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The effect of pesticides on the composition of aquatic macrofauna communities in field ditches

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Abstract

Ditches surrounding agricultural fields in the Netherlands are predominantly used for flood control, and they accommodate aquatic plant and animal species. Studies addressing the effects of pesticides in combination with abiotic and biotic factors on aquatic biota in ditches are scarce. The current study aimed to investigate the effects of pesticides along with environmental factors, presence of other biota and time on the community composition of aquatic macrofauna in ditches next to flower bulb fields and pastures. Macrofauna samples and environmental data were collected during two consecutive years. Ponds in a sandy dune area of a nature reserve next to the polders were sampled as control sites. Data was analyzed with the variance partitioning procedure based on the redundancy analysis (RDA). The total variance in macrofauna community composition was divided into the variance explained by pesticides, environmental factors (water chemistry parameters and macrophyte coverage), time (study year and the number of the month), shared variance, and unexplained variance. The total explained variance in macrofauna community reached 22.6%. The largest proportion of explained variance was attributed to environmental factors (10.1%) followed by pesticides (5.4%) and time (4.8%). When each macrofauna group was analyzed separately, presence of other biota and environmental factors explained the largest proportion of variance in most of the macrofauna groups. Results of the study indicate that environmental factors, biotic interactions and temporal variation influence freshwater macrofauna considerably along with pesticides. We suggest that environmental managers should consider the multiple stressor contexts of aquatic ecosystems.

Zusammenfassung

Die Gräben, die in den Niederlanden landwirtschaftliche Flächen durchziehen, dienen hauptsächlich der Wasserstandskontrolle. Sie beherbergen aquatische Pflanzen- und Tierarten. Wir untersuchten den Einfluss von Pestiziden zusammen mit Umweltfaktoren, Vorhandensein anderer Taxa und Probetermin auf die Zusammensetzung der aquatischen Makrofauna in Gräben in der Nachbarschaft von Blumenzwiebelfeldern und Weiden. Proben wurden in zwei aufeinanderfolgenden Jahren genommen. Tümpel im Sanddünengebiet eines nahegelegenen Naturschutzreservats dienten als Kontrollen. Die Daten wurden mit der Varianzpartitionierung nach Redundanzanalyse analysiert. Die Gesamtvarianz der Zusammensetzung der Makrofaunagemeinschaft wurde untergliedert in die Varianzanteile, die durch Pestizide, Umweltfaktoren (hydrochemische Parameter und

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Makrophytenbestand) und Termin (Untersuchungsjahr und Monat) erklärt wurden, sowie gemeinsame Varianz und unerklärte Varianz. Die insgesamt erklärte Varianz der Makrofaunagemeinschaft erreichte 22,6%. Die größten erklärten Anteile entfielen auf Umweltfaktoren (10,1%), Pestizide (5,4%) und Termin (4,8%). Wenn die Makrofaunagruppen getrennt analysiert wurden, erklärten Umweltfaktoren und die Anwesenheit anderer Taxa in den meisten Fällen die größten Varianzanteile. Unsere Ergebnisse zeigen, dass Umweltfaktoren, biotische Interaktionen und zeitliche Variation die Süßwassermakrofauna erheblich neben den Pestiziden beeinflussen. Das Umweltmanagement sollte die vielfältigen Zusammenhänge von Stressoren in aquatischen Ökosystemen berücksichtigen.
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Keywords: Abiotic factors; Biotic factors; Freshwater macrofauna; Pesticides; RDA

Introduction

Ditches are the typical aquatic ecosystems in the Netherlands and in addition to their direct function of water level control also have high aquatic biodiversity (Verdonschot, Keizer-Vlek, & Verdonschot 2012). Drainage ditches contain high numbers of aquatic plant and animal species, as well as semi-terrestrial species. Macrofauna in turn play an important role in the food chain and biochemical cycles in aquatic ecosystems. Thus, the presence of macrofauna in the sediments enhances the microbial nitrogen cycle by bioturbation. Bioturbation facilitates the transport of inorganic and organic nitrogen between sediment and water (Kristensen & Kostka 2005; Laverock, Gilbert, Tait, Osborn, & Widdicombe 2011). Thus, macrofauna take part in the processes of nitrification and denitrification, which in turn link nutrients in water to microbial communities in sediments (Stief 2013). Macrofauna living in the water column feed on unicellular algae and bacteria, consuming fixed nitrogen and controlling the nitrogen pool in aquatic ecosystems (Stief 2013).

To protect aquatic biodiversity and its ecosystem functions, it is important to understand the effects of chemicals on aquatic biota in the field. The reason for this is that in the real environment various abiotic and biotic factors influence the performance of aquatic organisms and affect the fate of pesticides in the aquatic environment. Several studies emphasized the importance of considering ecological parameters in ecotoxicological studies (Maund et al. 1997; Liess et al. 2003). A number of studies did include ecological factors in the assessment of pesticide effects on aquatic biota in the field. For instance, in the field study of Berenzen, Kumke, Schulz, and Schulz (2005) the effects of pesticides on macroinvertebrates were analyzed in combination with stream characteristics and water chemistry parameters. The study of Szöcs, Kefford, and Schäfer (2012) addressed the effects of pesticides in combination with salinity and other environmental factors (habitat and water chemistry parameters) on macroinvertebrate communities in streams. Martin, Bertaux, Le Ber, Maillard, and Imfeld (2011) investigated the responses of macroinvertebrate communities in stormwater wetlands to pesticide runoff taking into account physicochemical characteristics, hydromorphological features and vegetation coverage. Bollmohr et al. (2011) assessed the effects of pesticides along with physicochemical characteristics on meiobenthic communities in estuary. However, to our knowledge, the effects of pesticides on aquatic biota in combination with abiotic, biotic factors and time have not been previously studied in the field.

In the present study we aimed to quantify what proportion of the total variance in community composition of aquatic macrofauna (including crustaceans, annelids, molluscs, fish, insects) can be explained by pesticides, environmental factors (water chemistry parameters and macrophyte coverage), presence of other biota (abundance of other macrofauna groups) and time (seasonal and annual variation). To answer these questions, macrofauna sampling, measurements of water chemistry parameters and pesticide concentrations in ditches of Dutch polders with intensive flower bulb crops were performed during two consecutive years (2011–2012). Variance partitioning based on the redundancy analysis (RDA) was used to rank the groups of explanatory variables (pesticides, environmental factors, biota, time and shared variance) with respect to the amount of explained variance.

Materials and methods

Research area

The research area is located in the flower bulb growing region of The Netherlands. There is an elevation gradient in the area: the height above sea level decreases gradually from the nature reserve (the highest site is located 4.26–4.5 m above the sea level) toward the polders (the lowest site is located −0.49 m to −0.25 m below the sea level). The nature reserve area is located on the northern part of the polder, so that no contamination comes from the north and north-west side.

Sampling sites

During the year 2011, macrofauna and water chemistry samples were collected at 14 sites within the area: two sites in ponds within the nature reserve area, two sites in

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