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Temporal coincidence of amphibian migration and pesticide applications on arable fields in spring

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Abstract

Pesticide management may differ between crop species and farm type, particularly with regard to type, number, amount and date of pesticide applications. Such variations in pesticide application strategies entail different temporal coincidence with amphibian species and with species' population proportions. For the first time, we assessed the presence of *Bombina bombina*, *Rana arvalis*, *Pelobates fuscus* and *Triturus cristatus* in agricultural fields. We quantified the temporal coincidence of pesticide applications with the breeding migrations of adult amphibians and evaluated a realistic exposure to pesticides, including the interception by various crops at different growth stages. The level of species-specific coincidence depended on the performed pesticide management, determined by the timing, crop, number and type of pesticide applications. Late migrating species, such as *B. bombina* and *P. fuscus*, overlapped more with pesticide applications than early migrating species, such as *R. arvalis*. Up to 86% of the reproducing population proportion of *P. fuscus* experienced a temporal coincidence with a single pesticide application during stem elongation in winter rape (80% interception). In maize, up to 17% of the reproducing population proportion of *B. bombina* encountered a single herbicide application during bare soil/emergence (no interception). Local monitoring of amphibian migration combined with adjusted pesticide management is recommended to reduce temporal coincidence and thus potential risk of pesticide exposure of amphibians.

Zusammenfassung

Das Pestizidmanagement kann zwischen Kulturpflanzen und Anbauweise variieren, besonders in Bezug auf Art, Anzahl, Menge und Zeitpunkt von Pestizidanwendungen. Diese Variation bedingt unterschiedliche Koinzidenz von Amphibienpräsenz und Pestizidanwendungen. Wir haben zum ersten Mal die Präsenz von *Bombina bombina, Rana arvalis*, *Pelobates fuscus* und *Triturus cristatus* auf landwirtschaftlichen Flächen bewertet. Wir haben die zeitliche Koinzidenz dieser vier Amphibienarten mit Pestizidanwendungen während der Frühjahrswanderung zu und von den Laichgewässern quantifiziert und die realistische Exposition gegenüber Pestiziden eingeschätzt, inklusive einer Pestizidinterzeption durch die Kulturpflanzen bei verschiedenen Wachstumsstadien. Die Höhe der artenspezifischen Koinzidenz war dabei abhängig von dem angewendeten Pestizidmanagement. Spät wandernde Arten wie *B. bombina* und *P. fuscus* koinzidierten häufiger mit Pestizidanwendungen als frühe Arten

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wie *R. arvalis*. Bis zu 86% der reproduzierenden Individuen von *P. fuscus* koinzidierten mit einer einzigen Pestizidanwendung in Winterraps bei 80% Interzeption. Bis zu 17% der reproduzierenden Individuen von *B. bombina* koinzidierten mit einer Herbizidanwendung in Mais bei 0% Interzeption. Das lokale Monitoring von Amphibienwanderungen in Kombination mit Anpassungen im Pestizidmanagement erscheint als geeigneter Ansatz um die zeitliche Koinzidenz zu mindern und das Risikopotenzial von Pestizidanwendungen für Amphibien zu reduzieren.

Introduction

Intensification of agriculture is discussed as a significant factor for the decline in amphibian populations (Petersen et al. 2004; Mann, Hyne, Choung, & Wilson 2009). With 40% global land coverage, the agricultural landscape is regarded as one of the largest terrestrial biomes on earth (Foley et al. 2005), and also represents an essential habitat for amphibians (Brühl, Schmidt, Pieper, & Alscher 2013). According to the German Federal Statistical Office (Statistisches Bundesamt 2013), about 52% of German land area was used for agriculture in 2009, 70% of which (about 130,000 km^2) was cropped area with associated pesticide applications.

Although the public associates amphibians mostly with an aquatic environment, most temperate amphibians live in terrestrial habitats outside the breeding season for hibernation, foraging and growth. In general, these terrestrial habitats can be kilometers away from breeding ponds (Günther 1996). In agricultural landscapes, breeding habitats (i.e. ponds and temporary wetlands) often are completely surrounded by arable land. Therefore, amphibians regularly have to cross agricultural land during migration from terrestrial to aquatic habitats for reproduction (Günther 1996; Berger, Pfeffer, & Kalettka 2011; Fryday & Thompson 2012). Exposure to agro chemicals, such as fertilizers and pesticides, is likely during migrations over arable land (Becker, Fonseca, Haddad, Batista, & Prado 2007; Berger, Graef, & Pfeffer 2012). Due to their permeable skin (Gallant, Klaver, Casper, & Lannoo 2007), amphibians are more sensitive than mammals and birds to dermal uptake of chemicals (Quaranta, Bellantuono, Cassano, & Lippe 2009). The dermal uptake of pesticides can cause lethal or sub-lethal effects (Brühl, Pieper, & Weber 2011). Uptake via contaminated food is also conceivable, but given the potential for dermal uptake, food intake is less likely to be the major source of pesticide exposure (Smith 2007). Recent laboratory studies showed high toxicity of commonly used pesticides to terrestrial amphibians at field application rates (Belden, McMurry, Smith, & Reilley 2010; Brühl et al. 2013). Therefore, field cultivation and, in particular, pesticide applications may create a sink for populations. Pesticides may promote local extinctions in combination with reproductive failure (Taylor, Scott, & Gibbons 2006; Salice, Rowe, Pechmann, & Hopkins 2011) and decreased habitat/population connectivity (Ficetola & De Bernardi 2004; Becker et al. 2007; Harper, Rittenhouse, & Semlitsch 2008).

Whereas the toxicity of pesticides to amphibians is scientifically established (Mann et al. 2009; Brühl et al. 2013), few studies contain detailed information on fine-scale movement patterns in agricultural landscapes (Miaud & Sanuy 2005; Oromí, Sanuy, & Sinsch 2010) or quantify the population proportion affected by applications of agrochemicals (Berger et al. 2012). Such information is often lacking, which makes realistic assessments of terrestrial pesticide exposure of amphibians difficult (Smith et al. 2007; Brühl et al. 2011).

Pesticide management differs between crops and farm, particularly with regard to type, number, amount and date of application of pesticides. Such variations in pesticide application strategies entail different temporal coincidence with amphibian species migrating through or remaining in agricultural fields. Our study was designed to investigate the temporally distinctive spring migration of adult amphibians and its temporal overlap with pesticide applications. Therefore, we quantified population proportions of four amphibian species migrating just before, during and directly after pesticide applications. We investigated the fire-bellied toad (*Bombina bombina* (Linnaeus, 1761)), moor frog (*Rana arvalis* (Nilsson, 1842)), spadefoot toad (*Pelobates fuscus* (Laurenti, 1768)) and crested newt (*Triturus cristatus* (Laurenti, 1768)), covering a wide range of life cycles and migration types for temperate amphibians. All four species are protected under the European Habitats Directive (EEC 1992). For the first time, we assessed their presence in agricultural fields and obtained a realistic estimate of exposure to pesticides, by also taking into account the interception by various crops at different growth stages. We highlight the critical temporal coincidence of amphibian activity and pesticide applications in order to improve the basis for terrestrial exposure assessment of amphibians.

Material and methods

Study area

The study area (700 ha) is located 50 km east of Berlin and is part of the young moraine landscape in the northeastern plain of Germany. The climate is continental with an average air temperature of 8.3 °C and a mean annual precipitation of 530 mm (Berger et al. 2011). The landscape mainly consists of arable fields, ranging in size from 10 to 90 ha, and 56 small water bodies ranging from 0.025 to 1.56 ha