Environmental Pollution 186 (2014) 90–97

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Landscape parameters driving aquatic pesticide exposure and effects

Katja Bunzel [a,b,c,*], Matthias Liess [b], Mira Kattwinkel [b,d]

[a] UFZ – Helmholtz Centre for Environmental Research, Department Bioenergy, Permoserstrasse 15, 04318 Leipzig, Germany
[b] UFZ – Helmholtz Centre for Environmental Research, Department System Ecotoxicology, Permoserstrasse 15, 04318 Leipzig, Germany
[c] University Koblenz-Landau, Institute for Environmental Sciences, Quantitative Landscape Ecology, Fortstrasse 7, 76829 Landau, Germany
[d] Eawag, Swiss Federal Institute of Aquatic Science and Technology, Ueberlandstrasse 133, CH-8600 Duebendorf, Switzerland

ARTICLE INFO

Article history:
Received 14 August 2013
Received in revised form
18 November 2013
Accepted 27 November 2013

Keywords:
Pesticide sources
Macroinvertebrates
SPEAR
Monitoring
Mitigation measures

ABSTRACT

Pesticide contamination is considered one of the reasons streams fail to achieve good ecological and chemical status, the main objectives of the Water Framework Directive. However, little is known on the interaction of different pesticide sources and landscape parameters and the resulting impairment of macroinvertebrate communities. We evaluated the potential effects of diffuse and point sources of pesticides using macroinvertebrate monitoring data from 663 sites in central Germany. Additionally, we investigated forested upstream reaches and structural quality as landscape parameters potentially mitigating or amplifying the effects of pesticides. Diffuse pesticide pollution and forested upstream reaches were the most important parameters affecting macroinvertebrate communities (pesticide-specific indicator $SPEAR_{pesticides}$). Our results indicate that forested upstream reaches and riparian buffer strips at least 5 m in width can mitigate the effects and exposure of pesticides. In addition, we developed a screening approach that allows an initial, cost-effective identification of sites of concern.

1. Introduction

In agricultural areas, pesticides are major stressors in freshwater ecosystems and potentially have adverse effects on aquatic communities. A considerable number of investigations have shown the negative effects of pesticide contamination caused by diffuse agricultural sources on aquatic macroinvertebrate communities (Liess and von der Ohe, 2005; Schäfer et al., 2012; Thiere and Schulz, 2004). In addition, several studies have detected significant amounts of pesticides in the effluent of wastewater treatment plants (WWTPs) (Berenzen et al., 2003; Gerecke et al., 2002; Wittmer et al., 2010). In a previous study, we showed that pesticides from these point sources can significantly affect the macroinvertebrate community within 3 km downstream of WWTPs (Bunzel et al., 2013). However, we could not detect significant insecticidal effects of diffuse agricultural sources of pesticides, because of the scarcity of adjacent arable land and the frequent occurrence of riparian buffer strips in our dataset.

In addition to the various pesticide sources, landscape parameters potentially mitigate or amplify the effects of pesticides on macroinvertebrate communities. For example, previous studies have shown that forested stream sections can partially mitigate the effects of pesticides and considered them as potential sources for recolonisation of downstream sites (Liess and von der Ohe, 2005; Schäfer et al., 2007; Schriever et al., 2007a). Furthermore, Rasmussen et al. (2012) suggested that hydromorphological degradation often interacts with pesticide pollution in agricultural areas which, in turn, can cause altered effects of these stressors.

In general, there is a lack of studies that investigate the effects of diffuse or point sources of pesticides and provide an overview of the different sources and landscape parameters that influence the effects of pesticides on the macroinvertebrate community. This knowledge would be valuable to water authorities with respect to the Water Framework Directive (WFD) objective of achieving good ecological and chemical status for all water bodies. Information from these studies would allow authorities to target limited monitoring capacities and to develop appropriate mitigation measures for pesticide contamination.

Against this background, the overall aim of the present study was to conduct a comprehensive assessment of the effects of pesticides on macroinvertebrate communities by including all relevant pesticide sources and landscape parameters. We first evaluated the insecticidal effects of diffuse (arable land and garden allotments, taking into account riparian buffer strips) and point sources (WWTPs) on the macroinvertebrate community using governmental monitoring data from 663 sampling sites. In addition to the 327 Hessian sites used in Bunzel et al. (2013), we analysed 336 sites

* Corresponding author.
E-mail addresses: katja.bunzel@ufz.de (K. Bunzel), matthias.liess@ufz.de (M. Liess), mira.kattwinkel@ufz.de (M. Kattwinkel).

0269-7491/$ – see front matter
http://dx.doi.org/10.1016/j.envpol.2013.11.021

in the German federal states of Saxony, Saxony-Anhalt and Thuringia. We investigated the different pesticide sources, as well as forested upstream reaches and structural quality as landscape parameters that influence the effects of pesticides. In a last step, we set up a screening approach reflecting the risk to macroinvertebrate communities as a result of pesticide contamination.

2. Material and methods

2.1. Study area

We analysed 663 sampling sites in four central German federal states: Hesse – 327, Saxony – 160, Saxony-Anhalt – 127 and Thuringia – 49 (Fig. 1). Agriculture is the main land use in all four states; agriculture covers 42% of the total area in Hesse, 55% in Saxony, 62% in Saxony-Anhalt and 54% in Thuringia. The next important land use is forest, which covers 40% of the total area in Hesse, 27% in Saxony, 24% in Saxony-Anhalt and 32% in Thuringia.

2.2. Macroinvertebrate data

We used WFD monitoring macroinvertebrate data provided by the respective official authority: Hesse – Hessian State Office for Environment and Geology (HLUG); Saxony – Saxon State Office for the Environment, Agriculture and Geology (LfLUG); Saxony-Anhalt – Saxony-Anhalt State Agency for Flood Protection and Water Management (LHW); and Thuringia – Thuringian Authority of Environment and Geology (TLUG). We applied the following criteria to obtain a relatively harmonised dataset: a) sampling from March to June 2005 or 2006, b) a stream width smaller than 10 m, c) a minimum of 1500 m from the stream source, d) no lake or reservoir within 1500 m upstream, e) at least 10 species identified and f) existing data on structural quality (see Section 2.5). We excluded five sites in Saxony and six sites in Saxony-Anhalt because they were either in a former open-cast mining area or close to recently flooded open-cast mines.

Three-fourth of the sites were sampled in March or April and, therefore, before the main application time for pesticides in Germany. At these sites, the species had several months to recover from possible effects from the previous year. Therefore, the potential alterations in community composition represent rather long-term than acute effects.

We used the macroinvertebrate index $SPEAR_{pesticides}$ to quantify the effects of insecticide toxicity of pesticides on the macroinvertebrate community (Liess and von der Ohe, 2005). Pesticides are generally applied on a seasonal basis. Therefore, $SPEAR_{pesticides}$ incorporates the physiological sensitivity of the species to organic toxicants, post-contamination recovery (generation time and migration ability), and the presence of sensitive aquatic stages during the main application time for pesticides.

Based on these biological traits, the identified taxa were classified as sensitive species (SPecies At Risk – SPEAR) or tolerant species (SPEnotAR) based on their vulnerability to pesticides. Subsequently, the relative abundance of sensitive taxa in the community ($SPEAR_{pesticides}$) was calculated for each site:

$$SPEAR_{pesticides} = \frac{\sum_{i=1}^{n} \log(x_i + 1) \cdot y}{\sum_{i=1}^{n} \log(x_i + 1)} \times 100 \quad (1)$$

where n is the number of taxa; x_i is the abundance of taxon i, and y is: 1 if taxon is classified as SPEAR, otherwise 0.

$SPEAR_{pesticides}$ has been applied successfully to indicate insecticidal effects of pesticides on macroinvertebrate communities in different geographical regions (Schäfer et al., 2013). This index is also potentially applicable across different types of water courses and has been shown to be independent of other environmental factors (Liess and von der Ohe, 2005; Schletterer et al., 2010). The index $SPEAR_{pesticides}$ was calculated using the SPEAR Calculator (available online at http://www.systemecology.eu/SPEAR/index.php).

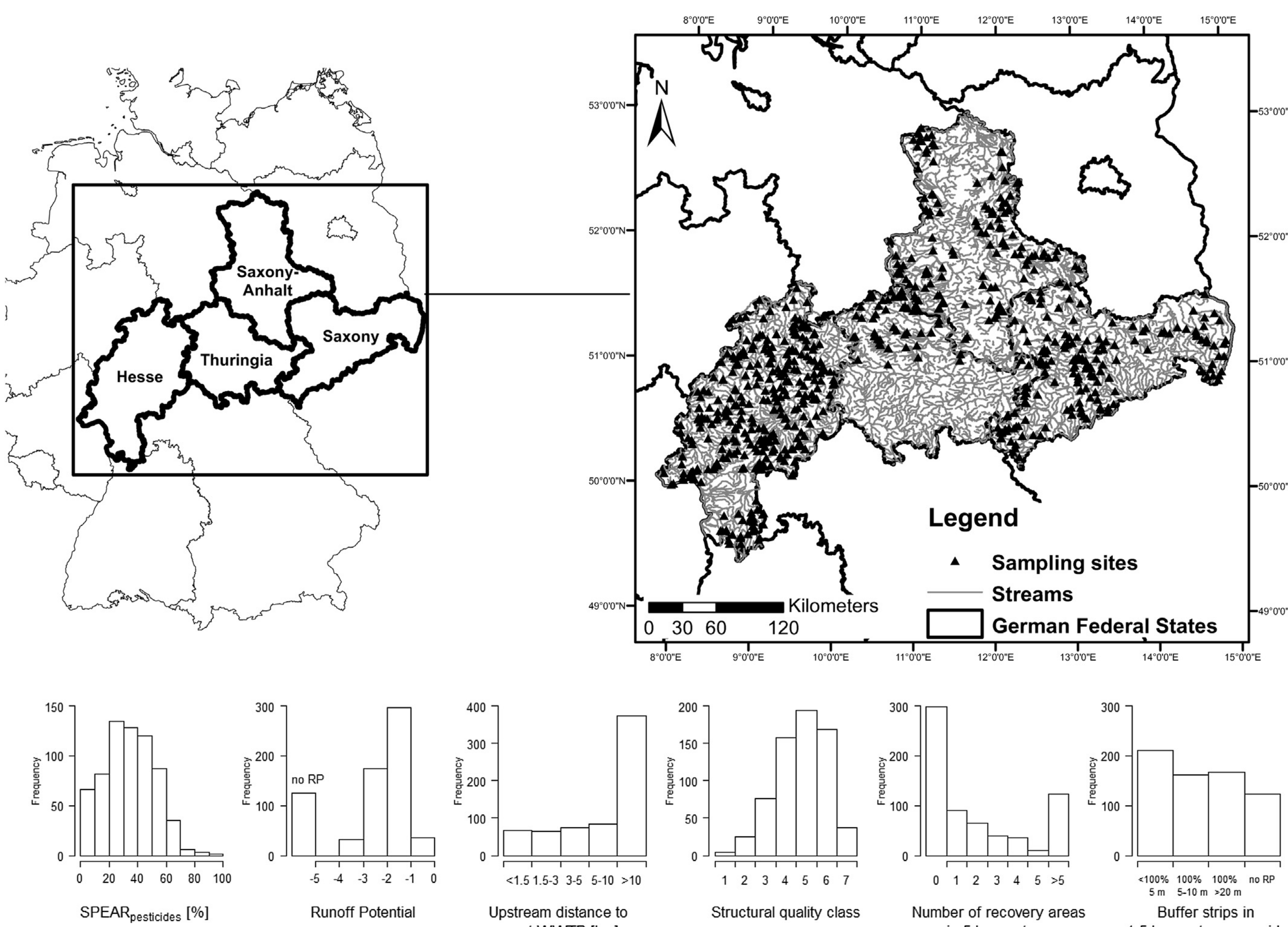

Fig. 1. Distribution of sampling sites and histograms of the main variables investigated.