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Effect of Cadmium on Oviposition and Egg Viability in *Chironomus riparius* (Diptera: Chironomidae)

Kendall A. Williams, David W. J. Green, David Pascoe,* and Deborah E. Gower

Department of Applied Biology, University of Wales Institute of Science and Technology, P.O. Box 13, Cardiff CF1 3XF, United Kingdom

Although the importance of toxicity data on freshwater macro-invertebrates for establishing water quality criteria is now well recognised (Murphy 1980; Maciorowski and Clarke 1980; Williams *et al* 1984) few attempts have been made to determine the relative sensitivities of different life stages or ages within a species. Previous work with insects (Sanders and Cope 1968; Clubb *et al* 1975; Maki *et al* 1975) has suggested that earlier life stages may be more sensitive than later ones although toxicant effects on the egg itself have been virtually ignored. A recent study (Gauss *et al* 1985) found that fourth instar larvae of *Chironomus tentans* were 12-27 times more resistant to copper stress than first instars, and that in addition, the eggs were much more resistant than either of these instars. Similar observations have been made in this department concerning the toxicity of cadmium to *Chironomus riparius*.

The selection of water of a suitable quality for egg-laying has been demonstrated in mosquitoes (Hudson 1955). However, there is virtually no information available on oviposition behaviour in relation to toxicant stress or water quality although some authors (e.g. Sutcliffe and Carrick 1973) have speculated on the presence of chemo-receptors in insect antennae and their possible involvement in testing water quality prior to oviposition.

The present study aimed to investigate the extent of selection by *Chironomus riparius* females between a range of cadmium solutions as sites for oviposition and the effect of cadmium on egg hatching.

MATERIALS AND METHODS

Newly emerged adults were collected from a laboratory culture of *C. riparius* and released into a wooden-framed cage (54 cm x 54 cm x 54 cm). The sides of the cage consisted of fine nylon mesh and the top, clear perspex. Adults (♂ + ♀) were introduced daily into the cage, maintaining a population of several hundred at any one time. Stock solutions of cadmium ($CdCl_2 2\frac{1}{2}H_2O$) were diluted to give nominal concentrations of 0.3, 30, 100 and 300 mg Cd L^{-1}, in addition to a control comprising dechlorinated

*Correspondence and reprint author

Cardiff tap water only [pH,7.56 ± 0.05 (95% CI's); DO, >90% a.s.v; Hardness,98 mg L^{-1} as $CaCO_3$; Conductivity, 242 µmhos cm^{-1} ± 7.07; Cadmium, 0.006 mg L^{-1} ± 0.003] Equal amounts (25 mL) of each solution were placed in petri dishes (2 per concentration) and positioned on the bottom of the cage at random. To avoid possibility of any positional selectivity, the pattern of distribution of the ten dishes was changed daily so that by the end of the test (10 days) each dish had been in each position once. The cage was maintained at 20°C, illumination (12 h per day) being provided from overhead only. After each test period (24 h) egg ropes were counted and removed and the test solutions renewed. Records of pH and temperature were made daily.

Experiments were conducted to investigate the effect of cadmium and the removal of the jelly-like matrix on subsequent egg hatching. The hatching of egg ropes which had been laid (and subsequently kept) in cadmium solutions (0.3, 30, 100 and 300 mg L^{-1}) was compared with that of:-

i) egg ropes which had been laid by females in dechlorinated water and transferred to a cadmium solution,

ii) eggs which had been dissected from the jelly-like matrix of egg ropes laid in dechlorinated water and subsequently placed in cadmium, and

iii) control egg ropes laid in and allowed to develop in dechlorinated water.

In each test, 5 egg ropes or 20 separate eggs were placed in 25 mL of solution. pH, temperature and conductivity were monitored daily and egg viabilities were recorded after 120 h.

RESULTS AND DISCUSSION

Throughout all tests temperature and pH remained at 20°C ± 0.5 (95% CI's) and 7.3 ± 0.4 respectively.

The cumulative numbers of egg ropes laid at each cadmium concentration and control are shown in Figure 1. Significantly higher numbers of egg ropes were laid in the control and lower concentrations of cadmium (0.3 and 30 mg CdL^{-1}) than in solutions of 100 and 300 mg CdL^{-1} ($p<0.05$, Mann-Whitney U test). Female *C. riparius* do, therefore, appear to discriminate between different concentrations of cadmium or some related physical/ chemical parameter.

The selection of a site for oviposition is important since the survival of eggs and larvae will depend on a hospitable environment. Since first instar chironomid larvae have been shown to be extremely sensitive to heavy metals in this department and by Gauss *et al* (1985) the presence of such toxicants at the oviposition site could be critical and it would be advantageous for *C. riparius* females to be able to detect and possibly avoid metals.

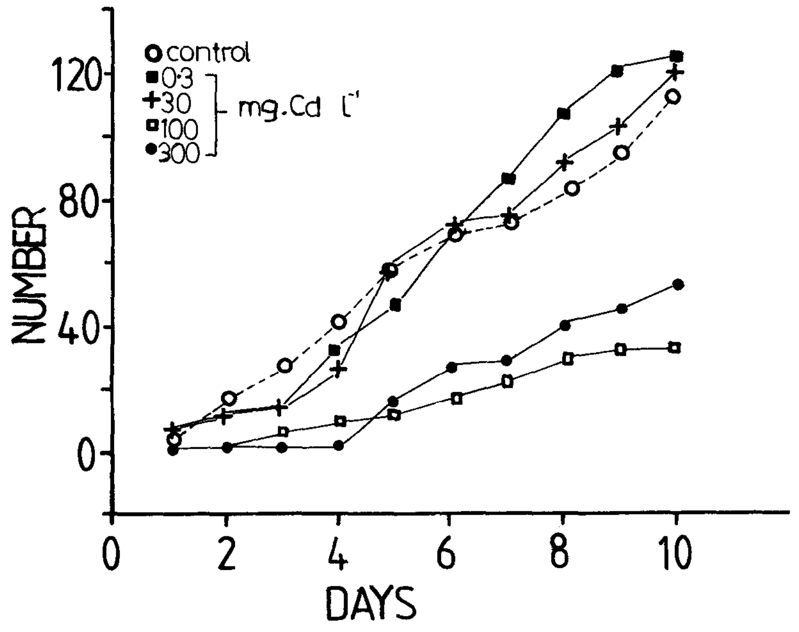

Figure 1. The cumulative number of egg ropes laid at various concentrations of cadmium and in control water.

Although, in the present study, females were able to discriminate between solutions containing varying concentrations of cadmium, their detection was relatively insensitive and would not lead to avoidance of solutions containing levels acutely toxic for early instar larvae. It would however avoid oviposition in concentrations acutely toxic to eggs (Figure 2).

The eggs of *C. riparius* are laid within a 'protective' gelatinous matrix which expands in water to several times its original size. Exposure of egg ropes to cadmium subsequent to their complete formation in control water had no effect on the development of the embryos (Figure 2), with 80-100% of the ropes hatching at each concentration. Exposure to cadmium of eggs which were separated from the gelatinous matrix reduced the percentage hatching to approximately 60%. Thus the matrix itself would not appear to be completely responsible for protection against the toxicant. However, in the case of egg ropes laid directly into cadmium solutions, percentage viabilities were much lower (Figure 2). Thus, although the egg stage of *C. riparius* is extremely resistant to cadmium toxicity, it is apparent that exposure during oviposition reduces and prevents the complete development of the embryos. Similar findings were made by Wegner and Hamilton (1976) investigating the viability of

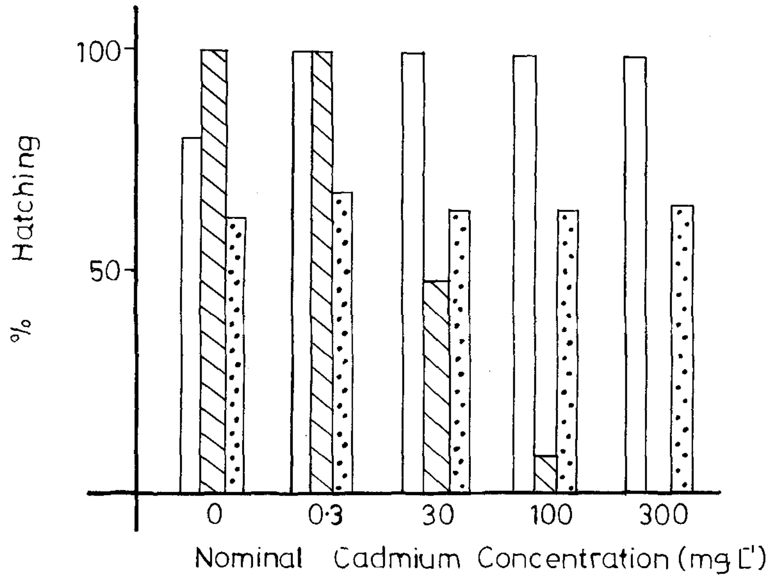

Figure 2. The effect of cadmium on the percentage hatching success of *C. riparius* eggs.
Egg ropes transferred to cadmium solutions (unshaded).
Egg ropes laid directly into solutions of cadmium (hatched).
Separate eggs (without egg rope matrix) transferred to cadmium solutions (dotted).
Percentage hatching in control water was 80-100% in all cases.

C. riparius eggs laid directly into solutions of calcium sulphide. At relatively low concentrations (up to 3.2 mg sulphide L^{-1}) little or no toxic effect was observed; however, at 56 and 100 mg sulphide L^{-1} the majority of eggs failed to develop and hatch.

Previous work with rainbow trout (Beattie and Pascoe 1978) has shown that cadmium is rapidly absorbed into the chorion of the egg from the surrounding water, considerably reducing the penetration of cadmium through the egg membrane. As a result the developing embryo is afforded considerable protection (Shazili and Pascoe 1986). There has been no comparable work with invertebrate eggs, although such a mechanism could explain the comparatively high resistance to cadmium exhibited by this stage of the life cycle.

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REFERENCES

Beattie JH, Pascoe D (1978) Cadmium uptake by rainbow trout, *Salmo gairdneri*, eggs and alevins. J Fish Biol 13:631-637

Clubb RW, Gaufin AR, Lords JL (1975) Acute cadmium toxicity studies upon nine species of aquatic insects. Environ Res 9: 332-341

Gauss JD, Woods PE, Winner RW, Skillings JH (1985) Acute toxicity of Copper to three life stages of *Chironomus tentans* as affected by water hardness-alkalinity. Environ Pollut (Ser A). 37:149-157

Hudson BNA (1955) The behaviour of the female mosquito in selecting water for oviposition. J Exp Biol 33:478-492

Maciorowski HD, Clarke RMcV (1980) Advantages and disadvantages of using invertebrates in toxicity testing. In: Buikema AL Jr, Cairns J Jr (eds) Aquatic invertebrate bioassays ASTM STP 715 American Society for Testing and Materials Philadelphia, Pa. p36-47

Maki AW, Geissel L, Johnson HE (1975) Comparative toxicity of the larval lampricide TFM. (3 trifluoromethyl-4-nitrophenol) to selected benthic macroinvertebrates. J Fish Res Bd Canada 32:1455-1459

Murphy PM. (1980) A manual for toxicity testing with freshwater macroinvertebrates and a review of the effects of specific toxicants. Department of Applied Biology, University of Wales Institute of Science and Technology, Cardiff,U.K. p105

Sanders HO, Cope OB (1968) The relative toxicities of several pesticides to naiads of three species of stonefly. Limnol Oceanogr 33:112-117

Shazili NAM, Pascoe D (1986) Variable sensitivity of rainbow trout (*Salmo gairdneri*) eggs and alevins to heavy metals. Bull Environ Contam Toxicol 36: 468-474

Sutcliffe DW, Carrick TR (1973) Studies on mountain streams in the English Lake District. I. pH, calcium and the distribution of Invertebrates in the River Duddon. Freshwat Biol 3, 5:437-462

Wegner GS, Hamilton RW (1976) Effect of calcium sulphide on *Chironomus riparius* (Diptera:Chironomidae) egg hatchability. Environ Entom 5:256-258

Williams KA, Green DWJ, Pascoe D (1984) Toxicity testing with freshwater macroinvertebrates: Methods and application in environmental management. In: Pascoe D and Edwards RW (eds) Freshwater biological monitoring. Advances in water pollution control. Pergamon, London p167

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