Effect of climatic factors on the diversity and abundance of Scolytinae and Platypodinae (Coleoptera: Curculionidae) in a pine-oak forest

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ABSTRACT

Objective: The aim of this work was to evaluate the diversity and abundance of bark beetles and ambrosial beetles and their relationship with temperature and relative humidity.

Design/methodology/approach: The study was carried out in a pine-oak forest of the northeastern Sierra of the state of Puebla, where a monitoring system was established using Lindgren traps baited with frontalin, brevicomine, alpha-pinene and beta-pinene.

Results: The presence of 23 species of bark beetles and ambrosial beetles was recorded. *Gnathotrichus sulcatus* (LeConte) and *Pseudips mexicanus* (Hopkins) were the most abundant species and their presence was significantly associated with places having high relative humidity.

Limitations on study/implications: The results obtained are limited to the studied ecosystem.

Findings/conclusions: It was concluded that the abundance of the species observed was closely related with climatic factors.

Keywords: Bark beetles, environmental temperature, relative humidity, semiochemicals, temperate forest

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INTRODUCTION

The family Curculionidae Latreille (1802) is one of the most diverse group of insects, characterized by containing some of the most economically important pests of ornamental, agricultural, and forestry crops [1, 2]. This group includes the bark beetles and ambrosial beetles (Scolytinae Latreille, (1807) and Platypodinae Shuckard, (1840)). Beetles are related to diverse processes in ecosystems, including nutrient cycling [3, 4], ecological succession [5], hydrological cycles [6], and wildfires [7], whose interaction and synergies may be intensified by climate change [8].

The Scolytinae and Platypodinae subfamilies comprise more than 6,000 and 1,000 species, respectively [1, 9]. They usually share habits and hosts (Kirkendall, 1983), and generally inhabit galleries created by females, where they lay eggs and obtain food [10]. Similarly, both subfamilies play an important role in forest ecosystems, as they eliminate diseased and unfitted plants [11], which allows the incorporation of organic matter into the soil.

In Mexico, 927 species of Scolytinae and 45 species of Platypodinae have been recorded. In the State of Puebla, 167 species of Scolytinae and four species of Platypodinae have been recorded [12]. Although there are many records of Coleoptera species in the northeastern Region of the State of Puebla, the presence of species in the subfamilies Scolytinae and Platypodinae has not been documented [13,15]. Therefore, the objective of this study was to correlate the effect of environmental factors on the diversity and abundance of species of these subfamilies in a temperate pine-oak forest in the northeastern region of the State of Puebla.

MATERIALS AND METHODS

This study was conducted in the forested area of the Tecnológico Nacional de México, campus Instituto Tecnológico Superior de Zacapoaxtla (TecNM/ITS-Zacapoaxtla) in the northeastern region of the State of Puebla (19° 49’ 50.34” and 19° 49’ 48.187” North latitude and −97° 34’ 9.544” and −97° 34’ 22.072” West longitude), with an average altitude of 2140 masl (Figure 1). The climate in this location has been humid and temperate (C(m)(f)) in the last 30 years, according to records from the National Meteorological Service (SMN, 2021). The region is characterized by 46 stormy days and 254 foggy days per year; with a minimum annual precipitation of 115.2 mm, average annual precipitation of 460.2 mm and maximum annual precipitation of 1012.5 mm; the minimum annual temperature is 12.9 °C, the average annual minimum temperature is 15.6 °C and the maximum annual minimum temperature is 20.9 °C. The vegetation corresponds to an oak-pine forest [16].

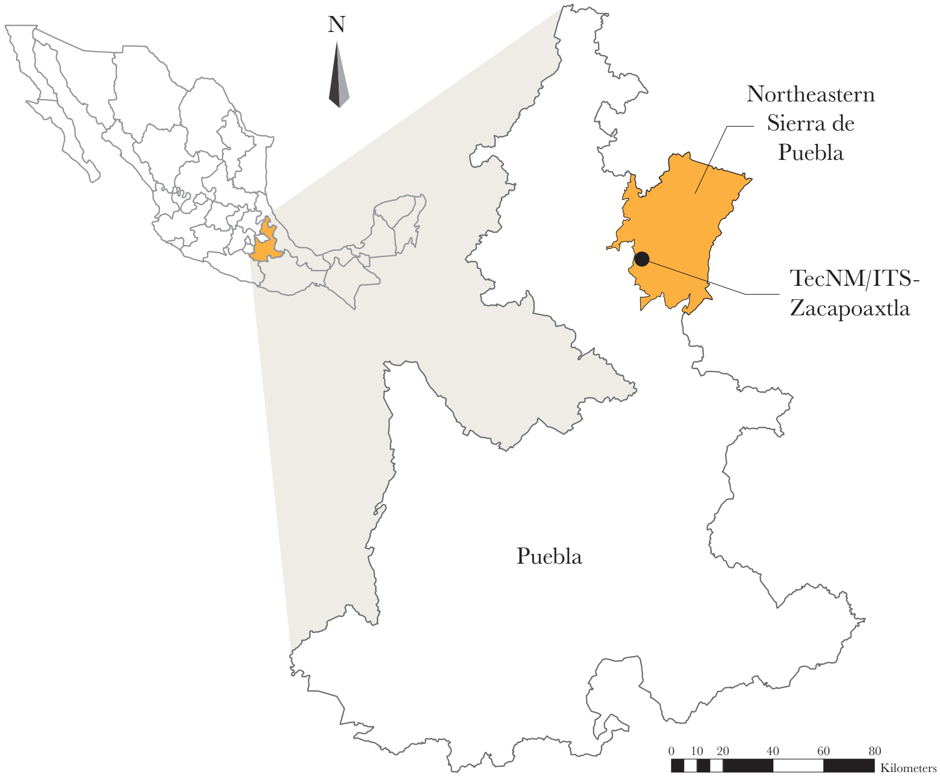

Figure 1. Location of the northeastern highlands of Puebla where this study was carried out

Samplings were performed from May 2018 to December 2019, inside the 22 hectares belonging to the Instituto Tecnológico Superior de Zacapoaxtla. Four Lindgren traps with eight funnels (BioQuip®) were installed randomly. The traps were placed in nonhost trees or in metallic structures at a height of 1.5 m from the ground, and 150 m separated among them. Traps were baited with Frontalin (pheromone), endo-brevicomine (pheromone), alpha-pinene and beta-pinene (kairomone) (Synergy Semiochemicals Corp®). To ensure an optimal level of attraction, the replacement of the attractants of traps was done every two months.

Insects were collected from the traps biweekly, the captured specimens were placed in bottles with ethyl alcohol (70%), then they were transferred to the Forestry Department of the TecNM/ITS-Zacapoaxtla. The scolytids were identified based on the taxonomic keys of Wood [1], Cibrián *et al.* [17], Camacho [18] and Armendariz *et al.* [19]. For platipodids, the taxonomic keys of Wood [20] weres used. Voucher specimens were deposited in the entomological collection of TecNM / ITS-Zacapoaxtla. The climatic factors were recorded every 30 minutes with a data Logger pro 2 (Hobo, USA) installed in the center of the 22 hectares of the property. We measured the minimum temperature, average temperature, maximum temperature, minimum relative humidity, average relative humidity and maximum relative humidity.

The sampling efficiency and the abundance coverage-based species richness estimator (ACE mean) [21], was estimated with the EstimateS v 9 program [22]. This estimator has previously been used to study Coleoptera communities in forest ecosystems [23]. A total of 100 randomizations were performed to obtain the species accumulation curve, obtaining the relationship between the number of species and the month of collection [24]. The separation between the curve of the recorded species and the curve of the estimated species indicates the number of species to be recorded within the community [25].

To determine the abundance and distribution of the species captured , the individuals were counted. Using the R-project program [26], the normality of the data was verified by means of the Shapiro-Wilk test (α=0.05), given that the data did not show normality, the Spearman test (p=0.001) was used to estimate the relationship of the monthly abundance of the beetles with the climatic variables.

RESULTS AND DISCUSSION

A total of 671 specimens were collected, belonging to 23 species, of which 17 belong to the subfamily Scolytinae: *Dendroctonus adjunctus* Blandford, *Dendroctonus approximatus* Dietz, *Dendroctonus mexicanus* Hopkins, *Dendroctonus valens* LeConte, *Gnathotrichus sulcatus* Wood and Bright, *Hylastes fulgidus* Blackman, *Hylastes incomptus* Blandford, *Hylastes tenius* Eichhoff, *Hylurgops longipennis* Wood and Bright, 1992, *Hylesinus* sp. (Fabricius, 1801), *Ips concinnus* Wood and Bright, *Ips emarginatus* LeConte, *Ips integer* Wood and Bright, *Pseudips mexicanus* Cognato, *Ips plastographus* Lanier, *Xyleborus* sp.1 Eichhoff and *Xyleborus* sp. 2 Eichhoff. The remaining six species belong to the subfamily Platypodinae: *Euplatypus pini* Hopkins, *Oxoplatypus* sp. Wood and four morphotypes *Platypodinae* sp. (1, 2, 3 and 4). The species accumulation curve for the TecNM/ITS-Zacapoaxtla forest, that corresponds to the proportion of total abundance of bark beetles and ambrosia beetles presented in the sample, in relation to the total abundance of the community [27], showed that the sampling efficiency for bark beetles and ambrosia beetles was 68.2% (Figure 2). Several authors have highlighted the ecological importance of Coleoptera [28, 29], thus, in the northeastern region of Puebla, research has been developed focused on describing the biodiversity of this group [13, 14], however, bark beetles and ambrosial beetles have not been part of such regional entomological inventories, Equihua and Burgos [30] have reported for the State of Puebla the recorded species captured in this work. It should be mentioned that the sampling efficiency achieved in this study was 68.2%, as it is estimated that exhaustive sampling is achieved with proportions greater than 70%. Similarly, Pérez and collaborators [31], during February 2010 to January 2011, estimated the diversity of Scolytinae and Platypodinae in two natural areas of the State of Tabasco, Mexico; where, they recorded 7057 specimens, belonging to 46 species and 26 genera, without managing to stabilize the species accumulation curve. Possibly, other monitoring strategies are needed to capture the full diversity of these subfamilies.

In this study the highest abundance (61%) of Scolytinae and Platypodinae species were recorded from October 2018 to February 2019). *Gnathotrichus sulcatus* was the species with the highest number of captures (269), followed by *Pseudips mexicanus* (60). In Mexico, 974 species of bark beetles and ambrosial beetles have been reported, of which 929 correspond to Scolytinae and 45 to Platypodinae. Likewise, 167 species of bark beetles and ambrosial beetles have been recorded for the State of Puebla, of which 163 are from the subfamily Scolytinae and 4 are from the subfamily Platypodinae [9]. In this study, 23 species were recorded, of which the subfamily Scolytinae obtained a higher proportion with 17 species compared to Platypodinae with four species. These differences may be due to the type of bait used since there is a variation in response to baits in bark beetle species [32]. Therefore, in relation to national and state records the diversity of bark beetles and ambrosial beetles captured represents 2.4 and 13.8 %, respectively. Similar results were

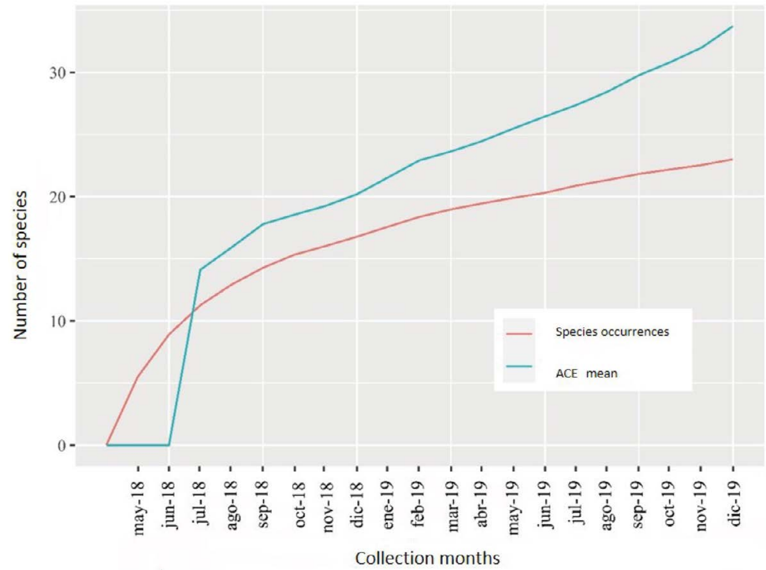

Figure 2. Species accumulation curve.

presented in a xerophytic vegetation environment in the Zapotitlán valley, Puebla [33] and matched with those results of temperate forests where richness and abundance were dominated by Scolytinae [1]. In contrast to forests, where bark beetles and ambrosial beetles are mainly species of the subfamily Platypodinae [34]. Likewise, the proportion coincided with that documented for the State of Puebla, where 97.6% of species recorded belong to the Scolytinae and 2.4% correspond to Platypodinae [9].

The average and standard deviation of the minimum temperature (5 °C±4.4), mean temperature (14 °C±2.3), maximum temperature (28 °C±3.7), minimum relative humidity percentage (29%±16.6), mean relative humidity percentage (85%±8.6) and maximum relative humidity percentage (100%±0.7) were obtained. Spearman's test showed that at least 12 species show a significant correlation between abundance and an environmental variable (Table 1). Of these, nine species showed a negative correlation with the percentage of relative humidity: *D. adjunctus*, *D. mexicanus*, *G. sulcatus*, *H. incomptus*, *I.*

Table 1. Relationships between the species of bark beetle and ambrosia beetles abundance and environmental factors, *(p<0.001).

	Minimum temperature (°C)	**Average temperature (°C)**	**Maximum Temperature (°C)**	**Minimum relative humidity (%)**	**Average Relative Humidity (%)**	**Maximum relative humidity (%)**
Scolytinae						
Dendroctonus adjunctus	−0.109	−0.215	0.169	0.119	−0.285	−0.583*
Dendroctonus approximatus	−0.512*	−0.576*	−0.064	−0.355	−0.049	0.056
Dendroctonus mexicanus	0.282	0.141	−0.006	0.46*	−0.143	−0.782*
Dendroctonus valens	0.174	0.145	0.335	0.38	0.033	0.085
Gnathotrichus sulcatus	0.156	−0.002	0.218	0.208	−0.336	−0.566*
Hylastes fulgidus	0.29	0.153	−0.417	0.247	0.08	−0.322
Hylastes incomptus	−0.092	−0.187	−0.061	0.041	−0.101	−0.544*
Hylurgops longipennis	0.148	0.077	0.105	0.284	0.133	0.017
Hylastes tenius	0.425	0.268	−0.18	0.459*	0.196	0.031
Hylesinus sp.	−0.141	−0.114	0.445	−0.247	−0.406	0.056
Ips concinnus	0.082	0.283	0.418	−0.31	−0.243	0.056
Ips emarginatus	0.333	0.148	−0.319	0.222	−0.117	−0.695*
Ips integer	0.246	0.143	−0.354	0.119	0.12	0.056
Pseudips mexicanus	0.175	−0.045	−0.06	0.218	−0.219	−0.712*
Ips plastographus	0.276	0.061	−0.069	0.28	−0.271	−0.84*
Xyleborus sp. (1)	0.256	0.095	0.063	0.253	−0.007	0.106
Xyleborus sp. (2)	−0.251	−0.087	0.394	−0.187	−0.325	0.074
Platypodinae						
Euplatypus pini	0.258	0.176	−0.097	0.429	0.184	−0.27
Oxoplatypus sp.	0.39	0.238	0.09	0.357	−0.328	−0.85*
Platypodinae sp. 1	0.19	0.242	−0.098	0.096	0.276	0.056
Platypodinae sp. 2	0.19	0.242	−0.098	0.096	0.276	0.056
Platypodinae sp. 3	0.296	0.182	−0.147	0.197	−0.314	−1*
Platypodinae sp. 4	−0.438	−0.486*	0.123	−0.222	−0.066	0.056

emarginatus, *I. plastographus*, *P. mexicanus*, *Oxoplatypus* sp. and *Platypodinae* sp. 3. While two species showed a positive correlation with minimum relative humidity: *D. mexicanus* and *H. tenius*. Additionally, the mean monthly temperature was negatively associated with two species: *D. approximatus* and *Platypodinae* sp. 4. Likewise, the minimum temperature was associated with one species *D. approximatus*. Of the captured species considered to be pests of economic and quarantine importance, Desmond and John [35] reported that *G. sulcatus* on the coast of British Columbia, Canada, had greater flight activity in April and May, a period that coincided with the increase of temperature, and had its maximum abundance at the beginning of May. In contrast, in this study, flight activity occurred from September to December. Data for this activity showed a negative correlation with the percentage of maximum relative humidity, according to the Spearman test, which is the factor that influences flight activity (Table 1, Figure 3).

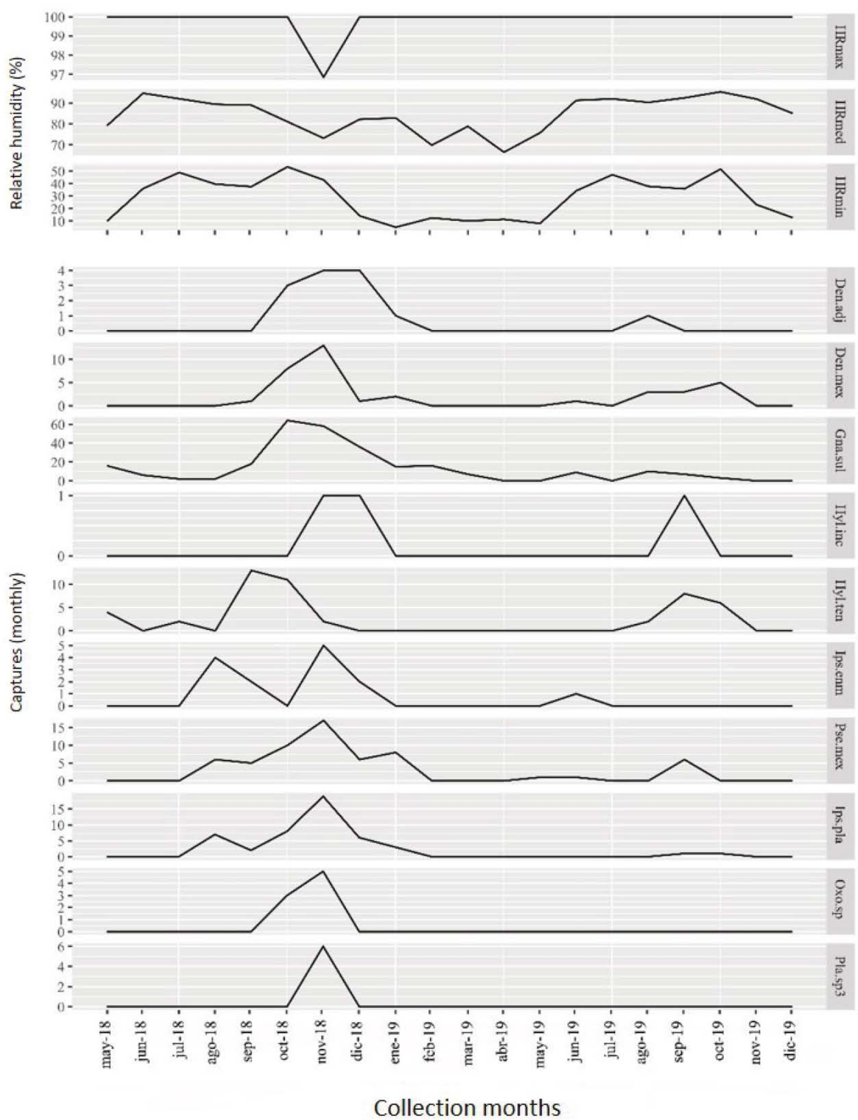

Figure 3. Relative humidity and number of bark beetle and ambrosia beetle captures.

Dendroctonus species have been considered important pests of forests. In Mexico, they are responsible for 40.5% of the area affected by pests (Pérez *et al.*, 2013). In Cofre de Perote National Park, *D. adjunctus* had the greatest increased by April, with a population decreased in August [36]. This data contrast with that reported for the state of Mexico [36], where the greatest population increased occurred during the months of August to December, a period where temperatures also declined . On the other hand, in the Aguascalientes state, *D. mexicanus* showed that, during the period from April 2015 to March 2016, the population increased was directly related to temperature [37], a difference from what was observed in this study, where temperature did not show a significant effect and minimum relative humidity was positively correlated.

During the sampling period, there was a decrease in temperature from December 2018, reaching in January 2019 the minimum temperature of −3.6 ° C; these records are similar to the minimum temperature of −3 °C provided by the National Commission for the Knowledge and Use of Biodiversity (CONABIO) for the area, and this decrease in temperature coincides with the decrease in insect captures. Low temperatures are one of the factors that cause a decrease of the populations of bark beetles and ambrosial beetles [38]. In Colorado, USA, temperatures below −30 °C killed most of the adults and larvae of *Dendroctonus engelmanni* Hopk. [39]. In this study, the Sperman test showed that the minimum temperature was negatively correlated with *D. approximatus*, which is not considered an important pest in Mexico [40]. In turn, the minimum temperature was not correlated with species considered pests for Mexico, a similar case was reported for *D. mexicanus* in the state of Hidalgo, Mexico, where the average minimum temperature was 4 °C, which did not affect the population decreased of *D. mexicanus* [41].

Our results show that environmental factors have a differential influence on the different species of ambrosial beetles and bark beetles. For example, while some species were favored by relative humidity or temperature, other species were affected by these environmental factors, affecting their population abundance. Similarly, other beetle species detected had apparently no association or response either to temperature nor relative humidity.

On a large scale, climatic factors influence the distribution of species [42], in the case of this study we were able to identify the relationship between environmental factors and the abundance of bark beetles and ambrosial beetles. In contrast, Hernández and Obregón [44], obtained non-significant data between average temperature and the abundance of bark beetles in a pine forest in the municipality of Zimapán, Hidalgo. This discrepancy of both results could be explained by the effect of factors such as topography, land use, soil type or biotic interactions [42].

In the case of bark beetles and ambrosia beetles, the female is responsible for locating and colonizing a new host [44]. To establish and reproduce, she must overcome the tree defenses, possibly the reason why subcortical species choose weakened or dead hosts [45]. In this study, the main environmental factor related to the abundance of 12 species was the percentage of maximum relative humidity, which was negatively related to the abundance of nine species, possibly because the species wait for the optimal time to take flight in search for hosts, as in lower humidity the trees develop more stress and are more susceptible to colonization [46]. On the other hand, the abundance of the species that did not show a significant correlation with climatic factors could be explained by the vigor of the hosts, as is the case of *Tomicus piniperda*, which showed the highest abundance in *Pinus sylvestris* L. with low vigor values [47]. There is also the possibility of being correlated with the type of forest management, as it has been demonstrated for *D. mexicanus* in the State of Michoacan, Mexico, where the highest number of insects captured was obtained in forests under silvicultural management, compared to conserved forests [48].

Knowing the influence of climatic factors on the flight activity of bark beetles and ambrosial beetles provides the basis for monitoring and control strategies for species with potential to become pest, however, it is necessary to explore the relationship of other factors such as soil, physiology and genetics of the hosts and their interaction with predators.

CONCLUSIONS

This study has identified the relationship between climatic factors and the abundance of bark beetles and ambrosia beetles in an oak-pine forest in the northeastern Sierra of the State of Puebla. The greatest increase in abundance was obtained during the months from August to December, a period that coincides with the decrease in the percentage of maximum relative humidity. Sampling for 20 months collected 68.2% of the diversity of bark beetles and ambrosia beetles in the study area. To increase the percentage of sampling effort, it is recommended to extend the collection time or the number of traps.

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