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Aquatic macroinvertebrate assemblages are affected by insecticide applications on the Argentine Pampas

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ABSTRACT

Agriculture intensification in Argentina has increased agrochemicals consumption in the last decades and might represent an environmental risk for adjacent water bodies. The objective of the present work was to assess the effect of land use on water quality and invertebrate assemblages in the Argentine Pampas streams. Eight streams were sampled on 4 occasions during the 2013/14 growing season. Three streams are located within a biosphere reserve, two drain basins with extensive livestock fields, and three run through intensively cultivated plots; one of them contained a 30 m wide uncultivated grass-covered strip between the crop and the stream. Macroinvertebrates were sampled from emergent vegetation by means of a D-net with a 500 µm pore size, and 30 cm diameter.

Higher nutrient concentrations were measured in the agricultural streams. Endosulfan was measured in sediments of the agricultural streams, concentrations being significantly lower in the stream with the buffer strip. Invertebrate assemblages in the cropped streams were significantly different from those in the livestock and reserve streams, those in the latter not being different from each other. Ampullaridae (*Pomacea canaliculata*) and Planorbidae (*Biomophalaria peregrina*) were the taxa best represented in the agricultural streams. Hyalellidae (*Hyalella curvispina*), Zygoptera and Planorbidae (*B. peregrina)* were the taxa best represented in the reserve and livestock streams. Present evidence suggests that the observed differences in the invertebrate composition in the agricultural streams were related with the impact of agrochemicals and that buffer strips represent a useful attenuation practice. Cattle breeding on natural pastures represented a land use with low impact on the invertebrate assemblages.

1. Introduction

The Pampas plain covers 60 million hectares and represents the main agricultural area of Argentina, accounting for 60% of total crop production (CASAFE, 2009). Over the last decades crop production has increased due to progressive agricultural intensification. Traditionally, a mixed system of livestock raising and crop production, mainly wheat and corn, was the main land use. Genetically modified soy, resistant to glyphosate, was introduced on the Argentine market in 1996. Soy production steadily increased since then to become the main crop. The area sown with soy increased from 37,000 to 19 million hectares between 1970 and 2015 (MAGyP, 2016). Argentina became the world's third largest producer, after the US and Brazil (Aizen and Harder, 2009). Soy was accompanied by large scale husbandry changes. Most of the soy production is carried out under the so called "no-till" system which avoids disturbing the soil but increases herbicide consumption for the chemical fallow. Wheat and soy varieties with a short growing period allowed two harvests per year – wheat followed by soy. Overall, pesticide consumption increased from 6 million kilograms in 1992 (Pengue, 2000) to 32 million kilograms in 2012 (CASAFE, 2013). The same trend was observed in fertilizer application, which increased at an annual rate of 18% from 1991 to 2007, reaching 3.2 million tons in 2013 (CIAFA, 2016).

Repeated agrochemicals applications represent an environmental risk to adjacent water bodies. Runoff represents an important non-point contamination source in agricultural watersheds (Liess, 1994). The exposure scenario of the resident fauna to agrochemicals is difficult to assess because of the ephemeral nature of peak concentrations attained in coincidence with runoff events occurring after field applications (Jergentz et al., 2004). Biological monitoring is an alternative approach to assess the environmental impact of agricultural practices. Changes in the invertebrate assemblage in response to agrochemical loads have repeatedly been reported (Leonard et al., 1999; Castillo et al., 2006; Schäfer et al., 2007; Liess et al., 2008). Moreover, shifts in the invertebrate community were used to assess agrochemical contamination (Johnson et al., 1993). Changes in species richness and abundance

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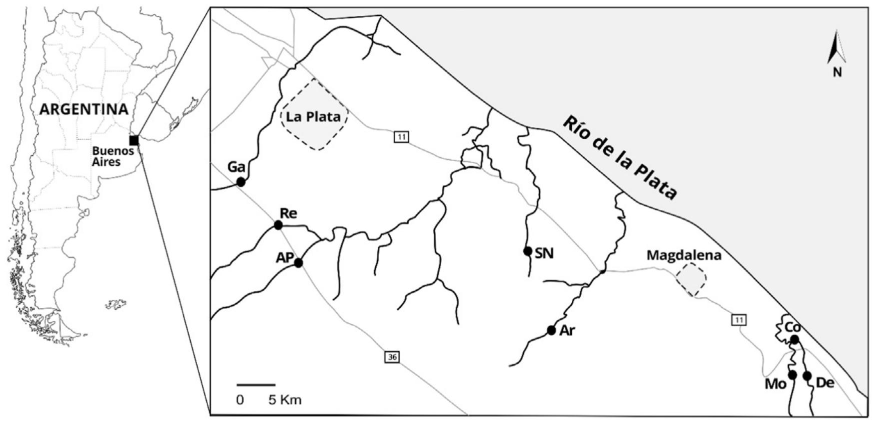

Fig. 1. Studied area and sampling sites.

represent a signal of impairment and might be used to register environmental degradation (Egler et al., 2012). The presence of insecticides in streams and sediments in the Pampas agricultural area has been reported (Jergentz et al., 2005; Marino and Ronco, 2005; Mugni et al., 2011; Aparicio et al., 2013; De Gerónimo et al., 2014; Lupi et al., 2015; Hunt et al., 2016). However, the effect of pesticide exposure on the resident fauna remains largely unreported. To our knowledge only Solis et al. (2016) described the composition of the invertebrate assemblages in streams with different land use in their watersheds, based on a limited number of studied streams. The objective of the present contribution is to further assess the effect of application of agrochemicals to crops on the invertebrate assemblages of adjacent streams on the Argentine Pampas plain.

2. Materials and methods

2.1. Study sites

Eight streams were studied in the Rio de la Plata coastal strip in Buenos Aires province, Argentina (Fig. 1). The streams run in a west-to-east direction towards the Río de la Plata. Stream depths ranged from 0.2 to 0.5 m and widths from 4 to 14 m. The climate is mild and humid with mean monthly temperatures range from 9.9 °C in July to 22.4 °C in January. Mean annual rainfall is 1060 mm with small seasonal variations (Hurtado et al., 2006).

The streams were sampled 4 times during the 2013-14 growing season in December 2013 and January, February and March 2014. The Remes (Re) (35°1´31.87´´S; 57°59´39.6´´W), Afluente Pescado (AP) (35°3′13.08″S; 57°58′35.3″W) and Gato (Ga) (34°58´ 53.8´´S; 58°3´12.1´´W) drain agricultural basins. Remes and Afluente Pescado streams are located close to each other and join to form the Pescado stream (Fig. 1). Next to Remes, the adjacent plot was cultivated up to a couple of meters from the stream, while at Afluente Pescado an uncultivated grassland strip was left between the crop and the stream. Corn was harvested on the plots adjacent to both streams. The strip was 30 m wide on the right bank and 80 m wide on the left bank. The Gato stream drains a basin with intensive horticultural farming, mainly of tomato and lettuce. The streams Arregui (Ar) (35°7´22.1´´S; 57°41´11.6´´W) and Sin Nombre (SN) (35° 2´22.8´´S; 57°42´40.5´´W) drain basins in which the main land use is extensive livestock raising on natural pastures. The Confluencia (Co) (35°7´53.10´´S; 57°24´1.47´´W), Destino (De) (35° 8´15.35´´S; 57° 23´40.2´´W) and Morales (Mo) (35°8´17.54´´S; 57° 23´57.7´´W) streams run through the "Parque Costero Sur" UNESCO Biosphere Reserve (Athor, 2009). The landscape is grassland with small patches of forest.

The Argentine Pampas streams lack forested borders. Conspicuous macrophyte growth is a common feature. Remes and Sin Nombre contained the largest macrophyte biomass, covering almost the whole water surface, composed mainly of *Typha domingensis* and *Ludwigia peploides*, accompanied in Sin Nombre by *Sagittaria montevidensis* and *Gymnocoronis spinlantoides*. The Morales and Destino streams also showed an important macrophyte covering; in Destino *L. peploides* and *Myriophyllum aquaticum* were dominant, accompanied by *Hydrochleis nymphoides*, while in Morales *Azolla filiculoides* and *M. aquaticum* were dominant. Confluencia and Arregui streams showed sparse mats of *Schoenoplectus californicus*, often accompanied by *A. filiculoides* and, in Arregui stream, by *Elodea* and mucilaginous algal mats. In the Gato stream the dominant macrophyte were *T. dominguensis* and dense stands of *L. peploides*; occasional algal mats were observed. The sampled site at Afluente Pescado showed the lowest macrophyte cover, represented mainly by *G. spinlantoides.*

2.2. Environmental variables

Dissolved oxygen, temperature, conductivity and pH in stream water were measured in situ with Yellow Spring Instruments SI 556 multiparameter equipment. The manufacturer´s calibration procedures were followed. Dissolved oxygen calibration was carried out in water samples of known concentration as determined by Winkler titration (APHA, 2012); conductivity and pH were calibrated with certified standards from Merck, 1 mS/cm for conductivity and buffer solutions of 4, 7 and 9 for pH calibration. Stream width and depth were assessed with a measuring tape.

2.3. Nutrients

Water samples were filtered through Whatman GF/C filters, and carried in coolers to the laboratory. Dissolved nutrients were determined in the filtrate. Soluble reactive phosphorus (SRP, molybdate-ascorbic), nitrite (NO_2, diazotation), nitrate (NO_3, hydrazine reduction followed by diazotation), and ammonium ($NH4^+$, indophenol blue) were determined following APHA (2012).

2.4. Pesticide analysis

Sediment samples were collected with a stainless steel scoop from the top two centimeters, and placed in amber glass jars. The samples were kept in coolers on ice until arrival at the laboratory where they were kept refrigerated until extraction (maximum 5 d). Sediments were extracted with a mixture of acetone and methylene chloride following You et al. (2004). Cleanup procedures were carried out using Florisil solid phase extraction (SPE) cartridges (USEPA, 2007). Endosulfan in bottom sediments was determined because it was the pesticide found in highest in the studied area in previous reports (Hunt et al., 2016; Solis et al., 2016). Endosulfan was measured following USEPA 8081A (1996); the sample extracts were injected into a GC-ECD (Thermo Scientific 1300), equipped with a HP5 column, 30 m and 0.32 ID, N_2 carrier, ramp and detector temperatures were: 100 °C (3 min), 15 °C/