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Cadmium Toxicity to Laboratory and Field Populations of *Daphnia galeata mendotae*[1]

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The relationships between toxicity and exposure time (toxicity curves) or between chronic and acute toxicity have long been of fundamental importance in fish toxicology, but only recently have been analyzed for zooplankton. As a method for estimating "maximum acceptable toxicant concentrations" (MATC) for fish that cannot be chronically tested in the laboratory, MOUNT and STEPHAN (1967) proposed the use of "application factors" (MATC/96-h LC50 ratios) derived from species that can be laboratory tested. Cadmium application factors subsequently reported for three species of fish all fell within the range of 0.002 to 0.008 (PICKERING and GAST 1972, EATON 1974, SPEHAR 1976). Studies of cadmium toxicity to laboratory Daphnia populations (MARSHALL 1978a) and zooplankton communities containing Daphnia (MARSHALL and MELLINGER 1978) have been reported, and the laboratory results were recently verified in the field (MARSHALL 1978b). However, no cadmium toxicity curves or application factors have been reported for Daphnia populations.

The purpose of this paper is to report on the relationship between exposure time and cadmium toxicity to laboratory and field populations of Daphnia galeata mendotae, as summarized in a cadmium toxicity curve, and to derive a cadmium application factor.

Materials and Methods

Laboratory populations of D. galeata mendotae originated from a culture maintained at the Environmental Research Laboratory-Duluth (EPA). A total of 40 populations were studied for 22 wk or, for a few cases, until they became extinct. In each of two experiments, four populations were maintained at each of five concentrations of added cadmium: 0, 1, 2, 4, and 8 µg Cd/L in the first experiment and 0, 5, 10, 15, and 20 µg Cd/L in the

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second. The populations were maintained in 500 mL of medium in 600-mL polypropylene beakers. The medium, consisting of filtered Lake Michigan water to which 2×10^4 cells/mL of Chlamydomonas reinhardi and prescribed amounts of $CdCl_2$ were added, was changed daily Mondays through Fridays, with a triple ration of food on Fridays. The populations were kept in constant darkness in an incubator at 18.5 ± 0.5°C except for the few minutes required each day for routine manipulations. The populations were censused at weekly intervals.

A natural population of D. galeata mendotae was a component of the Lake Michigan zooplankton community. Five in situ experiments were conducted in northern Green Bay, Lake Michigan, off Sister Bay, Wisconsin. In each experiment, two to four opaque polyethylene carboys (8-L or 20-L size) for controls and each of four concentrations of added cadmium were filled with water from the lower portion of the epilimnion (6 to 12 m). The concentrations of added cadmium were: 0, 50, 100, 150, and 200 µg Cd/L in the first three experiments; 0, 25, 50, 75, and 100 µg Cd/L in the fourth experiment; and 0, 5, 10, 20, and 40 µg Cd/L in the fifth experiment. For in situ incubation the carboys were suspended in the epilimnion at depths of from 2 to 12 m. Inclusive dates of incubations for the five experiments were 22—26 July, 27 July—1 August, 20—27 August, 27 August—11 September, and 11—20 September 1976. Epilimnion water temperatures during these incubations ranged from 17 to 21°C. After incubation, the zooplankton in each carboy was preserved in 4% formalin. D. galeata mendotae and other species in each sample were enumerated in an open-top, chambered counting cell, using a Wild M5 microscope.

Relative numbers of D. galeata mendotae in both laboratory and natural populations, N', were calculated from the equation

$$N' = N_{(Cd)}/\bar{N}_{(0)},$$

where $N_{(Cd)}$ is the number in a population at a given cadmium concentration after a certain exposure time, and $\bar{N}_{(0)}$ is the mean number in the controls. Median effective cadmium concentrations (EC50's) were calculated from linear regressions of N' on cadmium after different exposure times. Relative carrying capacity, K, was calculated from the equation

$$K = \bar{N}_{(Cd)}/\bar{\bar{N}}_{(0)},$$

where $\bar{N}_{(Cd)}$ is the average number of D. galeata mendotae in a laboratory population during the entire 22 wk, and $\bar{\bar{N}}_{(0)}$ is the mean average number in the control populations. Following a suggestion of SPRAGUE (1971) a "safe" cadmium concentration was estimated by calculating the concentration that would cause a 1% reduction of K (the chronic EC1).

Results and Discussion

The median effective cadmium concentrations and linear regression coefficients for regressions of N' on cadmium for the laboratory and field populations for different exposure times (T) are available from the author. The corresponding relationship between cadmium concentration (Cd) and exposure time (T) effecting a 50% reduction of N' is represented by the toxicity curve shown in Figure 1. The 96-h EC50 calculated from the equation shown in Figure 1 is 30 µg Cd/L, and the 48-h EC50 is 40 µg Cd/L. Other results from the laboratory experiments indicate that the effects in the first week are mostly due to increased mortality and that most of the compensatory increase in reproduction appears later (MARSHALL 1978a). These EC50's therefore may be justifiably compared with LC50's reported for acute cadmium toxicity to other species of _Daphnia_. The 48-h EC50 of 40 µg Cd/L is in reasonable agreement with the 48-h LC50 of 65 µg Cd/L reported for _D. magna_ by BIESINGER and CHRISTENSEN (1972) and the 48-h LC50 of 55 µg Cd/L reported for _D. hyalina_ by BAUDOUIN and SCOPPA (1974).

The long-term effects of increased cadmium concentrations on relative carrying capacity for _D. galeata mendotae_ populations, K, is represented by the equation

$$K = 1.0 - 0.065\ \mathrm{Cd},$$

and the corresponding chronic EC1 is 0.15 µg Cd/L. This is the same as the "safe" concentration reported by BIESINGER and CHRISTENSEN (1972) for _D. magna_.

Using values calculated above for populations of _D. galeata mendotae_, the cadmium application factor derived from the chronic EC1/48-h EC50 ratio is 0.004. This falls within the range (0.002—0.008) of values for cadmium application factors reported for fish (PICKERING and GAST 1972, EATON 1974, SPEHAR 1976). The value of the application factor can vary considerably, depending on what concentration is defined as "safe" for chronic exposure, as well as what acute EC50 or LC50 is used. If the chronic EC2 is defined as the safe concentration, the application factor becomes 0.008. If BIESINGER and CHRISTENSEN's (1972) 48-h LC50 and "safe" concentrations for _D. magna_ are used, an application factor of 0.002 is obtained.

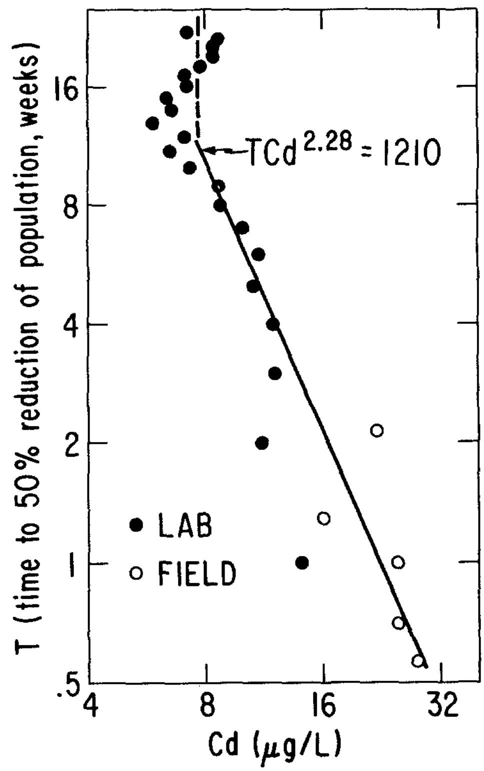

Figure 1. Cadmium toxicity curve for laboratory and field (_in situ_) populations of _Daphnia galeata mendotae_.

There is no reason to expect that the cadmium application factor for copepods and cladocerans would be significantly different, even though copepods are less sensitive to cadmium than cladocerans (MARSHALL and MELLINGER 1978). In deriving an application factor for zooplankton, the use of a 48-h EC50 for populations (as opposed to cohorts) has the advantage of being potentially applicable to the results of _in situ_ experiments in which several species are tested simultaneously under seminatural conditions. The use of laboratory populations of species that occur in the environment of interest has the added advantage of permitting the results to be verified in the field.

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