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DETERMINANTS OF SPECIES ASSEMBLAGES OF INSECT PESTS IN NATURAL FOREST ECOSYSTEMS

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Abstract:

To look at what influences the distribution and makeup of insect pests in natural forest ecosystems. We evaluate the impact of environmental factors, such as climate, vegetation structure, and habitat heterogeneity, on insect pest species assemblages by field surveys and ecological analysis. Furthermore, we investigate how insect pest populations are shaped by biotic interactions such interspecific competition and predator-prey dynamics. Our research sheds light on the various ecological variables that influence the variety and abundance of insect pests in forest ecosystems, offering important new information for approaches to pest control and conservation in these settings.

Keywords: Insect pests, Species assemblages, Natural forest ecosystems, Environmental factors, Biotic interactions, Habitat heterogeneity and Vegetation structure

Introduction

Pests were defined by the International Plant Protection Convention (IPPC) as species that are detrimental to natural flora, cultivated plants (agriculture, horticulture, and forestry), and plant products, which include wood products, dried plant materials for handicrafts, fresh fruits and vegetables for processing or consumption, and grains for food or feed. Insect pests include subsurface feeders that can harm social development and natural resources in a variety of global habitats as well as surface feeders that pierce, eat, or suck plants.

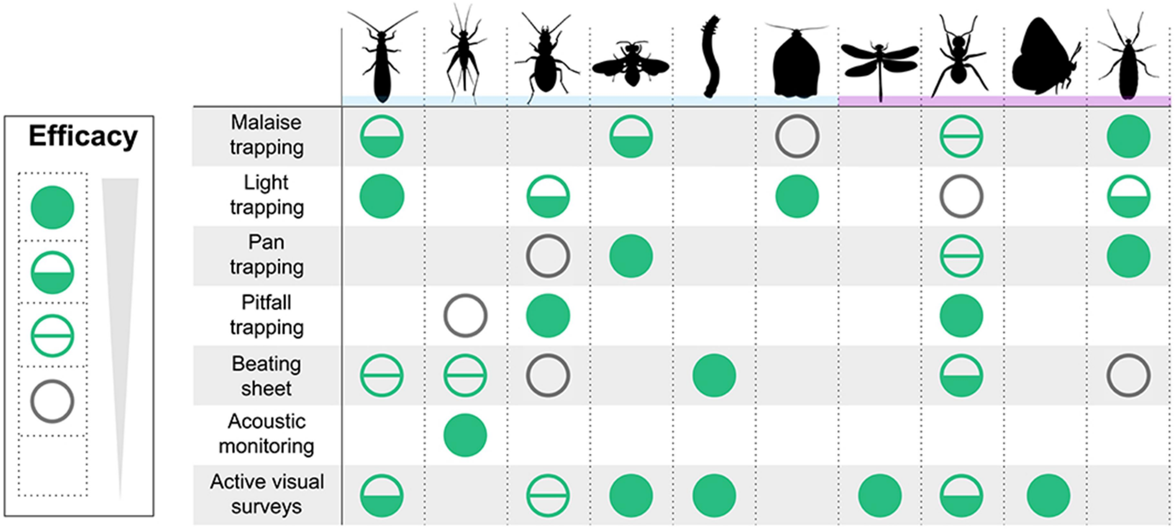
The danger of invasion can be calculated by modeling insect pest species assemblages (Worner and Gevrey 2006). In order to give a guide for the avoidance and management of insect pests in environmentally sensitive places, it is necessary to model the links between patterns of species assemblages and environmental conditions in alpine forest ecosystems. In order to create efficient biological control methods, we investigated the factors that influence the assemblages of insect pest species in alpine forest ecosystems. In semi-natural mature forests sampled along two orthogonal gradients of increasing latitudes and tree species richness, we assessed crown defoliation. We may examine the stationarity of AR patterns across a wide range of environmental situations by adjusting these two elements. More precisely, we contrasted how forest diversity affected overall defoliation at the stand and the degrees of tree species.

Species data;

In alpine forest ecosystems, a particular pest species may infiltrate several sections of its plant hosts. We conducted insect pest identification based on the expertise of biocontrol and pest science professionals, and we determined the harm caused by a certain insect pest based on the percentage of leaf loss, degrees of stunting, and proportion of seedling death in host species in the field.

The specialists used their experience and data from the first and second forestry pest survey studies in Qinghai Province, China, to determine if a particular insect species was a pest. A species was given a label indicating whether or not the experts considered it to be a nuisance. Nonetheless, a species was designated as a "possible insect pest" in the absence of appropriate data. The investigated insect pest species have the potential to infiltrate alpine woody plants, such as Populus cathayana, Picea crassifolia, Populus davidiana, and Hippophae rhamnoides, since they are highly fecund herbivores that cause harm to forest ecosystems.

High percentages of leaf loss, stunting, and seedling mortality of the host plant might result from their invasion. From 2014 to 2016, we looked at insect pests in over thirty host plant individuals twice during the plant growth seasons in each plot. The scientific names of insect pest species, the plant host portions that the pests have infiltrated, and the quantity of pest individuals in each plot were recoded (Wang et al. 2021). 172 insect pest species in all were investigated. These 172 insect pest species constitute a serious danger to forest ecosystems because they have the ability to infiltrate five regions of their plant hosts—leaves, roots, seeds, fruits, trunks, and twigs.



Species diversity

In order to measure the variety of insect pest species, we employed the methodology of Lewis et al. (2016), utilizing four indices: observable diversity, dark diversity, community completeness, and species pool. We determined the species richness, or the number of pest species, given the observed diversity at the research sites. Based on patterns of species co-occurrence in the forest ecosystems of China's Qinghai Province, we calculated dark diversity.

Using the Beals index to calculate the likelihood of a species existing at a study location, the co-occurrence patterns of different species were evaluated (Lewis et al. 2016). Each species was given a threshold value for inclusion in dark diversity since the Beals index was connected with species frequency according to the locations × species matrix for pest species (Lewis et al. 2016).

In order to account for outliers, these criteria were established at the 5% quantile of the predicted probabilities of occurrence for each species at the sites where those species were found (Lewis et al. 2016). The Lewis et al. (2016) study included the specifics for dark diversity evaluations. The species pool, which represented the amount of the site-specific species pool that was represented in local communities, was the sum of the observed and dark diversities for a particular study site. This allowed us to calculate the community completeness using the logarithmic ratio of observed and dark diversities (Partel et al. 2013).

The assemblages of insects in forests;

A vast variety of creatures may be found in forests (Smith & Smith 2000). Investigating the mechanisms that regulate species assemblages and distribution is necessary to comprehend the patterns of such variety (Drake 1990; Cottenie 2005). Spatial scale, habitat type, local environment, organism size, and dispersion capacity are often factors that affect these processes (Leibold 1998; Hillebrand 2004; Soininen 2010).

One of the most significant trends characterizing the variety of species across geographical contexts is thought to be the decline in species composition similarity with increasing spatial distance (Tobler 1970; Nekola & White 1999; Morlon et al. 2008; Thieltges et al. 2009). To explain these patterns, three distinct procedures have been put forth: (1) environmental biological interactions include intra- and interspecific competition, (2) neutral processes, and (3) processes (Hubbell 2001; Pitman et al. 2001; Leibold et al. 2004; Tscharntke & Brandl 2004; Cottenie 2005). Because environmental conditions may function as filters for species, there are changes in the composition of species assemblages across geographic regions due to environmental variability (Hanski & Heino 2003; Müller et al. 2011). Only species that can adapt to the local environment can survive when many species have access to the same habitat or the same capacity for dispersion (Leibold 1998; Chase & Leibold 2003). Because of this, variations in the environment over spatial distance will be accompanied by changes in species compositions. However, different environmental variables exhibit distinct patterns of spatial autocorrelation, and environmental fluctuations are spatially autocorrelated (Dormann et al. 2007). Tuomisto et al 2012). Spatial autocorrelation of species compositions can also result from neutral mechanisms predicated on the idea that species belonging to the same trophic level are biologically equivalent.

This perspective holds that species can be common or uncommon in any location, independent of environmental variability, and that species dispersion limitations result in spatially autocorrelated compositional differences (Hubbell 2001). Consequently, when habitat patches go farther apart, the homogeneity of species assemblages declines (Condit et al. 2002). In this sense, species mobility is significant. High dispersion species are more likely to travel great distances in search of new habitats as well as to connect existing habitats (Bush &

Whittaker 1991; Weddell 1991). Dispersal poses a risk to species, though, as it is not always the case that a dispersing individual would locate appropriate hosts (Müller et ation. 2011). The dynamics of biotic interaction have given rise to theories suggesting that assemblages should be dominated by good competitors. Low-level competitors, on the other hand, ought to be uncommon (Pitman et al. 2001; Tuomisto & Ruokolainen 2006). According to this viewpoint, species compositions should remain mostly unchanged throughout geographical distances as long as there is no trade-off between dispersion propensity and competitive competence. Furthermore, according to Tuomisto and Ruokolainen (2006), differences in species compositions are not significantly impacted by changes in the environment or geography.

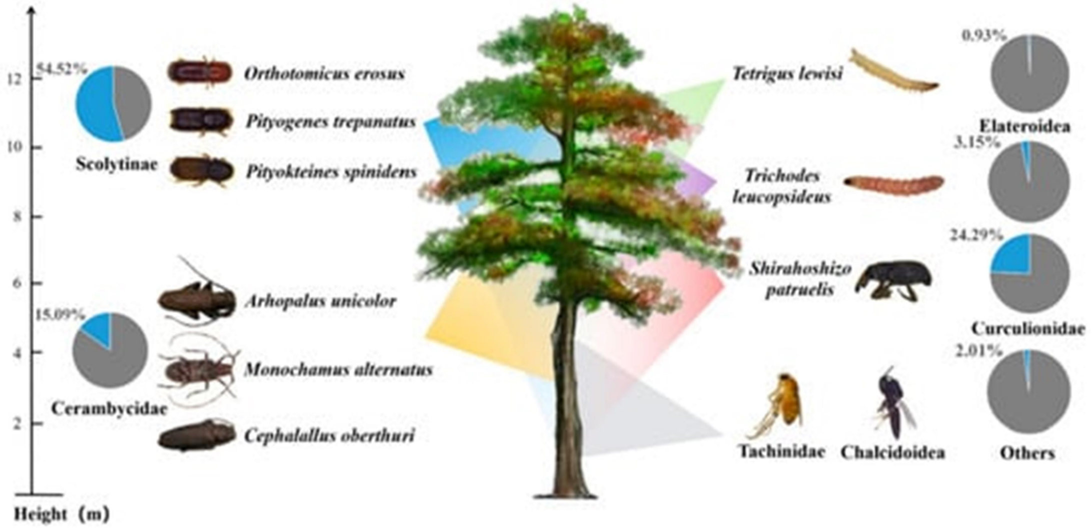
Important information for forest management and conservation may be obtained by analyzing the relative contributions of spatial and environmental factors on species compositions (Tuomisto et al. 2003). To separate the impacts of environment and distance on species assemblages and distribution, two potent statistical techniques were put forth. The first method (distance approach; Nekola et al. 1999) addresses the differences in compositional similarity of species abundances over distances in the environment and geography.

Tree diversity and insects;

The link between insects and forests is significantly impacted by the interactions between herbivorous insects and plants (Lieutier 2006). Both biotic and abiotic variables affect these interactions (Larsson 1989; Herms & Mattson 1992; Koricheva et al. 1998). One of the most significant elements influencing interactions between trees and herbivores as well as the ecosystem as a whole, including the stability of the food web and the variety of arthropods, is thought to be the diversity of trees (Haddad et al 2009, 2011). Moreover, the presence of appropriate host plants is a prerequisite for the existence and functionality of herbivorous insects. Given that many insects are specialized feeders, more tree species should result in a greater diversity of insect species, which in turn influences insect population dynamics and compositions. Nonetheless, the degree of herbivory in more diversified tree stands may not always mirror this. Therefore, it's critical to research how tree diversity affects herbivorous insects in order to comprehend:

- The results of the relationships that exist between herbivores and tree diversity.
- The mechanisms that underlie these relationships.
- The consequences for population dynamics, herbivore assembly structure, and other ecological activities.
- Novel techniques for overseeing forest ecosystems.

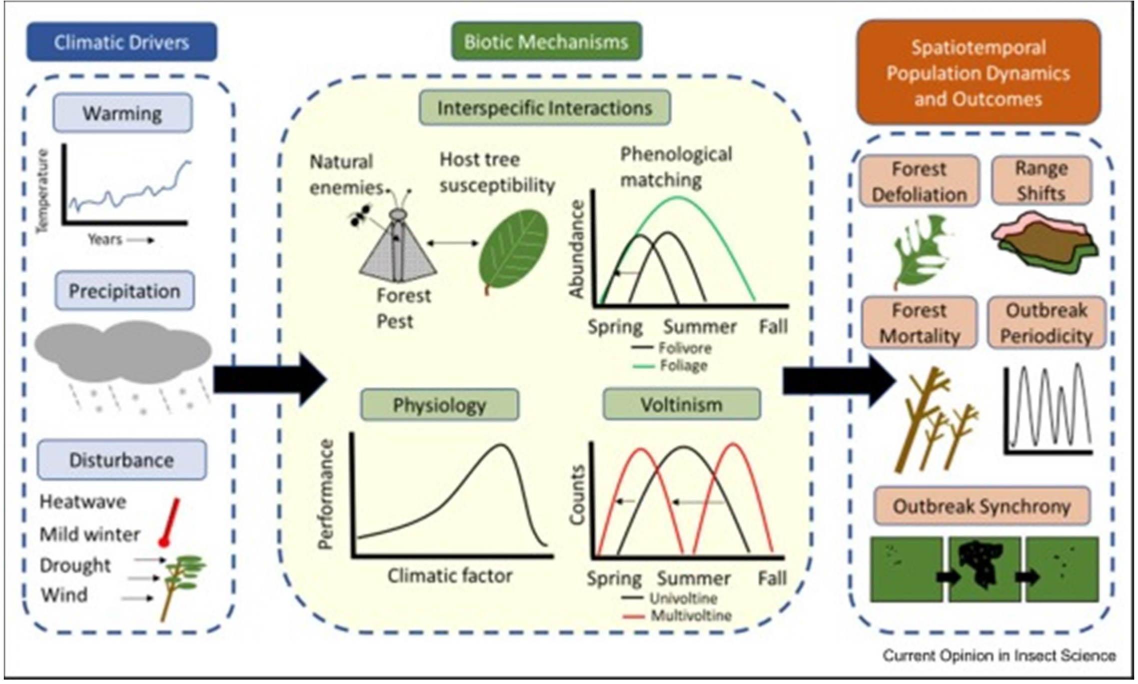
The "associational susceptibility" theory was formulated to explain why plant diversity increases with herbivore damage (Wada et al. 2000; White & Whitham 2000; Barbosa et al. 2009). This theory states that herbivores, particularly generalists on favored host plants, may become more numerous and move to alternative hosts in response to population growth. Moreover, the increased performance and quantity of herbivores due to a varied diet enhance plant damage (Brown & Ewel 1987; Wada et al. 2000; White et al. 2000). The idea of "associational resistance" was presented to explain how more plant diversity may reduce the harm caused by herbivores. In this approach, the reduction in herbivore damage with increasing plant variety is driven by natural enemies, resource dilution, and/or plant apparency (Tahvanainen & Root 1972;Barbosa et al. (2009); Root 1973).



Rarely are the impacts of tree diversity on herbivorous insects' interactions with their hosts examined in experimental research for a variety of tree stand compositions (Baeten et al. 2013). In the third chapter, I examine how insect herbivory is impacted by tree diversity and how well a generalist herbivore performs in lab and field studies. In particular, I look at two things: (1) will herbivore damage in the field rise or decrease as a result of tree variety; and (2) are these impacts due to variations in how different leaf quality—that is, the outcome of tree diversity—affects herbivore performance? Our findings indicate that as tree variety increases, herbivore damage decreases. Furthermore, there is no correlation between this decline with a shift in the host plants' palatability. The findings imply that the mechanisms behind associational resistance are significant for our research system. To understand the underlying mechanisms of associational resistance, more research is required.

<u>Population dynamics of forest insects ;</u>

Many insects have varying population densities both over time and in different geographical locations (Kendall et al. 1999; Liebhold & Kamata 2000). Population densities are low for extended periods of time, but occasionally they rise to epidemic levels, which seriously harms forest ecosystems both ecologically and economically (Berryman 1988; Thurber et al. 1994; Webb et al. 1995; Aukema et al. 2011). Certain species exhibit population cycles, or cyclical variations in population density, which often take place in certain habitat patches (Liebhold 1992; Johnson et al. 2005). Fundamental elements influencing death and survival rates in species populations are what drive population dynamics (Cornell & Hawkins 1995; Carey 2001). These elements consist of. Numerous components exhibit co-variation and interact in ecosystems, especially forests (Wallner 1987; Royama 1997; Hunter & Price1998). As such, it can be incorrect to attribute mechanisms that govern population dynamics to a single cause.



Current Opinion in Insect Science

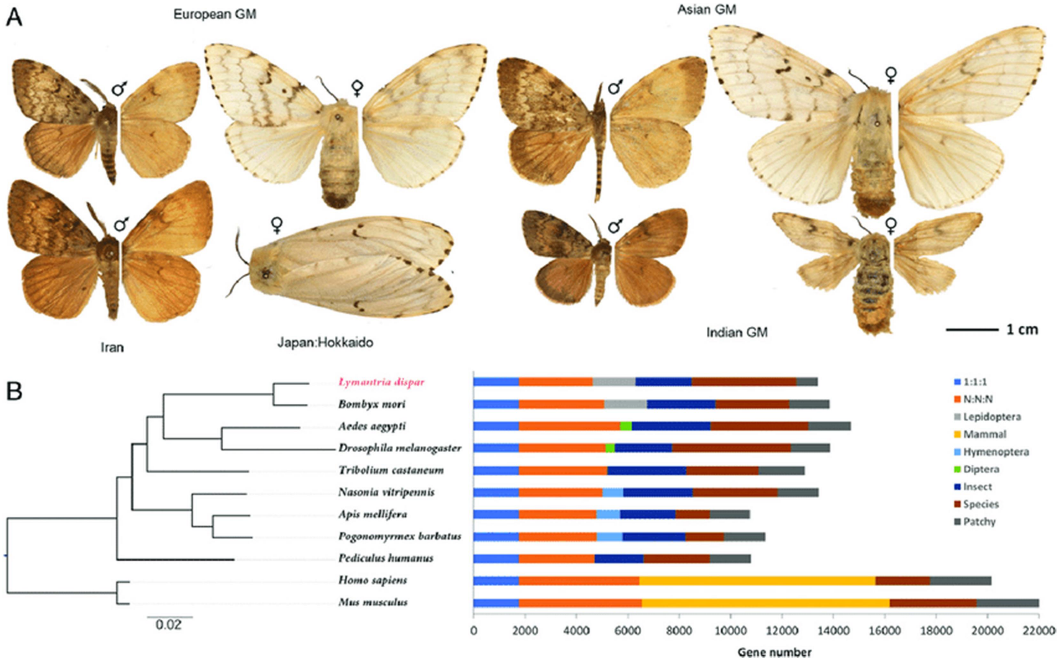
- Natural enemies (Berryman 1996; Anderson & May 1980).
- Weather-related impacts (Thomson et al., 1984).
- Price et al. (1980) reported on the interaction with the host plant.
- Ginzburg & Taneyhill (1994) and Edelsteinkeshet & Rausher (1989) discuss the impacts of motherhood.

Fundamental elements influencing death and survival rates in species populations are what drive population dynamics (Cornell & Hawkins 1995; Carey 2001). These include interactions with the host plant (Price et al., 1980), weather impacts (Thomson et al., 1984), natural enemies (Anderson & May, 1980; Berryman, 1996), and maternal effects (Edelsteinkeshet & Rausher, 1989; Ginzburg & Taneyhill, 1994). Numerous elements exhibit co-variation and interact in ecosystems, especially forests (Wallner 1987; Royama 1997; Hunter & Price 1998). As such, it can be incorrect to attribute mechanisms that govern population dynamics to a single cause.

As native and invasive forest pests, forest insects like the gypsy moth (Lymantria dispar L) and the larch bud moth (Zeiraphera diniana) are extensively researched examples for population dynamics (Berryman 1991b; Dwyer et al. 2004). Lymantria dispar, the gypsy moth, is a species of great economic significance since it severely defoliates forests in both its native and invaded areas. Similar to several other forest insects that feed on leaves, this insect's populations display regular gradations or "population cycles" (Varley et al. 1973; Kendall et al. 1999). It is hypothesized that the greatest death rates among these insect populations are caused by natural enemies, particularly parasitoids (Anderson et al. 1980; Berryman 1996; Myers 1993). But it's unclear exactly how parasitism affects the population cycles of a lot of forest insects. Regarding the true function of natural enemies in controlling the gypsy moth population, particularly in its invading region, there is disagreement (Berryman 1991a; Liebhold & Elkinton 1991). By examining the variables influencing the population dynamics patterns of forest insects, we may create management plans that anticipate and mitigate the possible harm caused by extensive defoliation. These elements include host plants, the weather, and natural enemies like as parasitoids, predators, and infections. I draw special attention to how natural adversaries affect this woodland insect's population dynamics.

Population dynamics and outbreaks of the gypsy moth;

The univoltine life cycle of the gypsy moth influences the dynamics of its population (Montgomery & Wallner 1988). During the winter, the insect diapauses as an egg mass. By ballooning, neonate larvae contribute significantly to the population's natural dispersion (Barbosa & Capinera 1978; Pogue & Schaefer 2007). Females often have six instars compared to five for males, which increases their exposure to natural enemies (Grijpma 1989). The pupae take about two weeks to mature, giving parasitoids and predators plenty of time to strike (Leonard 1981).

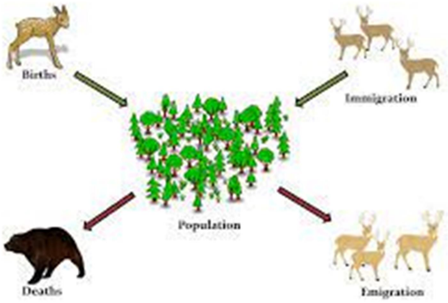


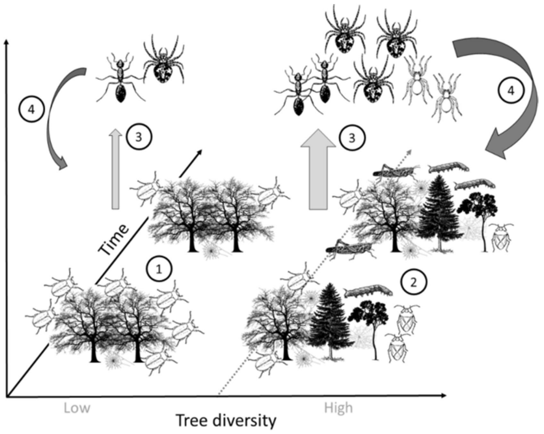
Similar to several other forest insects that feed on foliage, gypsy moth populations display regular gradations or cycles in their numbers (Varley et al. 1973; Leonard 1974; Berryman 1996; Kendall et al. 1999). These gradients appear to be concentrated in a few areas where favorable circumstances are thought to exist. For instance, since the 1970s, cycles have taken place in the same birch and alder woods in western Lithuania every 10 years (1971–1975, 1982–1983, 1993–1994; Zolubas et al. 2001). The various phases of the cycle (see fig. 1) are referred to in Europe by the following terms: postgradation or retrogradation (population density decreases after outbreaks), pro-gradation (population starts to erupt), culmination or outbreak (population reaches high levels of density), and latency (when population is at low levels of density), respectively. Ecologists employ the words "innocuous or endemic," "release phase," "outbreak phase," and "decline phase" in North America (Campbell 1981; Montgomery & Wallner 1988; Elkinton & Liebhold 1990). Indicators of the gradation phase are often provided by the quantity of egg masses per unit area of land or per tree in the spring before hatching (Liebhold et al. 1994). Indications of the population phase may also be obtained from the size of the egg masses and the percentage of aged egg masses (for further information see also Liebhold et al. 1994). Large-scale gypsy moth population outbreaks appear to be coordinated (Myers 1998; Johnson et al. 2005). Between 1990 and 1995, outbreaks occurred in fifteen European countries: Austria, the Czech Republic, France, Germany, Hungary, Italy, the Netherlands, Poland, Portugal, Russia, Spain, Romania, Serbia, Slovakia, and Switzerland. Even minor outbreaks happened in England at this time, despite the country's generally unfavorable environment. this insect (Wulf & Giraser 1996; Narang et al. 2001; Cannon et al. 2004; Lipa & Kolk 1995).

Appears to be a product of escaping these adversaries (Berryman 1991b, 1996, 1998; Montgomery & Wallner 1988). Compared to Europe, parasitism by tachinids is less common in North America. Nevertheless, a component regulating gypsy moth populations was postulated to be a delayed density dependency brought about by imported parasitoids (Berryman 1991a, b, 1998). This idea was not supported by any evidence (Liebhold & Elkinton 1991; Liebhold et al. 2000). However, in low-density populations, predation by small animals seems to be the primary cause of death, which inhibits the growth of gypsy moth populations to epidemic levels (Liebhold et al. 2000). Based on these findings, it was suggested that variations in the abundance of generalist predators might influence the occurrence of outbreaks (Liebhold et al. 2000; Johnson et al. 2006; Bjornstad et al. 2010). According to a recent study on the population cycles of gypsy moths in North America, trophic interactions regulate the behavior of the gypsy moth population even in the absence of significant environmental changes (Allstadt et al. 2013).

The effects of natural enemies on population dynamics ;

The natural enemies that the gypsy moth faces are various (Hoch et al. 2001). On the other hand, these opponents' effects differ according on the gradation phase (Novotny 1989; Maier 1990, 1995; Novotny et al. 1998; Hoch et al. 2001; Turcani et al. 2001). In Europe, the gypsy moth is vulnerable to around 150 species of parasitoids (109 Hymenoptera, 56 Diptera; Grijpma 1989). The percentages of parasitism range from 10% to 100% (Reardon 1981a). Although there is a pool of parasitoids, only a small number of parasitoid species can be regarded as established, and attempts to establish parasitoids throughout the gypsy moth's invasive area have only been partially successful (Campbell 1976; Reardon 1976; Montgomery Wallner 1988; Glare et al. 1998).

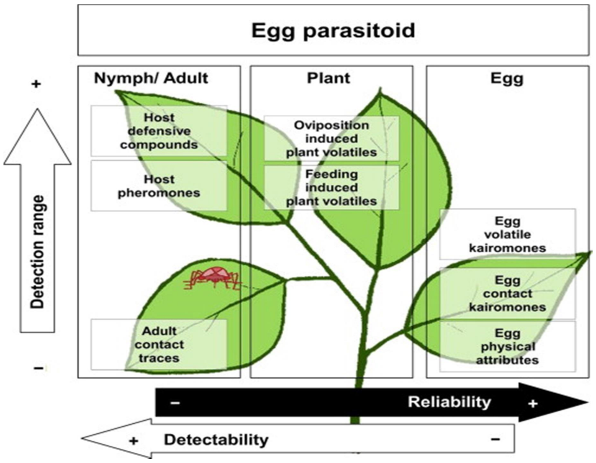


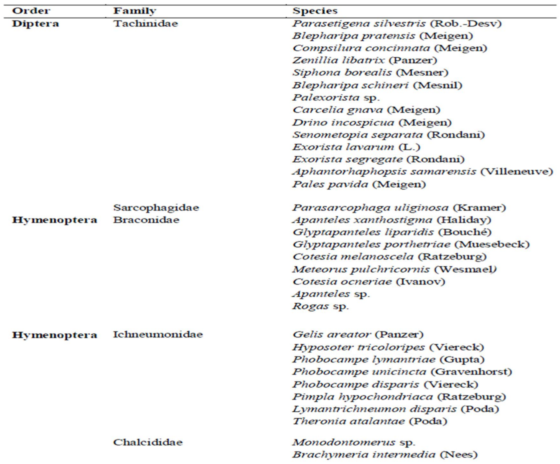


Egg parasitism ;

Six distinct groups of Hymenoptera have been found to harbor gypsy moth egg parasitoids and hyperparasitoids (Brown & Cameron 1982; table 1). The two most significant egg parasitoid species in Central Europe are thought to be Anastatus japonicas (Eupelmidae) and Ooencyrtus kuvanae (Encyrtidae) (Grijpma 1989). Anastatus catalonicus, Anastatus bifasciatus, and Anastatus japonicus are significant other parasitoids. In Germany, for instance, A. catalonicus attacked 40% of an egg mass (Maier 1995). In Turkey, egg masses are attacked by O. kuvanae, Anastatus disparis, and A. bifasciatus; nevertheless, O. kuvanae has greater mortalities than the other two species (Avci 2009). Within the gypsy moth's natural area, there appears to be a significant variance in the parasitism rates of egg parasitoids. In Central Europe, the rates range from 0% to 10% and sometimes even exceed 60% Avaci 2009; Maier 1995; Bathon 1996; Hoch et al. 2001; Turcani et al. 2001; during an outbreak in Turkey. According to these findings, parasitism rates appear to decline with latitude (fig. 2a). Furthermore, no relationship has been found in the native range between the density of egg masses and parasitism rates, and it appears that the rates of parasitism are greater in forests that have been frequently infected than in forests that have just recently been infested (Bathon 1996; Hoch et al. 2001; Turcani et al. 2001; Avci

2009). Egg parasitoids appear to be of minor significance in Asia (Korea and Japan) (Brown 1984; Schaefer et al. 1988). A. disparis and particularly O. kuvanae are thought to be the primary parasitoids of egg masses in North America (Hoy 1976; Reardon 1981b). Their combined rates of parasitism can be as high as 20–40% (Brown & Cameron, 1982; Brown, 1984; McManus & Coska, 2007). O. kuvanae exhibits considerable fluctuation in parasitism rates due to its dependency on egg mass size, while being thought to cause more mortality than A. disparis (Brown et al. 1983; Brown 1984).



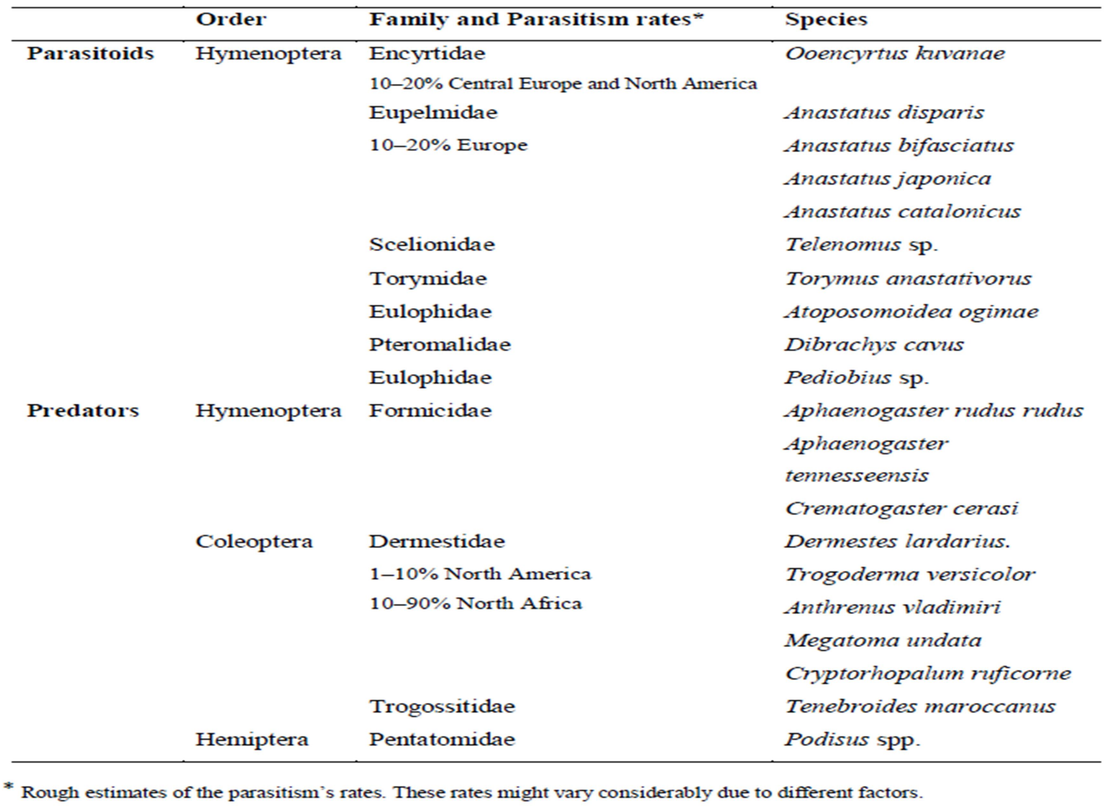


Order	Family	Species
Diptera	Tachinidae	*Parasetigena silvestris* (Rob.-Desv)
		Blepharipa pratensis (Meigen)
		Compsilura concinnata (Meigen)
		Zenillia libatrix (Panzer)
		Siphona borealis (Mesner)
		Blepharipa schineri (Mesnil)
		Palexorista sp.
		Carcelia gnava (Meigen)
		Drino incospicua (Meigen)
		Senometopia separata (Rondani)
		Exorista lavarum (L.)
		Exorista segregate (Rondani)
		Aphantorhaphopsis samarensis (Villeneuve)
		Pales pavida (Meigen)
	Sarcophagidae	*Parasarcophaga uliginosa* (Kramer)
Hymenoptera	Braconidae	*Apanteles xanthostigma* (Haliday)
		Glyptapanteles liparidis (Bouché)
		Glyptapanteles porthetriae (Muesebeck)
		Cotesia melanoscela (Ratzeburg)
		Meteorus pulchricornis (Wesmael)
		Cotesia ocneriae (Ivanov)
		Apanteles sp.
		Rogas sp.
Hymenoptera	Ichneumonidae	*Gelis areator* (Panzer)
		Hyposoter tricoloripes (Viereck)
		Phobocampe lymantriae (Gupta)
		Phobocampe unicincta (Gravenhorst)
		Phobocampe disparis (Viereck)
		Pimpla hypochondriaca (Ratzeburg)
		Lymantrichneumon disparis (Poda)
		Theronia atalantae (Poda)
	Chalcididae	*Monodontomerus* sp.
		Brachymeria intermedia (Nees)

Larval and pupal parasitism ;

Slovakia, Austria, and Germany have reported over 23 species of parasitoids and hyperparasitoids (table 2; Bathon 1993; Maier 1995; Hoch et al. 2001; Eichhorn 1996; Turcani et al. 2001). The two tachinids with the greatest death rates are Blepharipa sp. and Parasetigena silvestris. In Austria, Germany, Lithuania, Poland, and Slovakia, these species collectively represent the majority of tachinid parasitoids (Maier 1990, 1995; Eichhorn 1996; Hoch et al. 2001, 2006; Turcani et al. 2001; Zolubas et al. 2001; Sukovata & Fuester 2005). Due to their specialization and univoltine nature, these two species have life spans that are comparable to those of their hosts (Montogomery & Wallner 1988; Maier 1990). Parasetigena silvestris directly places the egg on older larvae resting in the trunk flaps, whereas B. pratensis places it on the devoured foliage (Odell & Godwin 1984; Gould et al. 1992). Consequently, oviposition is greatly enhanced by the quantity of host-damaged leaf clusters and the density of larvae, which in turn improves the response to variations in host density (Odell & Godwin 1979, 1984; Williams et al. 1992). In Europe, other frequent species of tachinids include Compsilura spp. and Exorista spp.

During an epidemic phase in Turkey, 20% of the larval and pupal deaths were attributed to Exorista segregate, Compsilura concinnata, and other species (Avci 2009). In low-density periods in Italian willow woodlands, C. concinnata also parasitized gypsy moths (Camerini 2009). Although they generally do so at low or rising population levels, other significant species, including those of the Braconidae, Ichneumonidae, and Chalcididae families, can cause large rates of parasitism (Maier 1995; Bathon 1996; Schopf & Hoch 1997; Hoch et al. 2001; Turcani et al. 2001; Zolubas et al. 2001). In Europe, latency and progradations of Glyptapanteles liparidis and Glyptapanteles porthetriae appear to be common (Schopf & Hoch 1997; Hoch et al. 2001; McManus & Csoka 2007). The family Ichneumonidae contains Phobocampe sp., which in postgradations causes significant parasitism rates for the larvae and pupae (Maier 1995; Zolubas et al. 2001). These species might be multivoltine or oligovoltine. Additionally, because they are not unique to the gypsy moth, they are more active in low density populations and less responsive to changes in population densities. For instance, Glyptapanteles liparidis is a useful species in low-density regions and places where populations are growing due to its strong seeking capabilities (Schopf & Hoch 1997). The interaction between this gregarious endoparasitoid and the larvae is influenced by a variety of conditions, just like that of the other parasitoids. Larval age, alternate hosts, host size, and parasitoids complex are a few examples of these parameters (also refer to Schopf 1991; Schopf & Rembold 1993; Schopf & Steinberger 1996).



	Order	Family and Parasitism rates*	Species
Parasitoids	Hymenoptera	Encyrtidae	*Ooencyrtus kuvanae*
		10–20% Central Europe and North America	
		Eupelmidae	*Anastatus disparis*
		10–20% Europe	*Anastatus bifasciatus*
			Anastatus japonica
			Anastatus catalonicus
		Scelionidae	*Telenomus* sp.
		Torymidae	*Torymus anastativorus*
		Eulophidae	*Atoposomoidea ogimae*
		Pteromalidae	*Dibrachys cavus*
		Eulophidae	*Pediobius* sp.
Predators	Hymenoptera	Formicidae	*Aphaenogaster rudus rudus*
			Aphaenogaster tennesseensis
			Crematogaster cerasi
	Coleoptera	Dermestidae	*Dermestes lardarius.*
		1–10% North America	*Trogoderma versicolor*
		10–90% North Africa	*Anthrenus vladimiri*
			Megatoma undata
			Cryptorhopalum ruficorne
		Trogossitidae	*Tenebroides maroccanus*
	Hemiptera	Pentatomidae	*Podisus* spp.

* Rough estimates of the parasitism's rates. These rates might vary considerably due to different factors.

Conclusion:

Gives important information on the variables affecting the distribution and composition of insect pests in natural forest ecosystems. We discovered that a variety of environmental factors, including habitat heterogeneity, vegetation structure, and temperature, significantly influence the assemblages of insect pest species. In addition, biotic interactions—such as interspecific competition and predator-prey dynamics—also add to the variety and quantity of insect pests in these environments. Our results highlight the significance of taking into account a variety of ecological parameters when creating conservation and pest control plans for natural forest ecosystems. The intricate relationships that exist between insect pests and their surroundings help us anticipate and control any pest outbreaks, which in turn helps to maintain the resilience and well-being of forest ecosystems.

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