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#### ABSTRACT

Artificially increased habitat complexity can improve the biocontrol service provided by generalist predators as it can reduce intraguild predation (IGP). However, several counteracting mechanisms can buffer the effect of reduced IGP. Here, we investigated whether the cardboard bands installed in pear trees in early winter improve the suppression of the serious pest pear psylla (Cacopsylla pyri) by winter-active spiders (Anyphaena accentuata and Philodromus spp.). We also investigated in laboratory experiments whether the increased abundances of some predators (Philodromus sp.) would result in negative or positive predator-predator interactions and whether the type and/or intensity of interaction is temperature dependent. On average, pear trees with cardboard bands hosted less psylla than control trees. This pattern can be attributed to predation by winter-active spiders, as 45% of individuals were psylla positive using molecular gut-content analysis. However, 58% of Anyphaena spiders were also Philodromus positive. The suppression efficiency for psylla increased asymptotically with the increasing density of winter-active spiders. In the laboratory, the per capita capture rate of philodromids decreased with the density of conspecifics, which translated in an asymptotic increase in predation pressure on the pear psylla. Nonconsumptive intra-trophic-level interference was more intense at 12 °C than at 7 °C. The results show that artificially increasing habitat complexity by installing corrugated cardboard bands around the trunks and branches of pear trees increased predation pressure on the pear psylla as it most likely reduced IGP among winter-active spiders. However, increased intra-trophic-level interference due to increased abundances of spiders reduced their per capita capture rate and caused only an asymptotic increase in the overall predation pressure on the pest. The installation of corrugated cardboard bands around trees could represent an environmentallyfriendly management practice in fruit orchards that improves the biocontrol service provided by generalist predators.

### 1. Introduction

In the temperate zone, winter is the period when most arthropods from fruit trees hibernate in soil, litter, or dense ground vegetation (Kirchner, 1987; Alford, 1999). However, a few arthropods, such as collembolans, psyllids, and spiders, remain active during winter (Korenko and Pekár 2010; Pekár et al., 2015; Petráková et al., 2016). Indeed, winter-active spiders, such as Philodromus and Anyphaena, can feed even at below zero temperatures (Korenko et al., 2010). Generalist spider predators are considered to have limited biocontrol potential due to predation on alternative prey and other predators, slow reproductive response, and slow aggregative response (Symondson et al., 2002). During winter, however, these winter-active generalist predators can reduce the pest population substantially due to the paucity of alternative prey and the reproductive diapause of pests (Pekár et al., 2015). On the other hand, the paucity of alternative prey can also intensify intraguild predation (IGP) among winter-active spiders (Symondson et al., 2002; Rickers et al., 2006). It is therefore necessary to search for a way to reduce IGP among winter-active generalist predators while increasing their predation pressure on the pest.

One promising area with respect to increasing predation on the pest is the manipulation of habitat structure, such as artificially increased within-field habitat complexity (Isaia et al., 2010; Korenko and Pekár 2010; Simon et al., 2010). Increased habitat complexity generally enhances the abundance of natural enemies (Langellotto and Denno, 2004), which can consequently lead to improved pest suppression (Finke and Denno 2006; Miyashita and Takada, 2007; Isaia et al., 2010). It can reduce IGP by providing shelters for predators from lower

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Fig. 1. Corrugated cardboard bands installed on a pear tree in order to increase the habitat complexity.

trophic levels, by reducing encounter rates among predators, or by reducing the capture capability of the top predator (Finke and Denno 2006; Janssen et al., 2007; Ferreira et al., 2011). Such a measure was shown to lead to the enhanced abundances of the predator at lower trophic level, i.e. mesopredator, and/or an enhanced capture rate of the pest by predators at both trophic levels (Denno et al., 2005; Griffen and Byers 2006).

Although more complex habitats generally increase the abundance of generalist predators (Langellotto and Denno, 2004), several counteracting mechanisms can buffer the effect of enhanced abundance on pest suppression. For example, more complex habitats can shelter the pest from predation, decrease the capture capabilities of predators, or provide alternative prey other than the pest to predators (Denno et al., 2005; Birkhofer et al., 2008; Vucic-Pestic et al., 2010).

A large number of studies have investigated counteracting mechanisms at the inter-trophic level (i.e., predator-prey or top predatormesopredator). However, interactions among predators at the intratrophic level can also significantly influence pest suppression, whether negatively or positively (Uetz 1989; Schmidt et al., 2014). For example, increased abundances of a mesopredator due to reduced IGP can intensify non-consumptive interference, which can reduce the per capita capture rate and consequently the overall predation pressure on the pest (Hughes and Grabowski 2006; Schmidt et al., 2014). On the other hand, as similarly sized predators pose only a small risk to each other (Rypstra and Samu, 2005; Korenko and Pekár, 2010; Michalko and Pekár, 2015), their increased abundance can, instead, enhance the per capita capture rate (Losey and Denno 1998; Sih et al., 1998). For example, the escape of a pest from one predator can make it more vulnerable to another one (Uetz 1989; Takada et al., 2013). The type and intensity of intra-trophic-level interactions among predators may be temperature dependent. The activity of ectotherms as well as the intensity of interactions increase with rising temperature (Kruse et al., 2008; Pekár et al., 2015; Michalko and Košulič 2016). Interference is more severe among predators with active rather than sitand-wait hunting modes, and ectothermic predators can switch from a less to a more active hunting mode with rising temperature (Wise, 2006; Kruse et al., 2008). Thus, the interference intensity among predators at the same trophic level may increase as well. Alternatively, predator-predator interactions may switch from positive to negative with rising temperature.

The pear psylla employed in our study system - Cacopsylla pyri L. (Hemiptera, Psyllidae) - is one of the most serious pests afflicting pear orchards in Europe, causing substantial economic losses in virtue of retarded tree growth, defoliation, and decreased fruit quality (Kocourek and Stará 2006; Daugherty et al., 2007; Civolani 2012). The pear psylla is in reproductive diapause from mid-autumn to late winter in Central Europe (Stratopoulou and Kapatos, 1995). During this period, winteractive spiders, namely Anyphaena accentuata (Walckenaer) (Anyphaenidae) and Philodromus spp. (Philodromidae), significantly reduce the psylla's population density; however, in a recent study, their potential was lowered by IGP evinced by Anyphaena on Philodromus (Pekár et al., 2015; Petráková et al., 2016). The installation of corrugated cardboard bands on fruit trees has been shown to reduce IGP and to increase the abundances of winter-active spiders (Isaia et al., 2010; Korenko and Pekár 2010). Nevertheless, as the effect of increased habitat complexity is system specific, it is unknown whether it actually improves the suppression of the pear psylla.

In this study, we investigated: (1) whether artificially increased

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