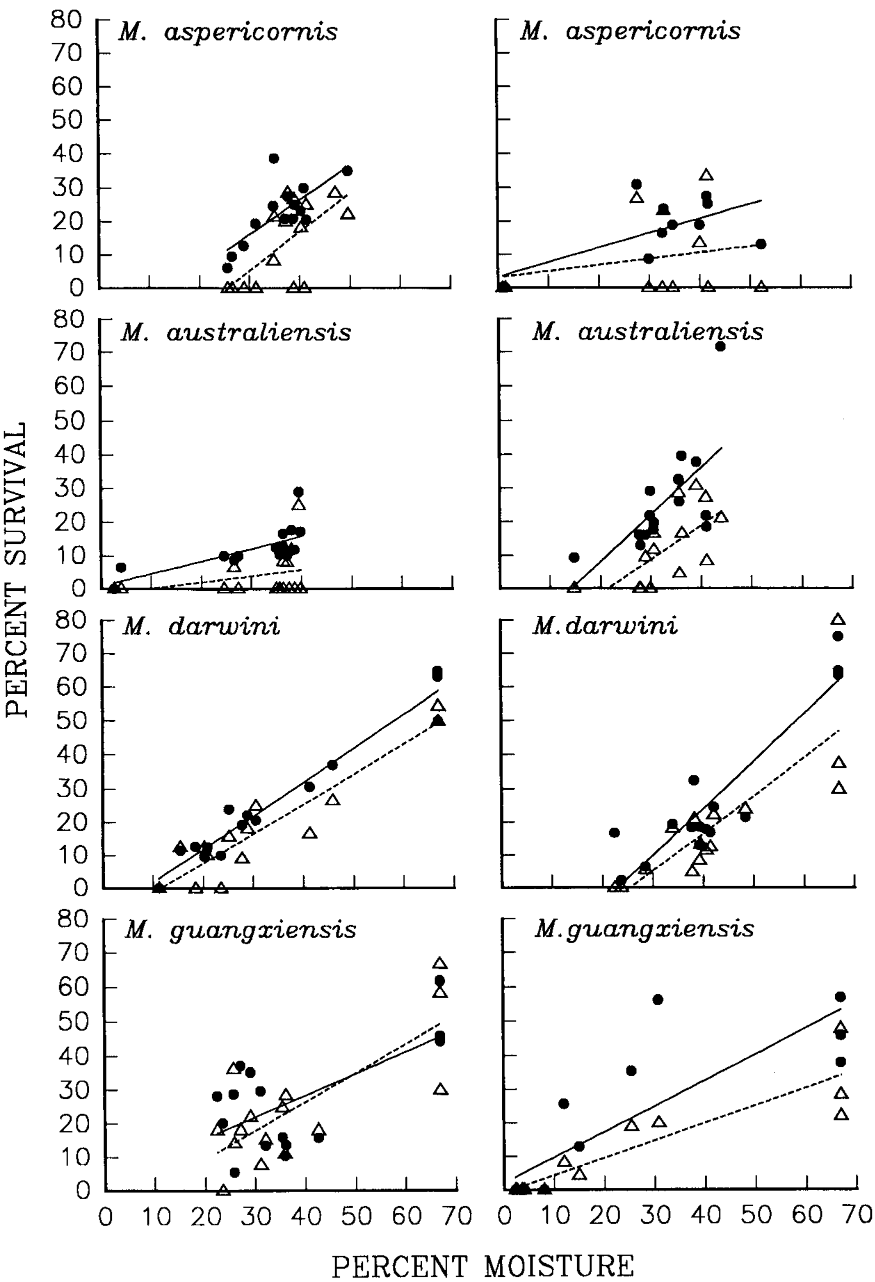

Fig. 1. Percentage survival of adult- (△- - -△) and copepodid- (●——●) stage *Mesocyclops* at 15°C (left) and 28°C (right) in relation to sediment moisture.

± 4.2%, 14.4 ± 1.7%, and 17.1 ± 1.6%, respectively.

Water content was the most important factor associated with the survival of copepods and had significant associations with the population levels of *M. aspericornis, M. darwini, M. guangxiensis,* and *M. australiensis* (F = 35.3, df = 1,24, $P < 0.001$, $R^2 = 0.44$; F = 22.3, df = 1,22, $P < 0.001$, $R^2 = 0.48$; F = 44.0, df = 1,24, $P < 0.001$, $R^2 = 0.65$; F = 6.6, df = 1,22, $P = 0.02$, $R^2 = 0.19$, respectively). For all species, survival rates of copepods were higher with increased water content. No copepods survived in containers where sediment moisture dropped below 14.8%.

Table 1. Numbers of copepodids and adult copepods (expressed as a percentage of the original inoculum) (±SE) after one month of desiccation.

			Species of *Mesocyclops*			
Treatment	Moisture % ±SE	Stage	*M. aspericornis*	*M. darwini*	*M. guangxiensis*	*M. australiensis*
15°C, 10:14 LD	30.0 ± 4.7	Copepodid	16.6 ± 3.1	17.3 ± 2.3	10.8 ± 5.4	27.0 ± 4.0
		Adult	8.8 ± 3.9	11.8 ± 2.4	4.3 ± 2.2	11.7 ± 2.9
28°C, 14:10 LD	33.6 ± 4.3	Copepodid	21.4 ± 2.5	17.5 ± 3.0	21.2 ± 3.0	12.3 ± 1.6
		Adult	13.3 ± 3.2	12.2 ± 2.6	17.9 ± 2.8	12.3 ± 1.6

Within the 28°C, 14:10 LD containers, both copepodids and adult copepods of *M. aspericornis* (F = 16.8, df = 1,12, $P < 0.001$, $R^2 = 0.53$; F = 24.3, df = 1,12, $P < 0.001$, $R^2 = 0.7$) and *M. darwini* (F = 28.4, df = 1,12, $P < 0.001$, $R^2 = 0.71$; F = 6.4, df = 1,12, $P = 0.03$, $R^2 = 0.36$) had significant associations with water content. Adult copepods of *M. australiensis* and adults and copepodids of *M. guangxiensis* had no significant association with moisture (F = 1.46, df = 1,12, $P = 0.25$, $R^2 = 0.03$; F = 0.69, df = 1,12, $P = 0.43$, $R^2 = 0.07$; F = 1.64, df = 1,12, $P = 0.23$, $R^2 = 0.06$) (Fig. 1).

Within the 15°C, 10:14 LD containers, both copepodids and adult copepods of *M. darwini* (F = 7.89, df = 1,12, $P = 0.02$, $R^2 = 0.39$; F = 40.5, df = 1,12, $P < 0.001$, $R^2 = 0.78$), *M. australiensis* (F = 6.57, df = 1,12, $P = 0.02$, $R^2 = 0.31$; F = 11.5, df = 1,12, $P = 0.005$, $R^2 = 0.43$), and *M. guangxiensis* (F = 108.0, df = 1,12, $P < 0.001$, $R^2 = 0.91$; F = 96.2, df = 1,12, $P < 0.001$, $R^2 = 0.90$) had significant associations with moisture content. Adult copepods of *M. aspericornis* had no significant association with moisture (F = 0.73, df = 1,12, $P = 0.41$, $R^2 = 0.08$) (Fig. 1).

Species differences in survival between different moisture content and temperature and photoperiod possibly reflect their geographic origin and may give an idea about the typical conditions under which they live. Within the 28°C, 14:10 LD containers, *M. guangxiensis* was the most numerous species, whereas in the 15°C, 10:14 LD cycle *M. australiensis* reached greatest numbers (Table 1). Of the 4 species, only *M. guangxiensis* and *M. australiensis* had significant associations with temperature and photoperiod ($t = 6.0$, $P < 0.001$; $t = 3.8$, $P < 0.001$). In the 15°C, 10:14 LD containers, numbers of *M. guangxiensis* were significantly lower than the other 3 species. However, within the 28°C, 14:10 LD containers, *M. australiensis* numbers were significantly lower than those of *M. aspericornis* and *M. guangxiensis,* but not of *M. darwini* (Table 1).

Four hours after reflooding, 87% of the containers were positive for copepodids, compared to 54.6% positive for adult copepods. The percentage of containers positive for copepodids and adults, respectively, for *M. aspericornis* (91.3, 52.5%), *M. darwini* (95.6, 79.2%), *M. australiensis* (100, 55.6%), and *M. guangxiensis* (65, 60.7%) was similar to the overall result. However, because 2 months had passed since the initial inoculation, numbers counted almost certainly would have been a mixture of the initial inoculation and its progeny. Although the copepodid stage appears to be the dominant resistant stage, the presence of adults after drying is consistent with the literature indicating that *Mesocyclops* spp. can resist desiccation as both late copepodid and adult stages (Marten 1989b, Dobrzykowski and Wyngaard 1993).

In this trial all species displayed desiccation resistance, with adequate numbers surviving to initiate new populations. The temperature range used in this trial was within the known ranges of *Mesocyclops.* However, water in containers in direct sunlight may exceed these limits (Rivière et al. 1987) and field evaluation would be useful. Containers must have at least the minimum nutritional and other physicochemical requirements reported by Jennings et al. (1994), and contain sufficient sediment to maintain moisture (Wierzbicka 1962; Marten 1989a, 1989b), if *Mesocyclops* are to be used as long-term biocontrol agents.

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