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PRIMARY RESEARCH PAPER

Individual and combined effects of humic acid on life-history characteristics of the water flea *Moina macrocopa* upon whole-lifespan cadmium exposure

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Abstract Investigation of the effects of natural compounds in aquatic ecosystems on the modula-tion of toxicity of coexisting xenobiotics is impor- tant for realistic ecological risk assessments. We investigated the individual and interactive effects of sublethal cadmium (Cd) concentrations and environ- mentally realistic humic acid (HA) concentrations on several life-history characteristics of *Moina mac- rocopa*. Female individuals were exposed to Cd and HA for their entire lifespan from the neonatal stage. The survival and reproductive output were recorded daily, and the growth and swimming velocity were determined upon maturity. Cd at the tested concentrations in single treatments did not significantly affect the growth and lifespan. But 5 µg/l Cd significantly decreased the swimming velocities and reproduction. Greater than 20 mg/l HA in single treatments significantly increased the individuals' growth, reproduction, and lifespan. Swimming velocities were significantly increased at 10 mg/l HA in single treatments. In combined treatments, such beneficial effects on all life-history characteristics were still seen under the co-occurrence of 1 µg/l Cd, but with 5 µg/l Cd, those beneficial effects on life-history characteristics except for swimming velocities were not observed. These dissimilar responses of different life-history characteristics indicate energy tradeoffs for maintenance, reproduction, and longevity, upon exposure to stressors in *M. macrocopa*.

Keywords Chronic toxicity · Co-exposure · Heavy metals · Humic substances · Zooplankton

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Introduction

Humic substances (HSs) are a group of ubiquitous, naturally occurring compounds in the environment. They make up about 50 to 80% of dissolved organic carbon (DOC) in freshwater habitats where typical DOC levels range between 1 and 100 mg/l (Steinberg et al., 2006). The composition of HSs varies from source to source because they originate from microbiological, chemical, and photochemical transformations of plant and animal residues (Rodrigues et al., 2009). Therefore, HSs can be viewed as superstructures of heterogeneous small organic compounds,