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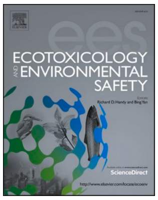

High sensitivity of invertebrate detritivores from tropical streams to different pesticides

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ABSTRACT

Freshwater organisms are often sensitive to pesticides, but their sensitivity varies across different taxa and with pesticide type and action mode, as shown by multiple acute toxicity tests. Such variability hampers predictions about how freshwater ecosystems may be altered by pesticide toxicity, which is especially critical for understudied areas of the world such as the tropics. Furthermore, there is little information about the sensitivity of some organisms that are key components of stream food webs; this is the case of litter-feeding detritivorous invertebrates, which contribute to the fundamental process of litter decomposition. Here, we examined the sensitivity of three common detritivores [*Anchytarsus* sp. (Coleoptera: Ptilodactylidae), *Hyalella* sp. (Amphipoda: Hyalellidae) and *Lepidostoma* sp. (Trichoptera: Lepidostomatidae)] to three pesticides commonly used (the insecticides bifenthrin and chlorpyrifos and the fungicide chlorothalonil) using acute (48 or 96 h) toxicity tests. Our study demonstrates that common-use pesticides provoke the mortality of half their populations at concentrations of 0.04–2.7 μg L^{-1}. We found that all species were sensitive to the three pesticides, with the highest sensitivity found for chlorpyrifos. Additionally, we used the approach of species sensitivity distributions (SSD) to compare our study species with *Daphnia magna* and other temperate and tropical invertebrates. We found that the study species were among the most sensitive species to chlorpyrifos and chlorothalonil. Our results suggest that tropical detritivores merit special attention in ecological risk assessment of pesticides and highlight the need for accurate ecotoxicological information from ecologically relevant species in the tropics.

1. Introduction

Tropical forests are declining at unprecedented rates in favor of agriculture (Gibbs et al., 2010), and such replacement causes severe impacts on stream ecosystems that are associated to multiple stressors (Rasmussen et al., 2016; Cornejo et al., 2019). Among these stressors, pesticides are of great importance as they are often toxic for freshwater organisms (Schäfer et al., 2011), causing sublethal and lethal effects and subsequent alterations in ecosystems (Bighiu et al., 2020; Bundschuh et al., 2020; Cornejo et al., 2020b). Many studies have examined the toxicity of different pesticides on a variety of freshwater invertebrates through acute and chronic toxicity tests, but the great majority of these studies have been conducted with species from temperate areas, mostly Europe and North America (Rico et al., 2011). Because of this paucity of data, water quality criteria in most tropical regions rely on extrapolations of ecotoxicological data from temperate zones using standard temperate species, assuming that their sensitivities are similar (Kwok et al., 2007; Schäfer et al., 2013), even though the fate and effects of

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pesticides may be different between climatic regions (Daam and Rico, 2018). This is an important research gap that hinders accurate assessments of the environmental risk of pesticides in tropical streams.

Additionally, there is little information about how some groups of organisms are affected by pesticides, and this includes litter-feeding detritivorous invertebrates (hereafter detritivores), which are major components of stream food webs (Cummins et al., 1989), especially in forested headwaters (Vannote et al., 1980). Litter decomposition is a key process and a fundamental component of stream ecosystem functioning, mediated by microbial decomposers and detritivores (Graça, 2001). These invertebrates feed on litter and thus contribute to its fragmentation, the production of fine particulate organic matter that serves as food to collectors (Cummins and Klug, 1979), and nutrient recycling (López-Rojo et al., 2019). Even if detritivores are less abundant and species rich in the tropics than in temperate areas (Boyero et al., 2011), they still play an important ecological role (Boyero et al., 2012; Cheshire et al., 2005; Yule et al., 2010). For this reason, and because they often belong to sensitive taxa (e.g., Trichoptera, Amphipoda; Boyero et al., 2020), it becomes crucial to assess how detritivores are affected by the presence and concentration of pesticides in streams.

Here, we examined the sensitivity of three common tropical detritivores [*Anchytarsus* sp. (Coleoptera: Ptilodactylidae), *Hyalella* sp. (Amphipoda: Hyalellidae) and *Lepidostoma* sp. (Trichoptera: Lepidostomatidae)] to three pesticides commonly used in agricultural land in Central America and western Panama: the insecticides bifenthrin and chlorpyrifos and the fungicide chlorothalonil. We performed acute (48 or 96 h) toxicity tests to assess the mortality and to calculate the mean lethal concentration (LC_{50}) of each pesticide for each species (with the only exception of the *Lepidostoma* – bifenthrin combination). We then used the approach of species sensitivity distributions (SSDs) to integrate acute toxicity data of multiple aquatic organisms from different trophic levels and geographic regions. SSDs are used to estimate hazardous concentrations (HC_p) that affect p% of species (Posthuma et al., 2002). We predicted that (1) our study species would be sensitive to the three pesticides tested, despite the existence of (2) differences among species and (3) differences among pesticides, with the insecticides being more harmful than the fungicide; and (4) our study species would be more sensitive than temperate species, including the standard species *D. magna.*

2. Materials and methods

2.1. Study area

Our study area was the upper catchment of the Chiriquí Viejo river, located on the Pacific coast of western Panama (8.25 – 9.00 °N, 82.25 – 83.00 °W). Catchment area is 1376 km^2, the length of the main river is 161 km and the highest altitude is 3474 m a.s.l. at the Barú Volcano (ETESA, 2008). The climate is tropical, with minimum, average and maximum air temperatures of 17.8, 28.0 and 35.5 °C, respectively (ANAM and CATIE, 2014). Total annual precipitation is 3400 mm on average, with a maximum of 7000 mm at high altitudes, 87.7% occurring in the wet season from May to December (ETESA, 2008). We conducted the study at the outdoor facilities of the Ministry of the Environment Station in the La Amistad International Park (PILA; 8.894 °N, 82.615 °W; MS Fig. S1), located ca. 400 m away from one of the streams where invertebrates were collected. This facilitated the collection and transport of invertebrates and water, and ensured similar temperature conditions between the collection sites and experimental location.

2.2. Pesticide selection

A total of 29 pesticides have been reported in the upper catchment of the Chiriquí Viejo river (Cornejo et al., 2019). We selected three for the present study based on their reported concentrations, persistence in the environment, physical properties, mechanisms of action and hazard (Table S1): the insecticides bifenthrin and chlorpyrifos and the fungicide chlorothalonil. Bifenthrin (C_{23}, H_{22} ClF_3O_2) is a pyrethroid insecticide commonly used in the control of foliage, which interferes with the sodium channel; in our study area it has been reported in ranges from 0.15 to 0.35 μg L^{-1}(Cornejo et al., 2019). Chlorpyrifos ($C_9H_{11}Cl_3NO_3PS$) is an organophosphate insecticide that acts as acetylcholinesterase (AChE) inhibitor it is widely used in agriculture and it has been reported in ranges from 0.14 to 15.24 μg L^{-1} in our study area (Cornejo et al., 2019). Chlorothalonil ($C_8Cl_4N_2$) is a polychlorinated aromatic compound that has been reported in ranges from 0.26 to 0.38 μg L^{-1} in sediment in the study basin (MIDA, 2016), and it has been shown to be lethal for temperate detritivorous caddisflies in microcosms (Cornejo et al., 2020a).

The three pesticides were purchased at local agricultural stores authorized for the sale and distribution of agrochemicals. The ranges provided for the three pesticides are those reported in a previous study conducted in the same area (Cornejo et al., 2019; MIDA, 2016). The dilutions were made using filtered stream water from the Chiriquí Viejo river collected within the PILA, where no pesticides had been detected (Cornejo et al., 2020b). Two ranges were set for working solutions: a first range of low concentrations (0.01, 0.1, 0.5 μg L^{-1}), and a second range of high concentrations (1.0, 1.5, 2.5, 5.0 and 10.0 μg L^{-1}). The working solutions were prepared from two nominal or stock solutions: 100 mg L^{-1} for the first range and 1000 mg L^{-1} for the second range. Stock solutions were prepared based on the concentration of the active principle indicated in the commercial products, using micropipettes with plastic tips and glass volumetric flasks. Nominal concentrations were used because we could not make measurements during the experiment due to logistical and financial limitations. Thus, we acknowledge that our results can be compared with other studies but should not be used in regulatory risk assessment (Von Fumetti and Blaurock, 2018).

2.3. Taxon selection, sampling and acclimation

We obtained a list of common detritivores and their distribution in the Chiriquí Viejo river upper catchment from previous studies (Cornejo et al., 2019, 2020b), and chose three taxa that were dominant in the area: *Anchytarsus* sp., *Hyalella* sp. and *Lepidostoma* sp. We did not identify the species, but confirmed that all individuals belonged to the same species (although we name them as genera hereafter for simplicity). We collected these detritivores in 1st and 2nd order independent tributaries of the Chiriquí Viejo river located within protected areas to guarantee that individuals had not been previously exposed to pesticides. These areas where the Barú Volcano National Park (PNVB), where we collected specimens of *Lepidostoma*, and the PILA, where we collected *Anchytarsus* and *Hyalella*. We used two sampling techniques: litter bags filled with *Alnus acuminata* Kunth. (Betulaceae) that were submerged in the stream for 15 days, and multihabitat sampling using a 0.5 mm D-net. At each sampling site we used a multiparameter probe (HACH; HQ40d) to measure pH, temperature (°C), conductivity (μS cm^{-1}), turbidity (NTU) and dissolved oxygen saturation (%); and a flowmeter (Flowatch 12, 300) to measure current velocity m s^{-1} (Table S2).

The collected invertebrates were placed in plastic containers filled with stream water and litter and provided with constant aeration, and transferred to the experimental facilities where they were counted and identified using a stereoscope. They were then placed in aquariums containing 1–2 L of stream filtered water, where they were acclimated for 96 h with constant aeration (provided through syringe tips connected to a pump), at an air temperature of 17.1 ± 0.8 °C, water temperature of 14.4 ± 0.2 °C, and light: dark regime of 12:12 h (the natural conditions at the time of the experiment). They were fed with fragments of *A. acuminata* litter for the first 48 h of acclimation and then fasted for the last 24 h before starting the acute toxicity tests (Table S3).

2.4. Toxicity tests

The tests were conducted in 216 microcosms distributed in 67 treatments, which corresponded to different combinations of taxa (*Anchytarsus*, *Hyalella* and *Lepidostoma*), pesticide types (bifenthrin, chlorpyrifos and chlorothalonil) and pesticide concentrations [0 (control), 0.01, 0.1, 0.5, 1.0, 1.5, 2.5, 5.0 and 10.0 µg L^{-1}]; the only combinations that were absent, due to logistical constraints, were those with *Lepidostoma* and bifenthrin. Thus, there were 24 microcosms per combination of taxon and pesticide, and three replicates per concentration (except controls, N = 6–9; Table S4; Fig. S1). Each microcosm contained 200 mL of filtered (100 µm) stream water, which was constantly aerated through syringe tips connected to an aquarium pump, and received five individuals of a given species (with 1080 individuals tested in total: 405 *Anchytarsus*, 405 *Hyalella* and 270 *Lepidostoma*).

Test methods were based on the Environmental Protection Agency standard protocol for toxicity testing with freshwater organisms (EPA, 2002). However, some environmental conditions were adapted to the ecological demands of the invertebrates tested. The experiment was performed in a static exposure regime with a single initial dose. During the experiment the air temperature was 17.1 ± 0.8 °C, the water temperature was 14.3 ± 0.2 °C and the light: dark regime was 12:12 h (which were the conditions in nearby streams at the time of the experiment). We assessed the effect of pesticide exposure using mortality as the end point. The tests lasted 48 (or 96 h in the case of *Anchytarsus* for bifenthrin and chlorothalonil) and lethal effects were monitored 24 and 48 h (or 96 h) after exposure, with dead organisms being removed.

2.5. Data analyses

Based on mortality at 48 or 96 h after exposure we calculated LC$_{50}$ values (i.e., the concentration required to kill 50% of the population) and associated 95% confidence intervals (CIs) for each species and pesticide concentration, using the *ecotox* package [Hlina et al. (2019) in R statistical software (R Core Team, 2020)]. We used the approach of SSD and HC$_5$ to compare our LC$_{50}$ values with those reported for aquatic organisms of different functional groups [collectors (Co); detritivores (De); herbivores (Hb); omnivores (Om); primary producers (Pp) and predators (Pr)], separated by pesticides and geographic distribution (see summary of data used in Table S5-S7). For this, we used the data available at the ECOTOX database of the United States Environmental Protection Agency (USEPA; https://cfpub.epa.gov/ecotox/search.cfm). We selected data from the ECOTOX database following these criteria (partly as in Maltby et al., 2005): (1) endpoints were LC$_{50}$ or median effect concentration (EC$_{50}$), regarding mortality or immobility for animals, and growth rate for algae; (2) test duration was 2–21 d for fish, and 1–7 d for invertebrates and algae; (3) the lowest value was selected when several duration values were studied in the same experiment; (4) the geometric mean was taken for data of the same species (and end point) but from different experiments; (5) data reported as $<$ or $>$ were not used; (6) only static tests carried out in the laboratory were considered; and (7) only values published in scientific literature were used since 2000. We calculated the SSD using the *ssdtools* R package (Thorley and Schwarz, 2018), and built different SSDs for LC$_{50}$/EC$_{50}$ for the three pesticides. The available distributions included the log-normal (lnorm), log-logistic (llog), and gamma distributions. The comparison between the sensitivity of tropical and temperate species to chlorpyrifos was verified using the Kolmogorov-Smirnov test.

3. Results

Mortality after 48 or 96 h of exposure was ≤ 10% in our control microcosms and corresponded to *Hyallela*. The results of the toxicity tests, LC$_{50}$ values (µg L^{-1}) and their 95% confidence intervals (CI) are shown in Table 1. LC$_{50}$ values indicated that chlorpyrifos was one order of magnitude more toxic than bifenthrin and chlorothalonil for the studied species. Both *Anchytarsus* (LC$_{50\text{–}96\ h}$ = 1.54 µg L^{-1}) and *Hyalella* (LC$_{50\text{–}48\ h}$ = 1.77 µg L^{-1}) had similar sensitivities to bifenthrin exposure. In the case of chlorpyrifos, *Hyalella* (LC$_{50\text{–}48\ h}$ = 0.037 µg L^{-1}) and *Lepidostoma* (LC$_{50\text{–}48\ h}$ = 0.038 µg L^{-1}) were the most sensitive species, followed by *Anchytarsus* (LC$_{50\text{–}48\ h}$ = 0.079 µg L^{-1}). For chlorothalonil, *Hyalella* (LC$_{50\text{–}48\ h}$ = 0.57 µg L^{-1}) was the most sensitive species, followed by *Lepidostoma* (LC$_{50\text{–}48\ h}$ = 2.72 µg L^{-1}) and *Anchytarsus* (LC$_{50\text{–}96\ h}$ = 1.96 µg L^{-1}).

Table 1
Results of the acute toxicity tests (24–96 h) with bifenthrin, chlorpyrifos and chlorothalonil for three detritivores, with mortality as endpoint; we show the LC$_{50}$ and R^2 of the test.

Pesticides	Species	Test duration (h)	LC$_{50}$ (95% CI; µg L^{-1})	R^2
Bifenthrin	*Anchytarsus*	24	10.7 (6.63–35.9)	0.54
		48	2.86 (1.69–5.8)	0.63
		96	1.54 (0.74–3.0)	0.67
	Hyalella	24	4.30 (3.15–6.45)	0.49
		48	1.77 (1.28–2.4)	0.74
Chlorpyrifos	*Anchytarsus*	24	0.211 (0.106–0.345)	0.82
		48	0.0799 (0.0333–0.148)	0.83
	Hyalella	24	0.106 (0.04–0.22)	0.90
		48	0.0370 (0.00671–0.0958)	0.88
	Lepidostoma	24	0.0470 (0.0193–0.0898)	0.86
		48	0.0384 (0.0147–0.0764)	0.86
Chlorothalonil	*Anchytarsus*	24	–	
		48	4.62 (2.81–10.7)	0.41
		96	1.96 (1.25–3.2)	0.85
	Hyalella	24	2.61 (1.73–4.25)	0.76
		48	0.57 (0.28–0.99)	0.84
	Lepidostoma	24	5.08 (3.32–10.20)	0.62
		48	2.72 (1.76–4.65)	0.69

The bifenthrin dataset used for the SSD analysis comprised LC$_{50}$/EC$_{50}$ values between 0.01 and 822 µg L^{-1} for 16 freshwater species (one alga, four crustaceans, eight insects and three fishes) from five different functional groups (Co, De, Om, Pp and Pr) of which only two invertebrate species corresponded to tropical detritivores (from the present study), with the rest being temperate detritivores (Table S5). Chlorpyrifos was the pesticide with the highest available information; the dataset comprised LC$_{50}$/EC$_{50}$ values between 0.05 and 22,440 µg L^{-1} for 49 freshwater species (four algae, 16 crustaceans, 21 insects and eight fishes) belonging to six different functional groups (Co, De, Hb, Om, Pp and Pr) of which 18 species were tested in tropical regions (including the three species of this study) and the rest in temperate zones (Table S6). For chlorothalonil, the dataset comprised LC$_{50}$/EC$_{50}$ values between 0.57 and 8069.3 µg L^{-1} for 10 freshwater species (four algae, three crustaceans, two insects and one fish) belonging to four different functional groups (Co, De, Om and Pp; Table S7).

The SSD curves are shown in Fig. 1 and the results are summarized in Table 2. The log normal model showed the best fit for the three pesticides tested (Table S8). Bifenthrin (HC$_5$ of 0.009 µg L^{-1}; Fig. 1A) and chlorpyrifos (0.012 µg L^{-1}; Fig. 1B) were more toxic, compared to chlorothalonil (HC$_5$ of 0.523 µg L^{-1}; Fig. 1C). The comparison between the sensitivity of tropical and temperate species to chlorpyrifos is presented in Fig. 2. We did not find significant differences (p = 0.59) between the HC$_5$ values of tropical species (n = 18; HC$_5$ = 0.009 µg L^{-1}) and those of temperate species (n = 34; HC$_5$ = 0.012 µg L^{-1}), although the HC$_5$ estimates for tropical species tended to be lower.

4. Discussion

Our study demonstrates that common-use pesticides can affect several species of tropical stream detritivores, provoking the mortality of half their populations at concentrations of 0.04–2.7 µg L^{-1}. This is

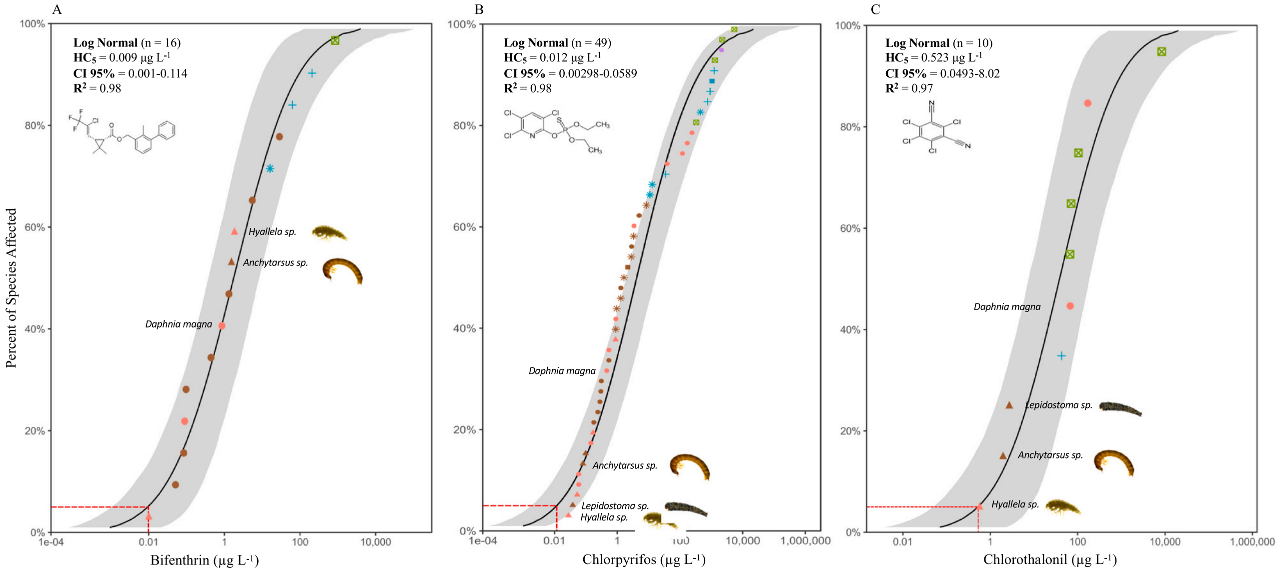

Fig. 1. Species sensitivity distributions (SSD) and hazardous concentrations of 5% using the LC_{50}/EC_{50} values of our species and those reported for freshwater species of different functional groups. The solid line is the fitted Log Normal Model, the section in gray represent 95% confidence interval, and the dashed line red represent hazardous concentrations of 5%. A = Bifenthrin (µg L^{-1}); B = Chlorpyrifos (µg L^{-1}); C = Chlorothalonil (µg L^{-1}). Color represents taxonomic group as follows: ●= Algae; ●= Crustaceans; ●= Fishes; ●= Insects. Shape represents functional group as follows: •= Collectors; ▲= Detritivores; ■= Hervibores; + = Omnivores; ⊠= Primary producers; ✱= Predators.

Table 2
Hazardous concentration for 5% of species (HC_5; µg L^{-1}) and their lower (95%) and upper (5%) confidence limits, calculated from species sensitivity distributions constructed for freshwater species.

Pesticide name	No. of species		HC_5 (95% CI)	R^2
Bifenthrin	All species	16	0.009 (0.001–0.114)	0.98
Chlorpyrifos	All species	49	0.012 (0.003–0.0589)	0.98
	Tropical	18	0.009 (0.0005–0.469)	0.99
	Temperate	34	0.012 (0.0027–0.0603)	0.98
Chlorothalonil	All species	10	0.523 (0.0493–8.02)	0.97

important because of the key role of detritivores in stream ecosystems as main agents (together with aquatic hyphomycetes) of leaf litter decomposition, a fundamental component of stream ecosystem functioning (Graça, 2001). Information about the sensitivity of these organisms is scarce because they are not standard organisms commonly used in toxicity tests (Freitas and Rocha, 2010). However, they are highly relevant from an ecosystem perspective, and likely to be strongly affected by pesticides compared to other organisms because they can ingest pesticides not only from the water but also while feeding on leaf litter, where pesticides can accumulate (Zubrod et al., 2015; Cornejo et al., 2020a).

The scarcity of information about pesticide effects on stream organisms is particularly scarce for tropical regions (Freitas and Rocha, 2010), and our current scientific knowledge in ecotoxicology is based mostly on research from temperate systems (Gunnarsson and Castillo, 2018). This is partly due to the limited basic knowledge of benthic fauna compared to that of Europe, North America and, to a lesser extent, Australia and New Zealand (Boyero et al., 2009). Many tropical insect larval stages have not been related to adults, so species cannot be identified, and their life histories are unknown (Boyero et al., 2009). For this reason, tropical studies have often used information from well-known, standard organisms such as *D. magna*, which are not the most sensitive (Schäfer et al., 2013). Our three study species were more sensitive that *D. magna* to chlorpyrifos and chlorothalonil (but not to bifenthrin), so the consequences of these pesticides in streams where these detritivores are present would be underestimated by considering the responses of *D. magna*.

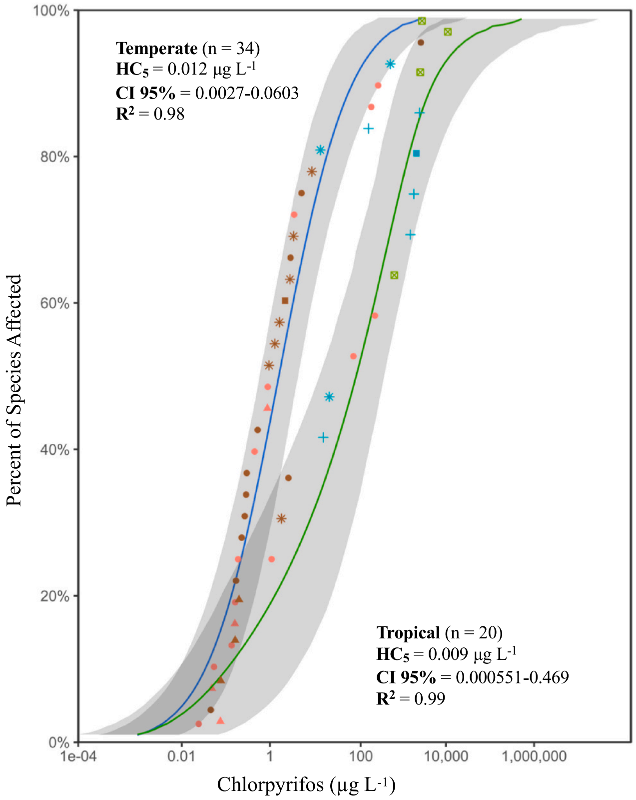

Fig. 2. Temperate (blue curve) and tropical (green curve) species sensitivity (SSD) for chlorpyrifos (µg L^{-1}). The solid line is the fitted Log Normal Model (blue for temperate species and green for tropical), the grey sections represent the 95% confidence interval. Color represents taxonomic group as follows: ●= Algae; ●= Crustaceans; ● = Fishes; ●= Insects. Shape represents functional group as follows: •= Collectors; ▲= Detritivores; ■= Hervibores; + = Omnivores; ⊠= Primary producers; ✱= Predators.

As in other studies, we found no systematic differences between the sensitivity of tropical and temperate species using the SSD approach (Diepens et al., 2014; Khatikarn et al., 2016; Kwok et al., 2007; Maltby et al., 2005; Rico et al., 2010, 2011). Others had hypothesized that tropical organisms would be more susceptible to pesticide exposure than their temperate counterparts, due to the higher temperatures in the tropics and hence the higher metabolic rates of tropical organisms (Castillo et al., 1997; Peters et al., 1997). However, available evidence suggests that sensitivity to pesticides does not depend on the climatic conditions (Daam et al., 2008), but it is rather determined by species-specific traits and the toxicodynamics of the chemical (Van den Berg et al., 2019). For example, Maltby et al. (2005) found that HC_5 values for chlorpyrifos, fenitrothion and carbofuran tended to the lower in tropical than temperate organisms, but the differences were not statistically significant, and Kwok et al. (2007) found that temperate species were more sensitive to carbaryl, DDT, and malathion, whereas tropical species were more sensitive to chlorpyrifos.

Despite the lack of differences between the sensitivity of tropical and temperate species to pesticides, the use of these pesticides most likely has different consequences in these two zones of the world. This is because the intensive agricultural practices in tropical countries lead to higher inputs of pesticides and spread of contamination over watersheds (Daam and Van den Brink, 2010), and regulations of pesticide use are often more permissive in tropical than in temperate countries (Castillo et al., 1997). Thus, tropical streams often reach pesticide concentrations that are much higher than those in temperate streams, with more serious consequences for populations and ecosystems. Unfortunately, tropical data are still scarce in the literature, and this precludes robust tests, so our results and those of previous authors should be taken with caution and be considered as preliminary.

In conclusion, our study demonstrates a clear sensitivity of several invertebrate species that are key for the functioning of the stream ecosystem to common-use pesticides in the study area. We also show that extrapolation of results from ecotoxicological tests with *D. magna* or other common test species would underestimate the real effects of pesticides in tropical stream ecosystems and communities. We highlight the need for more ecotoxicological studies that use tropical aquatic species from different trophic levels in order to assess the (Von Fumetti and Blaurock, 2018) ecological risk of pesticide pollution in stream ecosystems.

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CRediT authorship contribution statement

Aydeé Cornejo: Conceptualization, Funding acquisition, Project administration, Investigation, Supervision, Methodology, Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Francisco Encina-Montoya**: Funding acquisition, Investigation, Methodology, Writing - review & editing. **Francisco Correa-Araneda**: Funding acquisition, Investigation, Methodology, Writing - review & editing. **Dalys Rovira**: Funding acquisition, Investigation, Methodology, Writing - review & editing. **Gabriela García**: Investigation, Methodology, Data curation, Literature revision, Writing - review & editing. **Carlos Nieto**: Investigation, Data curation, Literature revision, Writing - review & editing. **Víctor Villarreal**: Investigation, Methodology, Data curation, Literature revision. **Nicomedes Jaramillo**: Investigation, Methodology, Writing - review & editing. **Edgar Pérez**: Investigation, Data curation, Literature revision. **Anayansi Valderrama**: Investigation, Methodology, Data curation, Writing - review & editing. **Javier Pérez**: Supervision, Investigation, Methodology, Writing - review & editing. **Luz Boyero**: Conceptualization, Funding acquisition, Supervision, Investigation, Methodology, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ecoenv.2021.112226.

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