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Article

Coloración y abundancia de *Dendroctonus mexicanus* Hopkins, 1905 en cuatro regiones de México

Coloring and abundance of *Dendroctonus mexicanus* Hopkins, 1905 from four regions of Mexico

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Resumen:

El incremento en la abundancia de escarabajos descortezadores en los bosques de pino y pino-encino en México ocasiona la muerte de grandes masas forestales. Se estima que tal comportamiento responde a un aumento en las temperaturas por efecto del cambio climático; sin embargo, se desconoce la función que desempeñan otras variables climáticas como la humedad y de qué manera influyen en ciertas características morfológicas; por ejemplo, la variación en la intensidad de la coloración del exoesqueleto, entre regiones. En el presente estudio se analizaron la variación de la intensidad de la coloración y la abundancia de las poblaciones de *D. mexicanus* procedentes de cuatro regiones (Hidalgo, Oaxaca, Jalisco y Nuevo León), y su relación con la humedad, la temperatura y la aridez. Algunos individuos de *D. mexicanus* exhibieron una coloración más obscura, lo que puede estar asociado a un porcentaje más alto de humedad, y otros con tonalidades más claras (café rojizo) recolectados en zonas con menor humedad (HMA: 82 % = más obscuros; 66 % = más claros). La región del estado de Hidalgo presentó el mayor número de individuos de *D. mexicanus,* en comparación con las de Nuevo León, Jalisco y Oaxaca. Los índices de aridez promedio máximo e índices de aridez promedio mínimo generaron evidencia de condiciones climáticas idóneas para la presencia de poblaciones de *D. mexicanus* más abundantes. Las temperaturas extremas y la humedad relativa del ambiente funcionan como factores limitantes en el incremento exponencial de la abundancia de las poblaciones de descortezadores.

Palabras clave: Abundancia, bosque de pino, coloración del exoesqueleto, *Dendroctonus mexicanus* Hopkins, 1905, humedad relativa, variables climáticas.

Abstract:

The increase in the abundance of bark beetles in the pine and pine-oak forests in Mexico causes the death of large forest stands. It is estimated that such behavior responds to an increase in temperatures due to the effect of climate change; however, the role of other climatic variables such as humidity and how they may influence other characteristics, such as variation in intensity of exoskeleton coloration between regions, is unknown. In the present study, the variation in the intensity of the coloration and abundance of *D. mexicanus* populations from four regions (*Hidalgo, Oaxaca, Jalisco* and *Nuevo León*), and its relationship with humidity, temperature and aridity were analyzed. Some individuals of *D. mexicanus* exhibited a darker coloration, which may be associated with a higher percentage of humidity, and others with lighter shades (reddish brown) from regions with lower humidity (AMF: 82 % = darker; 66 % = clearer). The region of the state of *Hidalgo* presented the largest number of *D. mexicanus* individuals compared to the regions of the states of *Nuevo León, Jalisco* and *Oaxaca*. The maximum average aridity indexes and minimum average aridity indexes generated evidence of ideal climatic conditions for the presence of more abundant *D. mexicanus* populations. Extreme temperatures and relative humidity in the environment function as limiting factors in the exponential increase in the abundance of debarker populations.

Key words: Abundance, pine forest, exoskeleton coloration, *Dendroctonus mexicanus* Hopkins, 1905, relative humidity, climatic variables.

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Introduction

The bark beetles of the *Dendroctonus* genus are distributed in the pine forests of North America (Islas-Salas, 1980), and extend to Nicaragua. Its presence in the state of *Chihuahua*, in central Mexico and, in particular, in the states of *Michoacán* and the State of Mexico (Islas-Salas 1980) is outstanding. It has also been reported abroad, such as in *Honduras* and *Belize* (Payne, 1980; Wood, 1982; Monser *et al.,* 2005; Clarke and Nowak, 2009; Armendáriz-Toledano *et al*., 2014).

There is an estimation of two to five generations of *Dendroctonus mexicanus* Hopkins, 1905 per year as this species is dependent on temperature; in this regard, it is considered one of the most aggressive species (Cibrián *et al*., 1995; Salinas-Moreno *et al.,* 2004; Trân *et al.*, 2007; Armedaríz-Toledano *et al.,* 2014). For example; according to Fonseca-González *et al.* (2014), the loss of *Pinus patula* Schiede ex Schltdl. *et* Cham. trees has been related to *D. mexicanus* on several occasions. Infestations of this insect and the death of trees have also been detected in the pine forests of *Aguascalientes* (Sánchez-Martínez *et al*., 2016).

Bark beetles are ectothermic species that are related to water and thermal balance; consequently, the most important abiotic factors that influence the distribution and abundance of insects are water availability and temperature (Chown and Nicolson, 2004; De la Vega and Schilman, 2015; Clark, 2019). There is evidence that has demonstrated that debarkers have a very important relationship between physiological characteristics and temperature, specifically tolerance and thermal preference (De la Vega and Schilman, 2015).

In Mexico, the relationship between the debarking beetle abundance and temperature in pine forests has been studied (Hernández-Muñoz *et al*., 2017; Morales-Rangel *et al*., 2018). However, it is necessary to generate more evidence on the population response of these insects to various climatic variables in a single site.

There are few investigations in the country that relate the abundance of specimens with humidity, despite the fact that a strong dependence of various species of beetles with this factor has been verified abroad (Johansson *et al.,* 2017; Härkönen and Sorvari, 2018).

Furthermore, on many occasions, humidity influences the phenotypic expression of beetle coloration. It has been observed that in the presence of high relative humidity in the environment, beetles tend to show dark tones close to black in the exoskeleton (Rassart *et al.,* 2008; Noh *et al.,* 2016; Carrascal *et al*., 2017; Sun *et al.,* 2017). This is caused by a three-dimensional sponge-shaped porous structure located about 3 μm below the cuticular surface, which contains air in the pores, and when the insect is in conditions of high humidity, the air is replaced by water and causes a change of coloration towards dark tones (Noh *et al*., 2016).

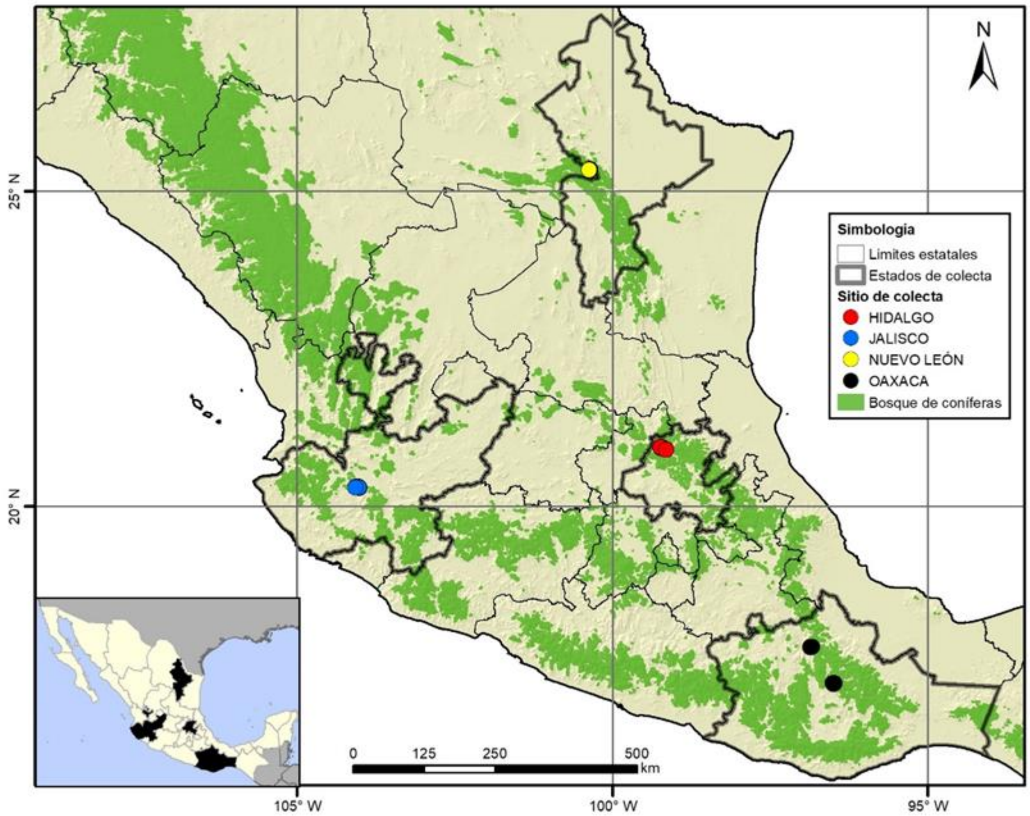
Climatic variability has effects on insects throughout their life history in physiological terms, such as the stage of development and diapause (De la Vega and Schilman, 2015). Extreme temperatures can be critical as they provoke insects to be unable to adaptively respond to any additional temperature changes and, therefore, will be vulnerable to predation, environmental catastrophes, or extremes of temperature (Byrne *et al.,* 2004). Critical temperatures for many species are unknown, but they are very interesting in ecological and evolutionary studies (Mitchell *et al*., 1993; Lighton and Turner, 2004).

Thus, this study analyzed the relationship between the variation in intensity of coloration of the exoskeleton of *Dendroctonus mexicanus* and the abundance associated with climatic variables such as humidity, temperature and aridity index that occur in four regions in which the species lives.

Materials and Methods

Location of sampling sites

In order to cover the natural distribution range of the pine-oak forest of Mexico, sampling of *D. mexicanus* was performed in four regions within the states of *Nuevo León* (1 950-2 650 masl), *Hidalgo* (1 342-2 611 masl), *Jalisco* (1 999-2 306 masl) and *Oaxaca* (2 113-2 889 masl) (Figure 1). Eight Lindgren Synergy Semiochemicals Corps™ insect collection traps composed of eight funnels, were placed in each region following an altitudinal transect between 1 300 and 2 900 m, which are areas suitable for the presence of barkers of the *Dendroctonus* genus.



Simbología = Simbology; *Límites estatales* = State boundaries; *Estados de colecta* = Collection states; *Sitios de colecta* = Collection sites; *Bosque de coníferas* = Conifer forest.

Figure 1. Location of *Dendroctonus mexicanus* Hopkins, 1905 collection sites within pine and pine-oak forests in the four states of Mexico.

The eight traps were placed with an altitude separation of 100 m between each one of them (Macías *et al*., 2004). The traps were installed in non-host trees, suspended 1.5 m from the ground (Rodríguez, 2009). At the top, the trap has an attractant that contains a pheromonal formula that is designed to attract *Dendroctonus* barkers such as *D. mexicanus*, which is a combination of semiochemicals (SQ's) from Synergy Semiochemical Corps™ (Macías-Sámano and Niño, 2016), which includes the Frontalina and Endo-brevicomina pheromones, plus alpha / beta-pinene as kairomona; the attractant was replaced every two months. In the lower part, the collection cup of each trap is accommodated, in which antifreeze was placed to sacrifice and facilitate the conservation of insects (Zylstra *et al.,* 2010). The collection of insects was carried out in periods of 15 days; they were subsequently kept into in Ziploc™-type bags. For the preservation of the collected individuals, a mixture of 50 % antifreeze and 70 % alcohol was used (Macías *et al*., 2004).

Monitoring of temperature (°C) and relative humidity (%) was evaluated using Hobos-type climate data collectors (EL-USB-2 RH/Micro DAQ™ Data Logger); climate data was recorded every 30 minutes for a one-year period (January-December 2015); with these numbers, the aridity index was calculated (Sáenz-Romero *et al.,* 2010; Soto-Correa *et al*., 2012). An adjustment was made to the aridity index which consisted of the ratio of the average temperature over the average relative humidity (temperature/humidity), in which the highest values are hotter places with less humidity, while the lower values refer to colder and wetter places.

Taxonomic identification of insects

The collection of insects was carried out from April to December 2015. The insects were transferred to the Ecology Laboratory of the Graduate School of Natural Sciences of the *Universidad Autónoma de Querétaro*, in the city of *Querétaro.* Subsequently, the barking beetles were cleaned and separated from other groups of insects. Identification of *Dendroctonus mexicanus* individuals and sexing was performed based on the criteria proposed by Wood (1982) and Cibrián *et al.* (1995).

Colorimetric intensity

A *D. mexicanus* random sample o was selected from the collections of each site within the gradients of each region; the specimens were mounted on entomological pins that were inserted into a 10 × 5 cm styrofoam platform (designed according to the available space of the microscope) lined with millimeter paper, always in the same position, at 20x magnification and under the same lighting; subsequently, they were placed in a Carl Zeiss™ stereoscope microscope and using the Z in 2 Blue edition (Zeiss, 2018) software, the illumination intensity readings of each color band (nm) (red, blue and green) were obtained, in the RGB18 model (Zeiss, 2018). The coloration was measured dorsally, from the head to half of the elytra.

Statistical design

To determine the possible significant differences in abundance, coloration between the four regions of the states of the Mexican republic and between sexes of barkers, an analysis of variance was used using the GLM procedure and Tukey tests (α = 0.05) with the SAS statistical package (9.3 version) (SAS, 2014)by the following formula:

$$Y_{ij} = \mu + R_i + S_j + R_i * S_j + e_{ij}$$

Where:

Y_{ijk} = Observation

μ= Effect of the general mean

R_i= Effect of the i–eth region of the state

S_j= Effect of the i–eth sex

R_i*S_j= Effect of the ij–eth interaction region of the State region of the state*Sex

e_{ij}= Error

To determine the possible relationship between moisture or humidity and staining intensity, a regression analysis was performed using the following model:

$$Y_{ij} = \beta_0 + \beta_1 X_i^2 + e_{ij}$$

Where:

$_{ij}$ = Mean of color intensity (color intensity per state)

β_0= Intercept

β_1= Slope

X_i = Moisture $(\%)^2$ or another climatic variable estimated of the *i*-*eth* provenance

e_{ij} = Error

Results

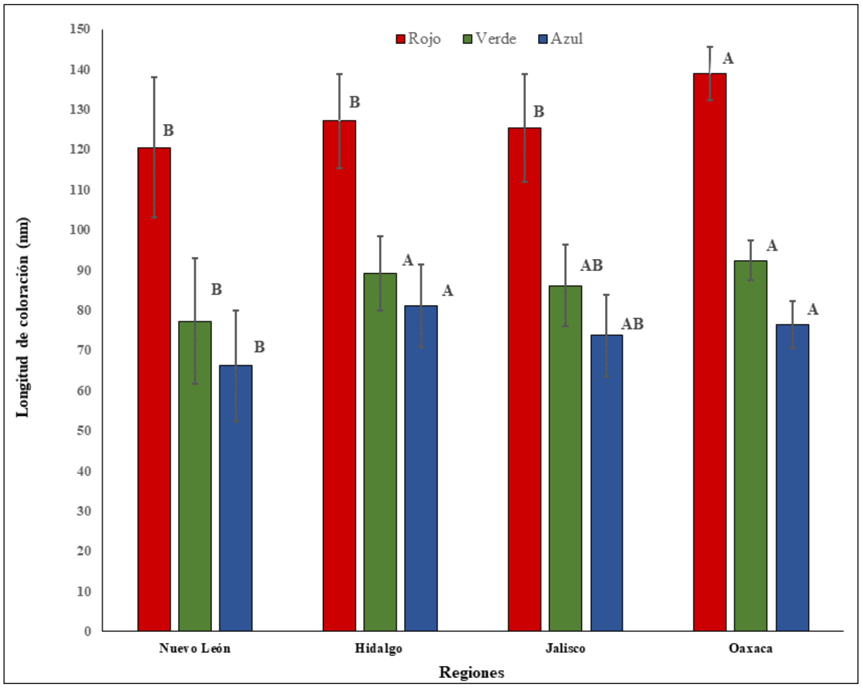
There are significant differences in the color intensity of the exoskeleton of *D. mexicanus* between the states (red P≤ 0.0004; green P ≤ 0.000, blue P ≤ 0.0014), contrary to what was found associated with the sex of the species where no significant statistical differences occurred, as well as for the Region * Sex interaction (Table 1).

Table 1. Analysis of variance of the intensity of color of the *Dendroctonus mexicanus* Hopkins, 1905 exoskeleton from four regions of Mexico.

F. V.	g. l.	Red	Green	Blue
		p≤0.05	p≤0.05	p≤0.05
Region	3	0.0004	0.0003	0.0014
Sex	1	0.6561	0.9467	0.1094
State*Sex	3	0.9461	0.1449	0.6514

F.V. = Variation factor; g.l. = Degrees of freedom.

The differences in the intensity of the red, green and blue bands of the exoskeleton of *D. mexicanus* show high values in individuals collected in the state of *Oaxaca* (red = 138; green = 92; blue = 76), which makes them darker in regard to the rest of the sites; it should be noted that a high similarity in coloration was determined with individuals from the state of *Jalisco*, which had similar values in green and blue bands (Figure 2). For the state of *Hidalgo*, it was observed that the blue band is similar to the localities of the states of *Jalisco* and *Oaxaca*; however, it was relatively different from the individuals from *Nuevo León*, which showed lower intensity values for the three color bands of the exoskeleton with lighter and redder individuals (red = 120; green = 77; blue = 66) (Figure 2).

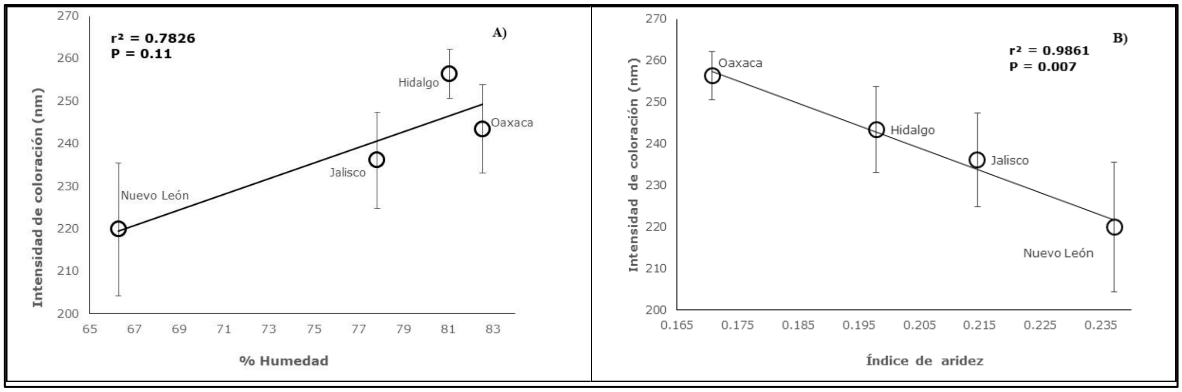


Longitud de coloración = Color length; *Regiones* = Regions; *Rojo* = Red; *Verde* = Green; *Azul* = Blue.

Figure 2. Tukey's mean test (α=0.5) for color length (red, green and blue) among the studied Mexican states.

The high pixel values for the three basic colors mean darker individuals like those observed in *Oaxaca* and the lower values, a lighter coloration like the specimens from the state of *Nuevo León*.

On the other hand, it was observed that there is a non-significant relationship between the percentage of humidity and color intensity of the species ($r^2 = 0.7826$; $p = 0.11$); it was estimated that in *Nuevo León,* the average environmental relative humidity is 66 %, a percentage lower than that of the states of *Hidalgo, Jalisco* and Oaxaca, and so, the insects have a lighter color. In *Hidalgo* and *Oaxaca*, the collected individuals have greater intensity where it is estimated that the average relative humidity was higher than 80 %; therefore, at higher relative humidity, specimens of *D. mexicanus* are darker (Figure 3, A).



Intensidad de coloración = Intensity of coloration; *Humedad* = Moisture; *Índice de aridez* = Aridity index.

A) Percentage of relative humidity; B) Aridity index.

Figure 3. Relationship between intensity of coloration of the exoskeleton of *Dendroctonus mexicanus* Hopkins, 1905 and climatic variables of the four sampling sites in Mexico.

Correlations between humidity and color intensity support the fact that humidity is an important environmental factor influencing changes in staining patterns of barking beetles. However, there is a relationship of greater precision when variables such as relative humidity and temperature are integrated into an aridity index ($r^2 = 0.9861$; $p = 0.007$); in this context, the darkest insects are those of the state of *Oaxaca* because the values of this index are lower than those of *Nuevo León* (Figure 3, B).

If moisture influences the intensity of coloration, it is also a determining factor that regulates the abundance of *D. mexicanus*. Under this reasoning, it can be affirmed that the northern regions of Mexico such as *Nuevo León* tend to present lower relative humidity, therefore, the response in the abundance of *D. mexicanus* would be less compared to southern regions such as *Oaxaca*, where high values of relative humidity and, consequently, of the abundance of the barkers are expected.

The regions with high relative humidity were *Hidalgo* and *Oaxaca*, while the opposite was registered in *Nuevo León*. For the first, there was a higher abundance of *D. mexicanus* (8 190 individuals) compared to the other three states whose average population was 2 000 total individuals during the sampling period (Table 2). The highest figure in the Hidalgo region may be the result of the combination of the different favorable climatic variables for the species of interest (average, maximum and minimum temperature, as well as average, maximum and minimum relative humidity) (Table 2).

Table 2. Tukey's multiple mean test (α = 0.05) of the climatic variables and total abundance of *Dendroctonus mexicanus* Hopkins, 1905 from the four states of Mexico.

State	***TMA*** **°C**	***Tukey***	***HMA*** **%**	***Tukey***	***TMIN*** **°C**	***Tukey***	***HMIN*** **%**	***Tukey***	***TMX*** **°C**	***Tukey***	***HMX*** **%**	***Tukey***	**Abundance** ***D. mexicanus***
Nuevo León	15.7	C	66.3	C	10.0	B	39.6	C	26.0	A	86.4	C	2 134
Hidalgo	16.3	B	82.5	A	12.6	A	66.1	A	22.3	C	92.7	B	8 190
Jalisco	16.7	A	77.8	B	12.3	A	53.1	B	24.0	B	94.1	A	1 731
Oaxaca	13.9	D	81.1	A	10.0	B	63.7	A	20.3	D	91.6	B	1 783

TMA = Annual mean *t*emperature; *HMA* = Annual mean humidity; *TMIN* = Minimal average *t*emperature; *HMIN* = Annual minimal humidity; *TMX* = Maximal mean temperature; *HMX* = Maximal mean humidity.

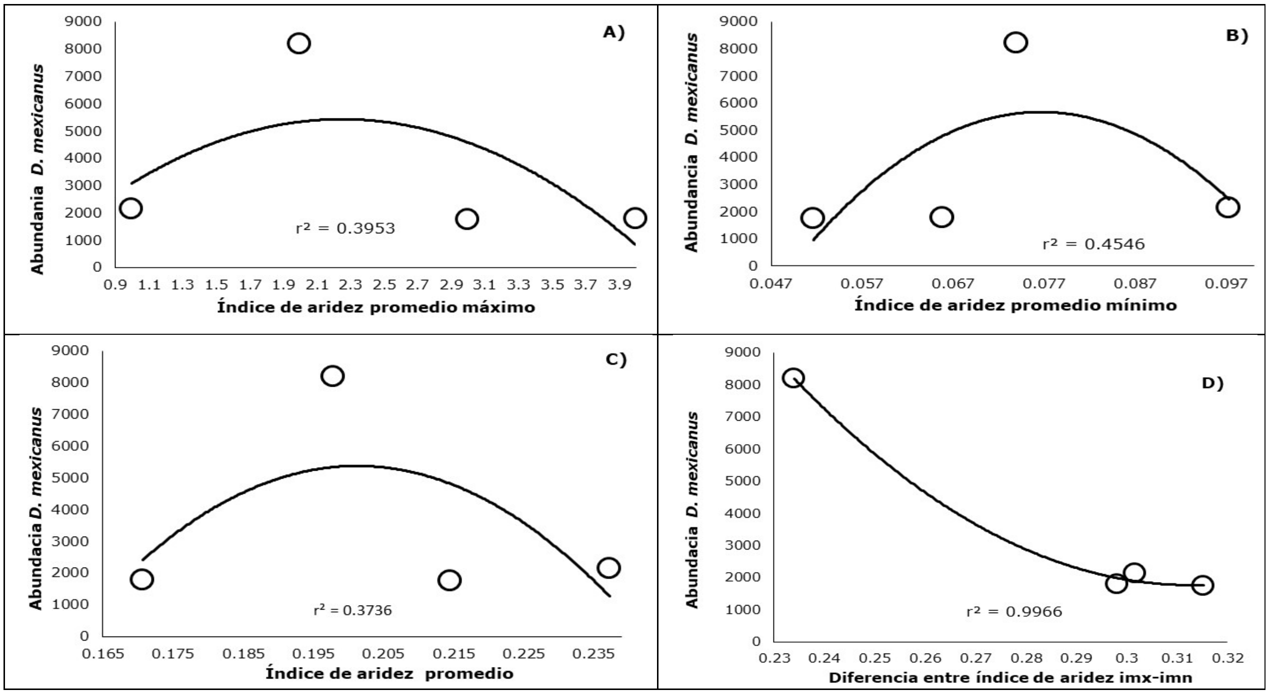
Particularly, in the present study, relative humidity and average temperature explain the behavior of *D. mexicanus* abundance in the four regions; for example, *Hidalgo* region has an average temperature of 16.3 °C and an average humidity of 82.5 %, which are similar to those of the *Jalisco* and *Nuevo León* sampling sites, but differ from the *Oaxaca* region (13.9 °C); on the contrary, the average relative humidity of *Hidalgo*, which is close to that of *Oaxaca*, but it is different for the of *Nuevo León* and *Jalisco* regions (66.3 and 77.8 % respectively) (Table 2).

The extremes of the temperature show significant differences between the sampling sites (P≤0.05) (Table 2). Although the maximum average temperatures suitable for the presence of high populations of debarkers occurred in the *Nuevo León* region, the minimum average humidity was very low for them (10 °C and 39.6 %), which is a limitation. When comparing *Oaxaca* to *Hidalgo*, there is a discrepancy of 2 °C less in *Oaxaca* in the mean temperatures and a difference of 2.6 °C in the minimum mean temperature, which may explain the abundance of *D. mexicanus*. This suggests that the existence of this barking beetle may be associated with extreme temperatures that are too high, and, in combination with extreme low temperatures, the abundance of this species is limited.

Regarding relative humidity, it is only in one direction, since the lower abundance of barking beetles is associated with lower humidity in the environment. The conditions that can lead to an increase in the *D. mexicanus* populations are mean temperatures near 16 °C with relative humidity around 80 %, with low variability in the maximum and minimum extremes of temperature with respect to the mean.

The analysis of temperature and humidity together in the aridity index facilitates the interpretation of the interaction between these variables regarding their influence on the abundance of barkers per site. The aridity averages within the *Hidalgo* region recorded an index of 0.20, similar to that estimated for the *Jalisco* and *Oaxaca* sites, but it differs from the *Nuevo León* site with a higher value (0.24).

On the other hand, it is observed that the maximum average aridity indexes for the regions of *Nuevo León, Jalisco* and *Oaxaca* reach values above 0.36, while for the region of *Hidalgo*, 0.30; this is indicative of a high probability that aridity indexes of maximum or greater value than 0.30 can limit the abundance of *D. mexicanus*. Unfortunately, there is no relationship between the insect abundance and the maximum average aridity index (r^2 = 0.39), abundance-minimum average aridity index (r^2 = 0.45) and abundance-average aridity index (r^2 = 0.37) (Figure 4, A, B, C). There is a relationship between the abundance and the variation between the maximum and minimum aridity indexes, the abundance of barking beetles being lower when the difference between the extremes is more pronounced; and, when the difference between the extremes of the aridity index was smaller, the average abundance was higher at the sampling sites (Figure 4, D).



Abundancia = Abundance; *Índice de aridez promedio máximo* = Maximum average aridity index; *Índice de aridez promedio mínimo* = Minimum average aridity index; Índice de aridez promedio = Average aridity index; *Diferencia entre índice de aridez imx-imn* = Difference between aridity index; imx = Maximum average aridity index; imn = Minimum average aridity index.

Figure 4. Total abundance of *Dendroctonus mexicanus* Hopkins, 1905 and average aridity index of four states in Mexico.

Discussion

The variation in the coloration of the exoskeleton of *D. mexicanus* individuals from the different regions of Mexico is a response to climatic variables such as humidity, which has been observed in other beetle species, in which the relative humidity of the environment is related with the coloration of the exoskeleton of such beetles (Rassart *et al*., 2008). This is explained by the structure of the exoskeleton that is porous, and the pores that contain water can be replaced by air, which, in turn, influences the variation in coloration of beetles (Carrascal *et al.,* 2017; Noh *et al.,* 2016). There is evidence on how environmental humidity influences color, such as the case of *Dynastes tityus* Linnaeus, 1763, which exhibits dark colors in the presence of high humidity percentages (≥ 80 %) (Rassart *et al*., 2008; Sun *et al*., 2017). With the above, it is possible to explain the estimate in the sites of *Hidalgo* and *Oaxaca*, where the highest relative humidity values (≥80 %) were present and the *D. mexicanus* individuals tend to be darker compared to those of the *Nuevo León* region, where clearer individuals were observed at lower relative humidity percentages than other sites in this study (66.3 %).

As relative humidity, temperature also assumes a direct relationship with the coloration intensity of the barker exoskeleton (Carrascal *et al*., 2017; Noh *et al*., 2016; Sun *et al*., 2017), as has been confirmed in *Chrysomela lapponica* Linnaeus, 1758 in which it was evident that darker colored beetles were associated at low temperatures and light colored ones at elevated temperatures; these differences imply an adaptive capacity of dark beetles due to their greater thermal capacity at low temperatures (Zverev *et al.,* 2018).

A direct relationship was identified between the intensity of coloration of the exoskeleton and the relative humidity; by integrating temperature and humidity in the aridity index, the ratio is adjusted even more, in an inversely proportional relationship in which, with greater intensity of color, the aridity index is lower. The regions with the highest humidity were *Hidalgo* and *Oaxaca*, where the tones of the beetles are darker.

A pattern of greater abundance of *D. mexicanus* was verified in places with high relative humidity; under this pattern, it was observed that the regions of *Oaxaca, Jalisco* and *Hidalgo* recorded more numerous populations of the barking beetles studied compared to the state of *Nuevo León*, whose values in this variable were lower, which coincides with other studies of beetles that also consume wood and that are favored by higher humidity (Johansson *et al.*, 2017; Härkönen and Sorvari, 2018). It should be noted that in the regions of *Oaxaca* and *Jalisco* a lower abundance was recorded with high percentages of humidity, which contradicts the previous assumption; however, this can be explained by the extreme temperatures, which is evident in ectodermal species since these variables influence many of their physiological processes (Fields *et al.,* 1992; Chown and Nicolson, 2004; Fields *et al*., 2012; De la Vega *et al.,* 2015).

The average temperature recorded in the *Hidalgo* region (16.3 °C), is associated with a greater abundance of insects; in other studies, it is corroborated that a high abundance of *D. mexicanus* occurs in sites whose average temperatures are close to 16 °C (Hernández-Muñoz *et al.*, 2017; Morales-Rangel *et al.,* 2018), which also has been recorded for *D. frontalis* Zimmerman, 1868 (Soto-Correa *et al.,* 2019). Other research also highlights the complexity of insect responses to thermal variability (Chidawanyika *et al.,* 2017). For example, extreme events in minimum temperatures are the limiting variables (Fields, 1992; De la Vega *et al*., 2015) and their variability may be the response to what happened in regions such as *Hidalgo* and *Oaxaca*, where a greater abundance of debarkers in these regions with a high relative humidity in the environment and stable average temperatures. In previous works, this link has also been estimated of a lower abundance of some beetles in extreme fluctuating temperatures (Jian *et al.,* 2018).

Oaxaca registered a minimum average temperature of 13.9 °C with a lower difference of 2.6 °C compared to the *Hidalgo* site; this difference in the minimum temperature may explain the discrepancy in the beetles' abundance between these sites, as observed in other insect studies in which the lethal temperature begins at 13 °C and below (Fields *et al*., 2012). In the United States of America, minimum temperatures are considered the determining environmental factor for the exponential presence of debarkers (Buotte *et al*., 2017).

In the *Nuevo León* region, the prevailing environmental conditions may be unfavorable for a larger population of *D. mexicanus*, with low average humidity and wide variation in extreme temperatures (39.6 % maximum on average and 10 °C minimum on average). In regard to the variation of extreme temperatures in the *Nuevo León* site, the difference was up to 4 °C between the average maximum and minimum temperatures in relation to the site in the *Hidalgo* region, where the greatest abundance of bark insects in the present study. The maximum average temperature becomes a determining factor in controlling the abundance of *D. mexicanus*, which may be a consequence of the extremely high average temperatures causing the drying of the tissues and the eventual death of insects (De la Vega and Schilman, 2015). The extremes in temperatures limit the abundance of insects because they are ectotherms (Chown and Nicolson, 2004; De la Vega and Schilman, 2015).

The proliferation of *D. mexicanus* is associated with high humidity, which has been explained in various laboratory studies with other beetles, since it has been recorded that high relative humidity avoids mortality due to dehydration (Noh *et al*., 2015).

On the other hand, in the *Hidalgo* region variable climatic parameters were registered that favored a greater abundance of the beetles of interest, such as average temperatures around 16 °C (Hernández-Muñoz *et al*., 2017; Morales-Rangel *et al*., 2018; Soto-Correa *et al*., 2019) and humidity of 80 %, with little variation in average minimum and maximum temperatures.

The aridity index is useful to observe and interpret how the variables temperature and humidity interact with respect to the abundance of *D. mexicanus.* Ectothermic species such as beetles are usually related to water balance and thermal balance, factors that influence a greater or lesser abundance of insects (Chown and Nicolson, 2004). On the other hand, it was possible to estimate a relationship between the abundance of *D. mexicanus* and the difference between the minimum and maximum average aridity indices, where there is a greater abundance of these insects when the difference between the two indexes is less, as has been observed in studies with temperature differences (Jian *et al*., 2018). The present study may be of great importance since it generates evidence that associated climatic factors determine the abundance of debarking populations within the evaluated forests and not only that dry conditions at the site can increase the abundance of the populations, as estimated in studies of the population dynamics of this type of barking beetle, in addition to the fact the humidity has a lot of influence in the coloration.

Conclusions

There is variation in the intensity of the coloration in the exoskeleton *D. mexicanus b*etween individuals from the regions of *Nuevo León* and *Oaxaca*, where it is observed that there are individuals with a darker coloration in regions with higher humidity, such as *Oaxaca*, and a less coloration. It is dark in the region with less humidity as *Nuevo León*.

The abundance of *D. mexicanus* is limited by climatic variables such as the occurrence of low humidity, extreme minimum and maximum temperatures, as well as the difference between the maximum and minimum aridity index.

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Conflict of interests

The authors of this article have no conflict of interest to carry out the study, write the manuscript or evaluate it.

Contribution by author

José Carmen Soto Correa: statistical analysis, writing of the manuscript; Dioselin Girón Gutiérrez: collection and evaluation of abundance of bark insects, estimation of insect colorimetry; Víctor Hugo Cambrón Sandoval: statistical analysis.

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