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Impact of pesticide application on zooplankton communities with different densities of invertebrate predators: An experimental analysis using small-scale mesocosms

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Abstract

We assessed the responses of zooplankton communities with different population densities of an invertebrate predator, *Mesocyclops pehpeiensis*, to insecticide (carbaryl, 0.5 mg L^{-1}) in small-scale mesocosm tanks (20 L). Cladocerans were eliminated by carbaryl application at both high and low predator densities. The density of rotifers increased after the elimination of the cladocerans by carbaryl application at low-predator density but not at high-predator density. Carbaryl application increased the relative importance of predatory interactions in the zooplankton community. The results suggest that predator abundance can affect the response of a zooplankton community to carbaryl application through predation on surviving zooplankton.

Keywords: Pesticide; Zooplankton; Mesocosm; Food web; Predation

1. Introduction

Zooplankton are important organisms in freshwater ecosystem since they occupy a central position in the food chain. They transfer energy from primary producers to higher trophic organisms such as fish, and their community structure, biomass, and production influence the whole food web structure of freshwater ecosystems through trophic interactions (Mills and Forney, 1988). At the same time, they are one of the groups most sensitive to toxic chemicals (Hanazato, 2001). Thus, they have been frequently used in ecotoxicological tests (OECD, 1981; Japanese Society of Environmental Toxicology, 2003). Among many toxic chemicals, pesticides affect zooplankton at individual, population, and community levels (Goodrich and Leach, 1990; Dodson et al., 1995; Hanazato, 1998a, 2001).

Recent ecotoxicological studies have concentrated on the community level responses of zooplankton to contamination by toxic chemicals, including pesticides (Hanazato and Kasai, 1995; Sierszen and Lozano, 1998; Lahr et al., 2000; Kreutzweiser et al., 2002), in relation to the zooplankton's functional roles in fresh-

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water ecosystems. As a community, zooplankton include many different species at different trophic levels in the food web. The application of toxicants can differentially alter the population densities of predators and prey, and affect prey–predator interactions in the community (Hanazato, 1998b; Preston et al., 1999a,b). Since predation has an important impact on zooplankton populations through top-down regulation, the impact of toxicants on a zooplankton community can be seriously affected by the presence of predators through changes in predator–prey interactions in the community. The influence of *Chaoborus* larvae (Diptera, Chaoboridae) and a predacious rotifer, *Asplanchna*, on the impact of insecticide application on a zooplankton community has been studied in mesocosms such as artificial ponds and enclosures (Hanazato, 1991; Peither et al., 1996). It may also be true that the presence of cyclopoid copepods, common invertebrate predators in freshwater, can influence the effects of insecticides on zooplankton communities. However, the relationship between the presence of copepods and insecticides in their effects on zooplankton communities is poorly understood, probably owing to the difficulties in manipulating the density of copepods in mesocosms.

We compared the response of zooplankton communities with different population densities of the predacious copepod *Mesocyclops pehpeiensis* to pesticide application in mesocosms. Mesocosms such as experimental ponds and enclosures are frequently used as model systems to examine the response of zooplankton to chemical application at a community level. However, their size often causes difficulties in controlling experimental environments. In particular, it is difficult to control invertebrate predators such as copepods, which often develop high population density in large mesocosms. To exclude these problems, we used small-scale mesocosms (20 L), in which we could control temperature, food condition, and predation pressure by the copepods.

2. Methods

2.1. Model ecosystem

The experiment was set up on 19 April 2003 (day 0) and terminated on 8 June 2003 (day 46). Twelve 20-L cylindrical polyethylene tanks (diameter, 30 cm; height, 31 cm) were used as the mesocosms. The tanks were lined with polyethylene film to avoid any influence of previous experiments. To establish the zooplankton communities, 1 kg of bottom mud from the eutrophic Lake Suwa (36°2′N, 138°5′E), Japan, containing resting stages of zooplankton was placed in each tank on day 0. The bottom mud was collected with an Ekman-Birge dredge from the lake on 9 April 2003, and was stored in a refrigerator (4 °C) until the experiment was set up. All the tanks were kept in a temperature-controlled room (20 °C) with a photoperiod of 16 h light and 8 h dark. The green alga *Chlorella* (Chlorella Industry Co. Ltd., Fukuoka, Japan) was added to the tanks to a final density of approximately 3.3×10^4 cells mL^{-1} on day 10 and every 3 days thereafter.

The experimental procedure is illustrated in Fig. 1. The tanks were divided into two groups: high and low predator (*M. pehpeiensis*) densities. Since some cyclopoid copepods emerged from the resting stage in the bottom sediment, maintaining the complete absence of the predators in the tanks was impossible. We increased the density of *M. pehpeiensis* by introducing 40 late copepodites or adults into each high-predator-density tank on day 24. The introduced *M. pehpeiensis* came from tanks prepared as a *Mesocyclops* pool. Those tanks included bottom mud of Lake Suwa and were maintained for more than 2 months with high *Chlorella* density and high densities of rotifers and small cladocerans, the food of *M. pehpeiensis*. In contrast, adult *M. pehpeiensis* in the low-predator-density tanks were caught using a pipette on day 24. To minimize disturbance to other zooplankton in the tanks, we caught *M. pehpeiensis* near the surface quickly and gently. On day 33, 10 mg of carbaryl (Wako Pure Chemical Industries Ltd., Japan) diluted with 50 mL of solvent (ethanol) was added to the tanks to produce a nominal concentration of 0.5 mg L^{-1}. Solvent only (50 mL) was added to half of the tanks with each predator density as controls (Fig. 1). The basic environmental factors in the tanks during the experiment are summarized in Table 1 and show little variance between the tanks.

2.2. Zooplankton sampling and analysis

Before the carbaryl application (day 33), samples were collected on days 12, 19, 24, and 33. After the