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Pesticide risk perceptions among bystanders of aerial spraying on bananas in Costa Rica

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ABSTRACT

Little is known about how bystanders perceive risks from pesticide use in areas with frequent aerial spraying of pesticides. This research aims to better understand how bystanders (school workers) from three counties of the Limón province in Costa Rica, who did not have a contractual relationship with agricultural production, perceive risks of pesticides in the areas where they work and live. A face-to-face survey was carried out among 475 school workers, of whom 455 completed all 33 questions on pesticide risk perception. An exploratory factor analysis characterized underlying perceptions of pesticide exposure. Nine factors explained 40% of total variance and concerned severity and magnitude of perceived risk, manageability, benefits and support of pesticide use, amongst others. We subsequently analyzed what variables explained the five factors with satisfactory internal consistency, using separate multivariable linear regression models. Older school workers, (male) elementary teachers, and women school workers (particularly from schools situated near agricultural fields with aerial spraying of pesticides), felt greater severity and/or magnitude of risk from pesticide use. This study shows that bystanders are concerned about health risks from pesticide use. Their risk perceptions are not only shaped by gender and age like previously reported in the literature, but also by job title and geographical context. Understanding of what hazards people care about and how they deal with them is essential for successful risk management, bystanders should therefore be considered as a relevant actor in debates around pesticide issues and for informing the development of regulations and risk reduction strategies.

1. Introduction

Exposure to pesticides from drift in banana production has been of concern to civil society groups (i.e. residents, non-governmental organizations, scholars, small farmers, trade unionists) (Nikol and Jansen, 2019; Fuertes, 2015; Hinrichs and Eshleman, 2014; Barraza et al., 2011, 2013). In export banana producing areas, light aircrafts are commonly used to spray fungicides, in particular mancozeb, to control black Sigatoka, the major fungal disease in banana, and other diseases (Friesen, 2016). In a country such as Costa Rica, with high rainfall and hot climate, the number of mancozeb sprayings per year is estimated between 50 and 70 (Kema, 2016). In Costa Rica, aerial applications are not allowed to occur at less than 100 m from public areas, this distance may be reduced to 30 m when a natural buffer zone is present (La GACETA, 2008). Much research addresses new ways to control Black Sigatoka (Córdoba and Jansen, 2014; Ganry et al., 2012).

Along with the study of environmental pesticide contamination and health effects of pesticides on farm workers and their families (van Wendel de Joode et al., 2012, 2014, 2016; Mora et al., 2018), the exposure of bystanders has recently received growing attention (Jallow et al., 2017; Kumari and Sharma, 2018). We understand bystanders as persons who are present in an area where pesticides (plant protection products) are being applied and their presence in that site is not directly related to their main job, leading them to be exposed to pesticides (EFSA, 2014). Pregnant women's and children's health may be particularly affected by pesticide exposure (Needham and Sexton, 2000). Alarcón et al. (2005) found that 80% of school workers and students developed acute illness after being exposed to pesticides used at schools

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and 20% by drift from the nearby agricultural fields. Results from research in the Caribbean lowlands of Costa Rica showed elevated urinary pesticide metabolite concentrations among children and pregnant women living near banana plantations (van Wendel de Joode et al., 2012, 2014); increased metabolite concentrations of chlorpyrifos (van Wendel de Joode et al., 2016) and the aerially sprayed mancozeb were associated with impairment of neuro- and socio-emotional development (van Wendel de Joode et al., 2016; Mora et al., 2018). An important exposure pathway of these chemicals may be through the air due to drift from sprayed areas to homes and schools. Several studies have demonstrated that pesticide drift can reach areas far from its origin forming a health risk for people living and working in these areas (Dalvie et al., 2014; Shunthirasingham et al., 2011; van Hemmen, 2006; Alarcón et al., 2005).

While pesticide exposure and its health effects on bystanders has perceived growing attention, the issue of bystander's risk perception has been studied much less (Calliera et al., 2019). Studies of risk perception examine people's opinion about hazardous activities and/or technologies to support societal decision making (Slovic et al., 1982) The acceptance, or rejection, of risks is socially constructed and relates to social organization (Douglas, 1992; Barraza et al., 2013). Understanding which hazards people care about and how they deal with them is essential for successful risk communication and management (Paek and Hove, 2017). A relatively impressive body of literature discusses pesticide risk perceptions of farmers and agricultural workers (Remoundou et al. (2015); Brisbois et al., 2019; Bhandari et al., 2018; Jallow et al., 2017; Remoundou et al. (2015); Damalas and Eleftherohorinos, 2011; Runkle et al., 2013), technicians (Ríos-González et al., 2013) and bystanders (Remoundou et al., 2015; Calliera et al., 2019), but, to our knowledge, bystanders' risk perceptions have not been studied in low- and middle-income countries.

For studying the perceptions of an important group of bystanders in Costa Rica we decided to focus on school personnel who live and work in areas with intensive pesticide use. Banana haspesticide consumption in Costa Rica, with 49.3 kg active ingredient per ha/year counting for about 22% of the total pesticides used in the country (Bravo-Durán et al., 2013). This large amount of pesticide and the consequences of pesticide drift have led to concern by people living and/or working in the area. An event in January 2009 brought school personnel in the picture of our research interest. *Karen Rodríguez*, an elementary school teacher from the province of *Limón*, presented a Writ of Amparo to the Constitutional Court, arguing that everyone at the school where she worked was exposed to pesticides sprayed aerially on the banana plantations which surrounded her school (Córdoba, 2009a). The Costa Rican Constitutional Court ruled in favor of *Ms. Rodríguez* (Costa Rica, 2009). We realized that perceptions of school teachers are especially pertinent as bystander perceptions since they live and work nearby the plantations but have no work history with it, whereas most other people living in these communities have a work history in banana production. The particular case of Ms. Rodríguez showed that risk perceived by these bystanders contributed to enforcement of pesticide application regulations to manage that risk.

The aim of this research is to understand, in the context of risk management strategies, how a group of bystanders (school workers) without a contractual relationship with agricultural production perceive risks of pesticide use in three counties of the *Limón* province in Costa Rica where pesticides are being applied aerially on bananas all year long on a weekly basis.

2. Methodology

In the current study, we apply quantitative methodologies in the line of the psychometric paradigm (Slovic, 1987). We adopted and adapted the general risk perception assessment and the psychometric paradigm assessment from the model "Biotechnology Risks and Benefits: Science Instructor Perspectives and Practices" proposed by Gardner (2009). This model provides a structured description of aspects involved with risk among educators and it is well suitable for assessing pesticide risk perceptions. Our study was part of the Infants' Environmental Health Study (*ISA*, for its acronym in Spanish), which carries out a community-based birth-cohort study in Matina County and a wider study of pesticide exposure and risk perception in Matina, Siquirres and Talamanca counties, thereby incorporating an ecosystem approach to human health.[1] This program also seeks to increase knowledge on what socio-demographic and geographic variables shape pesticide risk perceptions, to inform risk management strategies and societal decision making.

During October and November 2011, we conducted a face-to-face survey (Appendix 1) to determine perception of pesticide risk among school workers in three counties of the *Limón* province in Costa Rica: Matina, Siquirres and Talamanca (Fig. 1). We selected these counties because they differ in historical and current intensity of banana growing for export purposes. Matina has 9,929 ha (23.6% of national banana production), Siquirres 8,169 ha (19.4%), and Talamanca 1,911 ha (4,5%) (Sepsa, 2015, Fig. 1). Matina is almost completely planted with banana, Siquirres has a mixed pattern of banana and pineapple and other agricultural activities, and in Talamanca we find a smaller, but still concentrated area of export banana production besides areas with smallholder plantain production and many other agricultural activities. Aerial pesticide spraying takes place in the export banana zones of all three counties. In addition, we had preliminary knowledge of the social-environmental context resulting from previous research in these three counties (i.e. Barraza et al., 2011, 2013; van Wendel de Joode et al., 2012, 2014, 2016). The survey was carried out by the first author in collaboration with last-year students of the Professional Technical High School in Siquirres. All students were trained by the first author.

2.1. Participating population

In 2011, *Limón* had 6,669 school workers (López-Corrales, 2019). We aimed to survey with a confidence level of 95% and with a margin of error of 5%, resulting in a sample of at least 364 persons. Participants were selected to be as representative as possible of the personnel working in educational facilities in the three counties. We sent a letter of invitation to participate in the survey to the principals of all day elementary and secondary (high) schools (n = 207 and 31, respectively). In 23 out of 238 schools (10%) principals gave us a permission to apply the survey to their personnel; 11 out of 90 (12%) in Siquirres and eight out of 44 (18%) in Matina, and four out 94 schools in Talamanca (4%) respectively. The schools differed with respect to proximity to large-scale agricultural plantations; six out of eight schools (75%) in Matina County and three out of eleven (27%) schools in Siquirres County were situated at less than 100 m from banana plantations. In Siquirres one of these three school was also situated adjacent to a pineapple plantation and a fourth school was situated as less than 100 m from a pineapple plantation. The schools near banana and pineapple plantations were mostly elementary schools (four out of the six in Matina, and all four in Siquirres). In Talamanca County, all schools participating in the survey were situated at more than 3 km from banana plantations and no pineapple is grown; nevertheless the use of pesticides is a contentious issue in this area (Barraza et al., 2011; van Wendel de Joode et al., 2016).

Remarkably, all 475 school workers present when visiting the schools participated in the survey, and included school authorities, teachers, administrative personnel, cooks and cleaners (Fig. 2). We only analyzed the questionnaires with complete information on risk perceptions (n = 455), a 96% response rate of the school workers that were invited to participate.

[1] The Ecohealth approach embraces six principles: transdisciplinarity, systems thinking, multistakeholder participation, equity, environmental sustainability, and evidence for community-based interventions (Charron et al., 2012).

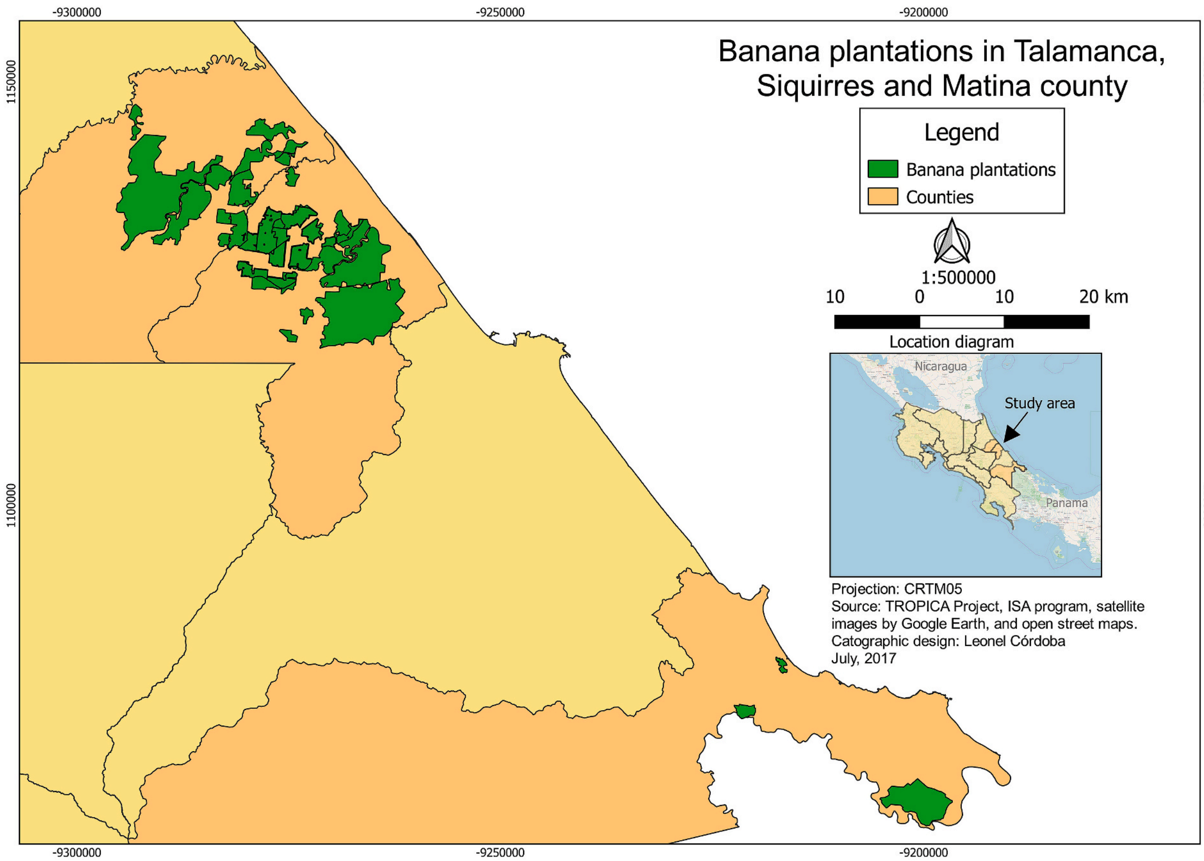

Fig. 1. School surveys were performed in the counties presented in orange; from upper-left to center-right, in order of appearance: Siquirres, Matina, and Talamanca). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

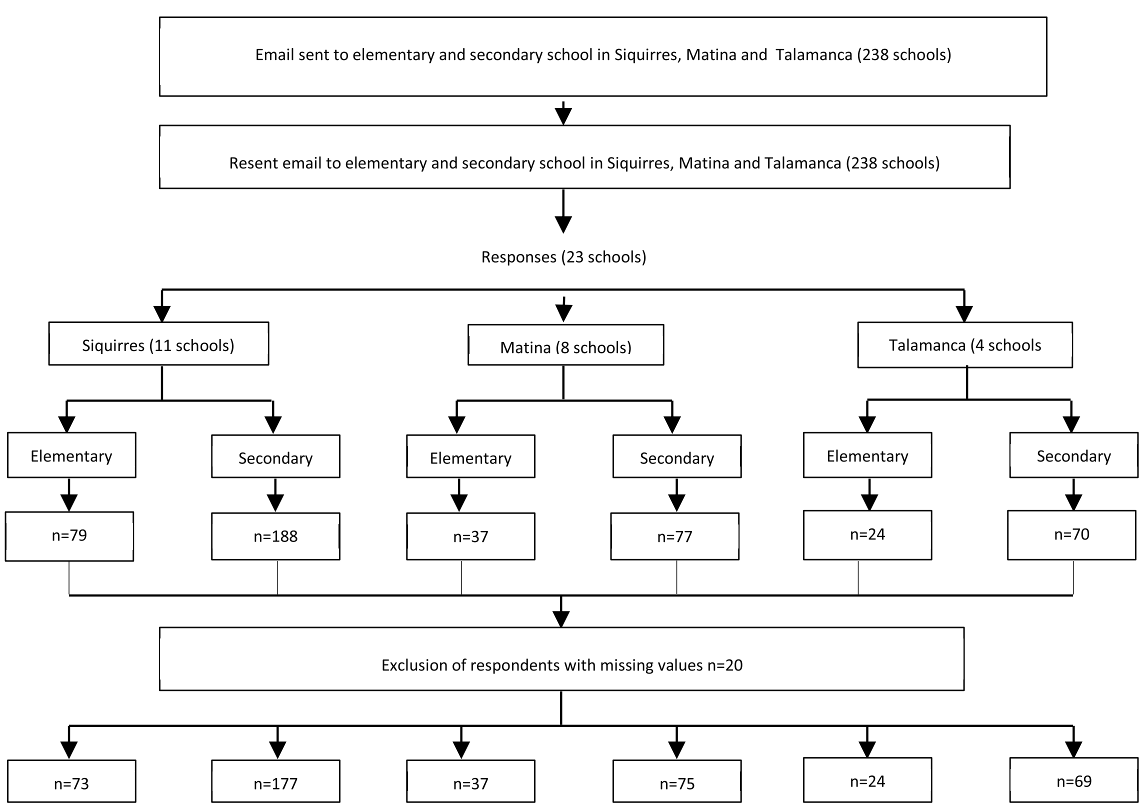

Fig. 2. Flowchart for the selection of the participating population and data clearing steps.

2.2. Survey instrument

The survey instrument was designed to define both the nature of risk perception and factors that contribute to the formation of risk perceptions (Table 2), as it captures the perceptions of exposure, human fatalities, human injuries, ecosystem harm, risk acceptability, risk as negative consequences, current risks, and future risks (Gardner, 2009). The questionnaire consisted of 33 questions and had to be filled in a Likert scale from 1 to 5 in terms of perceived risk for specific items, with the higher the scale the higher the perceived risk, except for Factor 4 (benefits).

2.3. Statistical analyses

All analyses were performed using SPSS software version 24 and JMP 8 (SAS Institute Inc., Cary, NC, USA). To identify psychometric constructs, we performed exploratory factor analysis (EFA) on 33 items of the questionnaire as described by Peterson (2000). We used EFA as an *a priori* theory on correlation of factors in this area of study was absent (Kramer et al., 2017). Spearman correlation coefficients between the 33 items of the questionnaire were all <0.7 and we therefore included all items in the EFA. We abstracted factors in descending order of explained variance (see Appendix 2) using eigenvalues ≥ 1. All items had communalities ≥ 0.3. The factorability of all items was then examined with Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (Kramer et al., 2017). The factor extraction was varimax rotation. Factor loadings represent the correlations between each of the variables included in the analysis and each summary factor is equivalent to Pearson correlation coefficients. Subsequently, factor scores, which are composite variables proving information about an individual's placement on a certain factor (s) (DiStefano et al., 2009), were estimated with Bartlett's approach of sphericity (significance <0.05) indicating that correlations exist among the variables (Hair et al., 2014). We chose this approach as it produces unbiased estimates of the true factor scores (Hershberger, 2005), obtaining scores that are highly correlated to their corresponding factor and not with other factors, although the estimated factor scores may still correlate between different factors (DiStefano et al., 2009). We calculated Cronbach's alpha to verify internal consistency of factors' composition.

For factors with Cronbach's alpha >0.70 (Factor 1 to 5), we ran separate bivariate linear regression models to explore what variables explained differences in factor scores: sex, age<35, and ≥ 35 years old, county where school is located (Matina, Siquirres, Talamanca), and job category (elementary school teacher, secondary school teacher, other workers). We subsequently included variables that explained difference in at least one of the factor scores in a multivariable linear regression model. We explored effect-modification by sex, by including it as cross-term in the models, and subsequently ran separate regression multivariable linear regression models stratified by sex.

To explore the influence of outliers, we performed additional analyses excluding the 1% of observations with the highest Cook's distance values (Zuurbier et al., 2011). For all models, the exclusion of outliers did not substantially change beta estimates ($\leq 10\%$). We revised the fit of the models, distribution of the residuals from the regression and criteria of homoscedasticity. Except for Factor 2, the fit was satisfactory for all models (F-test for lack-of-fit $p > 0.10$), and after exclusion of outliers the fit of this model was also satisfactory for Factor 2 ($p = 0.23$) whilst beta-estimates remained similar. Residuals of the models approximately followed a normal distribution as residuals were somewhat skewed (Shapiro-Wilk's $W \geq 0.98$ for all factors except for Factor 1 $W = 0.90$). We therefore ran a sensitivity analysis and dichotomized values of Factor 1 into values $>$ and $\leq$ median value, and subsequently ran multiple logistic regression analysis including the same covariates as for the multiple linear regression analysis. We found the same variables explained values of Factor 1 as when using linear regression modeling. This, together with our finding that exclusion of outliers did not substantially change beta estimated supports the validity of the results of the linear regression model.

3. Results and discussions

3.1. Sociodemographic information

School workers' demographic information ($n = 455$) is shown in Table 1. Most of the interviewees were women (62%), particularly at elementary schools (83%). In contrast, at secondary schools only half of the respondents were women. The demographic distribution of our sample was similar to the national population of school workers; the Costa Rican Ministry of Education (MEP) has 29,788 teachers (23.9% men and 76.1% women) in elementary schools and 33,883 (45% men and 55% women) in secondary schools all over the country (MEP, 2019). In addition, 54.9% of the school workers of our study was between 18-34 years old, and 45.1% between 35-63 years, which accurately reflected the age distribution of the Costa Rican teachers force with 55% of them with age less than 35 years old (Conare, 2019; Colypro, 2015).

Table 2 reports mean response values to questions among school workers grouped according to the nine factors extracted with EFA with its corresponding questions. Twenty-eight out of 33 questions were represented in the exploratory factor analysis, and six questions (Q2, Q4, Q17, Q27, Q28, Q30) loaded on two factors. The nine factors explained almost 40% of total variance, which is a rather small part of the total variance, but similar to other studies in this field (i.e. Kramer et al., 2017). According to Cohen (1988) this is a common constraint when we attempt to explain psychological constructs. Also, Hair et al. (2014) and Hayduk (2014) pointed out, in social sciences being able to explain only a part of total variance is satisfactory as a manifold contingency in social processes shape risk perceptions. The average (absolute) factor loading of complete sets of factor loadings was 0.52. Twenty-five percent of the reported factor loadings were less than 0.40; 17% were greater than 0.40

Table 1
Socio-demographic and job characteristics of school workers in the survey ($n = 455$).

	Women	Men	Total
Sex	283 (62.2%)	172 (37.8%)	455 (100%)
Age (years)[a]			
18–24	29 (10.2%)	15 (8.7%)	47 (10.3%)
25–34	109 (38.5%)	82 (47.7%)	203 (44.6%)
35–44	90 (31.8%)	47 (21.3%)	117 (25.7%)
45–63	55 (19.4%)	28 (16.3%)	88 (19.3%)
County			
Siquirres	158 (55.8%)	92 (53.5%)	250 (55.0%)
Matina	73 (25.8%)	39 (22.7%)	112 (24.6%)
Talamanca	52 (18.4%)	41 (23.8%)	93 (20.4%)
Job position[b,c]			
Elementary school teacher	91 (32.1%)	19 (11.0%)	110 (24.2%)
Secondary school teacher	123 (43.5%)	124 (72.1%)	247 (54.3%)
Janitors, office workers, cooks and miscellaneous workers	69 (24.4%)	29 (16.9%)	98 (21.5%)

[a] For 14 women (4.9%) and ten men (5.8%) information about age was missing and were imputed with a random value using the distribution of age, the imputation did not affect the distribution of age (see Appendix, table A1).
[b] Elementary and secondary school teachers included three and seven directors, respectively.
[c] Job position differed by sex (Pearson Chi-Square = 38.7, $p < 0.0001$).

Table 2
Description of mean response values to questions among school workers in the survey (n = 455).

Factors[a] and questions	Mean response (sd)			Factor loading
	All (n = 455)	Women (n = 283)	Men (n = 172)	
Factor 1 = Severity of risk (Initial eigenvalue = 5.71, Cronbach's alfa = 0.86)				
Q1. How much of a risk do you think, pesticide (herbicide, insecticide, fungicide, acaricide) applications are to human and environment health, and society in general? *1 = low risk … … 5 = high risk*	4.44 (0.10)	4.47 (0.06)	4.40 (0.08)	0.51
Q2. How many people do you think die every year because of pesticide use in Costa Rica? *1 = none … 5 = over one hundred*	3.32 (0.11)	3.43 (0.07)	3.15 (0.09)*	0.36
Q4. How many people do you think become ill because of pesticide applications every year in Costa Rica? *1 = none … 5 = over one thousand*	4.00 (0.10)	4.08 (0.06)	3.87 (0.08)*	0.32
Q5. How much harm do you think is done to the ecosystems (aquatic and terrestrial) because of the use of pesticides in Costa Rica? *1 = little harm … 5 = high harm*	4.58 (0.09)	4.62 (0.05)	4.50 (0.07)	0.52
Q7. How concerned are you about the negative consequences of pesticide applications in Costa Rica? *1 = not concerned at all 5 = very concerned*	4.16 (0.11)	4.27 (0.07)	3.99 (0.09)*	0.56
Q8. How serious threat do you think pesticide applications are today comparing to five years ago? *1 = not a serious threat … 5 = a very serious threat*	4.29 (0.10)	4.40 (0.06)	4.10 (0.08)*	0.82
Q9. How serious threat do you think pesticide applications will be in the future in Costa Rica? *1 = not a serious threat … 5 = a very serious threat*	4.46 (0.09)	4.54 (0.06)	4.32 (0.07)*	0.79
Q10. Do you think people are exposed to the risks from pesticides voluntarily or involuntarily? *1 = risk assumed voluntarily … 5 = risks assumed involuntarily*	4.09 (0.12)	4.15 (0.07)	3.98 (0.09)	0.51
Q17. Do you think people will die if pesticide applications go wrong, or spill accidents occur? *1 = certain not to be fatal … 5 = certain to be fatal*	4.35 (0.10)	4.45 (0.06)	4.18 (0.08)*	0.55
Q18. Do you think pesticides pose a risk to the health of future generations? *1 = little threat … 5 = great threat*	4.58 (0.08)	4.69 (0.05)	4.41 (0.07)*	0.64
Factor 2 = Magnitude of risk (Initial eigenvalue = 3.39, Cronbach's alfa = 0.79)				
Q2. How many people do you think die every year because of pesticide use in Costa Rica? *1 = none … 5 = over one hundred*	3.32 (0.11)	3.43 (0.07)	3.15 (0.09)*	0.56
Q3. How many people do you think suffer accidents because of pesticide applications every year in Costa Rica? *1 = none 5 = over one thousand.*	3.56 (0.11)	3.66 (0.07)	3.41 (0.08)*	0.78
Q4. How many people do you think become ill because of pesticide applications every year in Costa Rica? *1 = none … 5 = over one thousand*	4.00 (0.10)	4.08 (0.06)	3.87 (0.08)*	0.69
Factor 3 = Manageability of risk (Initial eigenvalue = 1.61, Cronbach's alfa = 0.75)				
				0.59

Table 2 (*continued*)

Factors[a] and questions	Mean response (sd)			Factor loading
	All (n = 455)	Women (n = 283)	Men (n = 172)	
Q20. Pesticide applications are not dangerous because governmental agencies are equipped to manage any problem that might arise. *1 = strongly disagree … 5 = strongly agree*	2.09 (0.14)	2.04 (0.08)	2.17 (0.11)	
Q21. There is no way for me to know if pesticides will be risky or not to human health. *1 = strongly disagree … 5 = strongly agree*	1.52 (0.15)	2.13 (0.09)	2.12 (0.12)	0.44
Q22. The human body will be able to adapt to face any hazards that might be associated with pesticide. *1 = strongly disagree … 5 = strongly agree*	1.85 (0.13)	1.83 (0.08)	1.90 (0.10)	0.53
Q27. No one can predict the risks that will be associated with pesticide applications. *1 = strongly disagree … 5 = strongly agree*	2.99 (0.15)	3.09 (0.09)	2.81 (0.12)	0.33
Q28. I support pesticides use if it does not affect my personal health. *1 = strongly disagree … 5 = strongly agree*	2.78 (0.17)	2.84 (0.10)	2.66 (0.13)	0.32
Q30. Pesticides use in agriculture will make Costa Rica economically very strong. *1 = strongly disagree … 5 = strongly agree*	2.15 (0.14)	2.04 (0.08)	2.33 (0.11)*	0.32
Factor 4 = Benefits (Initial eigenvalue = 1.60, Cronbach's alfa = 0.76)				
Q30. Pesticide use in agriculture will make Costa Rica economically very strong. *1 = strongly disagree … 5 = strongly agree*	2.15 (0.14)	2.04 (0.08)	2.33 (0.11)*	0.52
Q31. I feel absolutely no need to share my opinions with others about pesticide risks. *1 = strongly disagree … 5 = strongly agree*	2.15 (0.14)	2.21 (0.09)	2.04 (0.11)	0.33
Q33. Pesticide use helps small farmers to be competitive in both the national as well as international market. *1 = strongly disagree … 5 = strongly agree*	2.62 (0.15)	2.55 (0.09)	2.74 (0.12)	0.65
Factor 5 = Supportive of pesticide use (Initial eigenvalue = 1.34, Cronbach's alfa = 0.71)				
Q28. I support pesticides use if it does not affect my personal health. *1 = strongly disagree … 5 = strongly agree*	2.78 (0.17)	2.84 (0.10)	2.66 (0.13)	0.61
Q29. I support pesticide use if it does not affect the health of the communities. *1 = strongly disagree … 5 = strongly agree*	3.29 (0.16)	3.37 (0.10)	3.16 (0.13)	0.80
Factor 6 = Knowledge of risks (Initial eigenvalue 1.28, Cronbach's alfa = 0.67)				
Q12. Do you think the risks associated with pesticide use are well known by the persons who might be exposed? *1 = not known at all … 5 = well known*	2.80 (0.14)	2.76 (0.09)	2.85 (0.11)	0.53
Q15. Are the risks of pesticide applications new and novel or old and familiar to you? *1 = risk is new … 5 = risk is old*	4.20 (0.12)	4.27 (0.07)	4.09 (0.10)	0.35
Factor 7 = Unpredictability (Initial eigenvalue 1.24, Cronbach's alfa = 0.64)				
Q23. The development of pesticides will lead to risks that nobody can predict. *1 =*	3.53 (0.15)	3.55 (0.09)	3.48 (0.12)	0.52

(*continued on next page*)

Table 2 (*continued*)

Factors[a] and questions	Mean response (sd)			Factor loading
	All (n = 455)	Women (n = 283)	Men (n = 172)	
strongly disagree … 5 = strongly agree				
Q27. No one can predict the risks that will be associated with pesticide applications. *1 = strongly disagree … 5 = strongly agree*	2.99 (0.15)	3.09 (0.09)	2.81 (0.12)	0.47
Factor 8 = Selective exposure and fatality (Initial eigenvalue 1.09, Cronbach's alfa = 0.55)				
Q16. Do you think that the people who are exposed to the risks of pesticide use are the same who receive the benefits? *1 = people are the same … 5 = people not the same*	4.19 (0.13)	4.26 (0.08)	4.09 (0.10)	0.47
Q17. Do you think people will die if pesticide applications go wrong, or spill accidents occur? *1 = certain not to be fatal … 5 = certain to be fatal*	4.35 (0.10)	4.45 (0.06)	4.18 (0.08)*	0.32
Factor 9 = Personal risk and risk reduction (Initial eigenvalue 1.04, Cronbach's alfa = 0.44)				
Q25. If the use of pesticides continues like today it will put my own life at risk. *1 = strongly disagree … 5 = strongly agree*	4.18 (0.12)	4.22 (0.07)	4.13 (0.09)	0.38
Q26. The only way to control the risks from pesticide use is for people (both who apply them as well as the rest of the people) to radically change their behavior. *1 = strongly disagree … 5 = strongly agree*	3.87 (0.14)	3.99 (0.08)	3.67 (0.11)*	0.43
Overall (Cronbach's alfa = 0.82)				0.52

Note: [a] = % Variance explained by factor 1 = 11.4%; factor 2 = 5.1%; factor 3 = 4.6%; factor 4 = 4.4%; factor 5 = 4.0%; factor 6 = 3.3%; factor 7 = 2.5%; factor 8 = 2.5%; factor 9 = 1.8%; total variance explained = 39.6%. * mean responses to this question differed between men and women ($p < 0.05$).

and less than 0.50 and 57% were greater than 0.5. According to Hair et al. (1998) and Peterson (2000) those loadings are large enough to analyze their content.

Factor 1 (severity of risk) explained most of total variance (11.4%), and included 10 out of 33 questions of the questionnaire (Table 2). The factor loadings of these questions ranged from 0.32 to 0.82, indicating moderate to strong associations with Factor 1. The questions associated with Factor 1 reflected perceptions about the severity of risk implied by pesticide use. For nine out of ten questions, mean values were >4, reflecting a relatively high perceived severity of risk. Interestingly, women perceived more severity of risk than men, which is reflected by their higher mean response values for seven out of the ten questions associated with Factor 1. The second factor explained around 5% of total variability and reflects the magnitude of the risk due to pesticide use. The three associated questions (Q2, Q3 and Q4) of Factor 2 were related to the number of deaths, number of people being injured or getting ill due to pesticides each year. The former is in concordance with Gardner and Gould (1989) who pointed out that laypeople tend to shape their risk perception by the degree to which a certain technology can kill people at once. Again, women perceived a higher risk.

The questions associated with the following factors: Factor 3 (Manageability of risk), Factor 4 (Benefits of pesticides), and Factor 5 (Supportive of pesticide use) had similar response values for women and men, except for Q30 'Pesticides use in agriculture will make Costa Rica economically very strong' associated to both Factor 3 and Factor 4. Women agreed less with this statement than men. This could be explained as currently banana production provides jobs to more than 27,000 people (Sandra Vargas, National Institute of Statistics and Census, personal communication) in an area where jobs are scarce and particularly men are employed in this sector (83%); only in the packing plants we observe a lot of women workers. Also, previous research revealed inhabitants of the region are convinced that pesticides are needed to produce bananas for export purposes (Barraza et al., 2011). In addition, people consider that banana production contributes with high revenues to the country and perhaps, as mentioned by Lehrer and Sneegas (2018), they tend to believe that pesticides, if handled appropriately, will not cause any harm. So, overall, women perceived higher risks and less benefits than men. Subiza-Pérez et al. (2020) cite several studies that reported that women consistently perceive higher risks than men.

Table 3 shows beta coefficients (β) of sex, age, county and job position explaining factor scores 1–5 for all workers and stratified by sex, from separate multiple linear regression models.

3.2. *Severity and magnitude risk perception*

With respect to severity of risk (Factor 1), overall, women workers perceived a higher risk than men workers, and older workers aged ≥35 years perceived higher risk as compared to younger ones (Table 3). The higher risk perception in older workers was similar for women and men as both had a β-coefficient of 0.12, although the 95%CI was a bit broader for men, probably due smaller sample size (Table 3). Also, the magnitude of risk (Factor 2) was perceived higher among older school workers, both among women (β = 0.26, 95%CI 0.13, 0.39) and men (0.19, 95%CI 0.00, 0.39).

Regarding location, women from Matina perceived risks as more severe (Factor 1) (β = 0.19, 95%CI 0.01, 0.38) and of a greater magnitude (Factor 2) (β = 0.17, 95%CI 0.00, 0.34) as compared to women from Siquirres and Talamanca. Possibly, women school workers from Matina perceived higher severity of risk because schools in Matina were situated more frequently near banana plantations with aerial spraying than in Siquirres or Talamanca: 75% versus 27% and 0%, respectively. The relatively low level of concern in Siquirres was unexpected as at the time of data collection this county was a hive of civil society activity contesting pineapple companies in the area and State agencies (Ministry of Health, Costa Rican Water and Sewer Institute (AyA), and the Environment and Energy Ministry). Tests had found traces of herbicides in drinking water from aqueducts in several villages situated in Siquirres. Residents were no longer allowed to use the existing drink water supply and depended on drinking water brought in by water bowsers provided by AyA every other day (Córdoba, 2009b). Because of this situation, our hypothesis was that in Siquirres school workers would have had a higher perception of pesticide risks. Our data, however, suggest this was not the case, since women school workers in Matina perceived highest risk; possibly nearby aerial spraying is perceived more threatening than drinking water contamination since the water company (AyA) distributed drinking water in Siquirres. Nevertheless, also other latent causes (Hayduk, 2014) or 'structural reasons' (Galt, 2013), including past experiences, may be hypothesized. Matina county has had highest national banana production, and back in the seventies thousands of men became sterile due to exposure to the pesticide 1,2-dibromo-3-chloropropane (DBCP) (Barraza et al., 2013). It seems this catastrophe still plays a role in the population. In encounters between Matina dwellers and the authors, the conversations often brought up the DBCP aftermaths suffered by fathers, brothers, husbands, and sons of those who were exposed and were very young at that time. Recently, a new social movement called *Las Afectadas* (Women Affected by DBCP exposure) has emerged in Matina, claiming that women have also been affected by DBCP (Mora-Solano, 2017). This suggests that the DBCP consequences are still shaping people's perception of pesticide use in banana cultivation.

Interestingly, among men, particularly teachers from elementary schools perceived pesticide risk, both in terms of severity (Factor 1, β = 0.42, 95%CI 0.02, 0.83) and magnitude (Factor 2, β = 0.39, 95%CI

Table 3
Beta coefficients (β) with 95% confidence intervals of variables explaining factors scores 1–5 for all school personnel (n = 455) and stratified by sex; statistically significant β estimates are presented in bold.

	All				Woman				Men			
Variables[a]	β	95% confidence interval		R^2	β	95% confidence interval		R^2	β	95% confidence interval		R^2
Factor 1 Severity of risk												
Intercept	−0.05	−0.18	0.07	0.04	0.08	−0.05	0.21	0.04	−0.20	−0.45	0.05	0.06
Sex [Woman]	0.13	0.03	0.24		–	–	–		–	–	–	
Age [35 or more]	0.13	0.03	0.24		0.12	0.00	0.24		0.12	−0.07	0.31	
County [Siquirres]	0.03	−0.10	0.17		0.08	−0.07	0.24		−0.03	−0.29	0.23	
County [Matina]	0.08	−0.08	0.24		0.19	0.01	0.38		−0.01	−0.33	0.30	
Teacher elementary school	0.10	−0.07	0.26		0.00	−0.17	0.16		0.42	0.02	0.83	
Teacher high school	0.05	−0.09	0.20		−0.04	−0.19	0.12		0.14	−0.16	0.44	
Factor 2 Magnitude of risk												
Intercept	−0.03	−0.16	0.10	0.06	0.04	−0.10	0.18		−0.10	−0.36	0.15	0.08
Sex [Woman]	0.08	−0.03	0.19		–	–	–		–	–	–	
Age [35 or more]	0.24	0.14	0.35		0.26	0.13	0.39		0.19	0.00	0.39	
County [Siquirres]	−0.06	−0.20	0.08		−0.01	−0.19	0.16		−0.11	−0.36	0.15	
County [Matina]	0.07	−0.10	0.23		0.17	−0.03	0.37		−0.05	−0.36	0.26	
Teacher elementary school	0.17	0.00	0.34		0.11	−0.08	0.29		0.39	−0.02	0.80	
Teacher high school	0.14	0.00	0.29		0.10	−0.07	0.27		0.17	−0.13	0.46	
Factor 3 Manageability of risk												
Intercept	0.00	−0.14	0.15	0.02	−0.02	−0.19	0.16	0.02	0.08	−0.20	0.36	0.03
Sex [Woman]	0.00	−0.13	0.13		–	–	–		–	–	–	
Age [35 or more]	−0.03	−0.16	0.09		0.00	−0.15	0.16		−0.10	−0.31	0.11	
County [Siquirres]	0.13	−0.04	0.29		0.15	−0.06	0.36		0.12	−0.16	0.40	
County [Matina]	−0.11	−0.31	0.08		−0.18	−0.42	0.07		−0.05	−0.39	0.30	
Teacher elementary school	−0.13	−0.33	0.07		−0.15	−0.38	0.07		−0.03	−0.47	0.42	
Teacher high school	−0.13	−0.30	0.04		−0.05	−0.26	0.16		−0.27	−0.59	0.06	
Factor 4 Benefits of pesticide use												
Intercept	0.01	−0.13	0.16	0.01	−0.10	−0.27	0.07	0.01	0.13	−0.15	0.40	0.03
Sex[Woman]	−0.07	−0.20	0.06		–	–	–		–	–	–	
Age [35 or more]	0.01	−0.11	0.14		0.04	−0.11	0.20		−0.01	−0.22	0.20	
County [Siquirres]	0.06	−0.11	0.22		0.15	−0.05	0.36		−0.09	−0.37	0.19	
County [Matina]	−0.07	−0.26	0.12		−0.11	−0.35	0.12		−0.01	−0.36	0.33	
Teacher elementary school	−0.17	−0.37	0.02		−0.14	−0.36	0.08		−0.37	−0.82	0.08	
Teacher high school	−0.02	−0.19	0.15		0.05	−0.16	0.25		−0.06	−0.39	0.27	
Factor 5 Supportive of pesticide use												
Intercept	−0.05	−0.18	0.08	0.03	0.01	−0.15	0.16	0.03	0.01	−0.22	0.25	0.06
Sex [Woman]	0.08	−0.04	0.19		–	–	–		–	–	–	
Age [35 or more]	−0.01	−0.12	0.10		0.02	−0.13	0.16		−0.08	−0.26	0.10	
County [Siquirres]	0.20	0.05	0.35		0.24	0.05	0.43		0.17	−0.07	0.41	
County [Matina]	−0.16	−0.34	0.01		−0.27	−0.49	−0.04		−0.01	−0.31	0.28	
Teacher elementary school	0.10	−0.08	0.28		−0.01	−0.22	0.19		0.56	0.17	0.94	
Teacher high school	−0.10	−0.25	0.06		0.00	−0.19	0.19		−0.31	−0.59	−0.04	

[a] Reference category for sex = men; for age = <35 years; for county = Talamanca; for job = other school workers.

-0.02, 0.80), greater than secondary and other school workers. School personnel and children commented at workshops, held at 36 elementary schools in Matina in 2019, that they are sometimes exposed to drift from aerial applications when traveling to school (personal communication with the workshop organizers Reichel Rodríguez and Luis Diego Palomo). Pesticide aerial applications are visible and experienced by people in the region. From an historical perspective, in contrast to secondary schools, many elementary schools are located at less than 100 m from banana plantations (Córdoba Gamboa et al., 2020). Those facilities were built by the Ministry of Education to offer free elementary education to banana worker's children. This nearness of the schools to the fields may explain the difference in risk perception on workers of elementary and secondary schools. This involves the location of schools in the risk debate. van Hemmen (2006), for example, argues that aerial spraying should not be done in the direct vicinity of people, unless there is sufficient buffer zone.

3.3. Manageability of risk, benefits and supportive of pesticide use

Factor 3 (Manageability of the risk) and 4 (Benefits of use) were not explained by any of the variables (sex, age, county or job title), except for one question in Factor 3 and 4 about the perception that the use of pesticides will make Costa Rica stronger economically; women more strongly disagreed with this statement than men (Table 2). With respect to supporting pesticide use (Factor 5), compared with school workers from Talamanca, school workers from Matina were less supportive, particularly women, whilst school workers from Siquirres were more supportive, particularly male elementary school teachers (Table 3), despite their perception of a higher severity and magnitude of risk (Factors 1 and 2). This may be because men consider more the potential economic benefits from pesticide use (Factor 4) despite acknowledging their health risks. Barraza et al. (2011) performed a pesticide risk perception study among plantain and banana smallholders and found that men did not prioritize personal pesticide exposures, not because they do not care about it, but because they see more economical benefices of pesticide technology. Similar findings were also reported by Remoundou et al. (2015) who concluded that bystander men believe that harm, if any, has already occurred and cannot be avoided.

3.4. Contextualizing the findings

This study contributes to a small but growing body of literature on bystanders' pesticide risk perceptions. To our knowledge this is the first study on school workers' risk perceptions, therefore we can only compare with studies on other types of bystanders and populations. Risk perceptions in this study were explained by gender, age, county, and job title. In general, women, older workers, counties with higher banana production, and elementary school staff, perceived higher risks in terms of severity and magnitude.

The data of the current study show that *women school workers* perceive higher severity and magnitude of risk as compared to male school workers. Interestingly, literature in other fields finds women take less risks (Jianakoplos and Bernasek, 1998; Remoundou et al., 2015) and consistently perceive higher risk than men (Subiza-Pérez et al., 2020). This may be because women fulfill a more nurturing role as poetically expressed by Fine (2017): 'women, as the nurturers of precious offspring, have evolved to be more cautious about threats to physical health'. On the other hand, the differences may be rather due gender constructs (e.g. Soper, 1992), as our finding of differences in gendered risk perceptions between different counties indicate perceptions change with conditions in specific places. In addition to gender, we found, *older school workers* perceived higher risks than younger school workers, possibly because they remember the DBCP tragedy. The differences in risk perception between older and younger workers have been frequently reported in previous studies (Subiza-Pérez et al., 2020), but the direction of the association has depended on the risk and its context; for example, Subiza-Pérez et al. (2020) found younger adults perceived higher environmental risks that older adults.

Furthermore, perception in this study seemed to be influenced as well by nearness of schools to agricultural fields, as both elementary teachers and female school workers from Matina County perceived higher risks than persons who did not meet this condition; elementary schools and schools from Matina County were more often situated near agricultural fields than the other schools. This contrasts with results from Calliera et al. (2019) who found residents' risk perception of pesticides in a rural area of Italy was not shaped by closeness to the agricultural fields; instead, residents thought contamination of air by pesticides was generally present even though they judged air quality positively. The higher risk perception of elementary teachers as compared to other school workers may also indicate risk perceptions are constructed by job title, which agrees with results from a study by Barraza et al. (2011) who found indigenous small holders' and banana plantation workers' risk perceptions were modulated by factors such as people's tasks and positions in the production process and, gender amongst others. Finally, knowledge about risks obtained through social movements or training are also known to shape to a considerable extent people's thinking about pesticide effects on human health and the environment (Arancibia, 2016; Barraza et al., 2013; Muñoz-Quesada et al., 2019). Muñoz-Quesada et al. (2019) assessed risk perception among school children and their parents in Chile before and after a training session observing an increased awareness due to the training, which points at the importance of collective knowledge building. Our study did not evaluate the precise path of knowledge construction, this could be a topic for further study.

The data from this study evidence that bystanders who are not directly involved in crop production and commercialization, thus about an activity that is not central to their livelihoods, have a high level of concern and active thinking about the risks of pesticides. An important issue is whether these bystanders should be considered in risk regulation of pesticides. Over the last decade risk regulation processes have changed and become more complex. At the international level the Rotterdam Convention has come into force and gradually gains importance (Jansen and Dubois, 2014). Pesticide business is actively shaping various regulatory frameworks (Jansen, 2017). Food production companies have invested in technological innovation to reduce pesticide drift and contamination, such as better spraying equipment, GPS software for more exact flight patterns, and safer filling stations. Yet, effectiveness of these technological risk reduction strategies seems insufficient to prevent environmental pesticide exposures (van Wendel de Joode et al., 2014). Knowledgeable bystanders may be a good voice to deepen our insights into what is occurring in the surroundings of the fields and contribute to decisions on how to test the effectiveness of such risk reduction strategies. The relative independence from crop production as a livelihood provides a special perspective on the matter. This does not mean that these bystanders would be unable to take the economic effects of pesticide use into account. During our research, respondents were very willing to answer the survey, offering perspectives that may differ from other actors. If bystanders' perspectives are neglected in the development of risk regulation, this may lead in the long run to court cases, such as the one started by Ms. *Rodríguez*, and other forms of contestation, as well as a missed opportunity to develop more effective risk reduction strategies and protect bystanders' health.

This study had some limitations. With respect to the exploratory factor analysis, nine factors explained 40% of total variance, a relatively small part of the total variance. Also, the sociodemographic and occupational variables explained only a small amount of the total variance (4–8%) of each factor score. Yet, this is a common constraint when studying psychological or social constructs (Hair et al., 2014; Hayduk, 2014; Cohen, 1988) and five out of the nine factors had satisfactory consistency (Cronbach's alfa>0.7). Another limitation is a relatively small part of schools participated in the survey: only 23 out of 238 school principals replied (10%). These 23 schools might not represent the risk perception of school personnel of the other schools. Nevertheless, the demographic distribution of our sample was comparable to the national population of school workers, an indication our sample may have been unbiased and possibly reflects risk perception of all school workers in these three counties. Also, at the 23 participating schools, all school workers who were present at the day of the survey participated (n = 475), and 455 out of the 475 (96%) had complete information on risk perception.

4. Conclusions

The 33-question survey instrument that we modified from Gardner (2009), and successfully applied in this study, was useful to study the nature of bystanders' risk perception of pesticide use. The answers to the survey were grouped into nine factors of which five had satisfactory internal consistency (Cronbach's alpha >0.70): severity, magnitude, and manageability of risk, and benefits and being supportive of pesticide use. We therefore recommend using this survey in future studies on bystander's risk perception of pesticide use.

The rural school workers (bystanders) from this study, who did not have a contractual relationship with agricultural production, perceived a relatively high severity of risk due pesticide use as nine out of ten questions of this factor had an average score >4 (scale 1 to 5). Older school workers, (male) elementary school teachers, and women school workers, particularly from schools with near aerial spraying (Matina County), perceived higher severity and/or magnitude of pesticide risks than school workers who did not meet these conditions, which is valuable information for risk management strategies. Furthermore, women working at schools with near aerial spraying, situated in an area where many men became sterile because of DBCP exposure used at banana plantations during the seventies and early eighties (Matina County), were less supportive of pesticide use. In contrast, male elementary school teachers were more supportive of pesticide use despite perceiving a relatively high severity of risk. Surprisingly, workers from schools situated near areas with pesticide-contaminated drinking water (Siquirres County) were relatively supportive of pesticide use, possibly because the Costa Rica Water and Sewer Institute (AyA) distributed clean drinking water to these areas with water trucks. The results of this study show risk perceptions are not only shaped by gender and age like previously reported in literature, but also by job title and geographical context. Our findings can be explained by intensity of current exposures through aerial sprayings near schools as well as to historical perspectives of the development of banana cultivation and the DBCP tragedy. As understanding risk perceptions is essential to the successful design and implementation of risk reduction strategies, we conclude school workers are knowledgeable about pesticide risks and an important group to incorporate when developing these strategies.

Declaration of competing interest

The authors declare they have no actual or potential competing financial interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.envres.2020.109877.

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