

Uso del paisaje por una colonia de maternidad de murciélagos mexicanos de cola libre (*Tadarida brasiliensis*) en el norte de Sinaloa, México.

Landscape use by a maternity colony of mexican free-tailed bats (*Tadarida brasiliensis*) in the north of Sinaloa, Mexico.

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Resumen

La disponibilidad de presas de las cuales se alimenta *T. brasiliensis* (p. ej., polillas y otros insectos) depende de la productividad vegetal. En este estudio, considerando que la vegetación que se encuentra alrededor de la colonia de maternidad es variada: i) se utilizó el Índice de Vegetación de Diferencia Normalizada (NDVI por sus siglas en inglés) para determinar la productividad de toda la cobertura vegetal alrededor de la colonia de murciélagos, y ii) se relacionó la productividad de la vegetación con los parámetros poblacionales de la colonia de maternidad de *T. brasiliensis*. Los modelos demostraron que existe una relación significativa entre las hembras lactantes de la época reproductiva 2015 y el bosque tropical seco (BTS). La explosión productiva en el BTS coincide con la mayor demanda energética de las hembras lactantes, lo que sugiere que las presas son abundantes. Estudios posteriores con más detalles contribuirán a definir el efecto de los depredadores sobre los hábitats silvestres y la posterior transición de este a los hábitats agrícolas.

Palabras clave: NDVI, Migración, Noroeste de México, agroecosistemas.

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Abstract

The availability of the feeding sources for *T. brasiliensis* (e.g., moths and other insects) depends on vegetable productivity. Considering the established vegetation around the maternity colony is varied, in this study: i) NDVI was used to determine the productivity of all the vegetation coverage of the bat colony, and ii) the vegetation productivity was related to the populational parameters of the maternity colony of *T. brasiliensis*. The models showed a significant relationship between the number of lactating females in the reproductive season 2015 and the tropical dry forest (TDF). The productivity explosion in the TDF coincides with the higher energetic demand of the lactating females, which suggests that preys are abundant. Future, more detailed studies will contribute to specifying the predators effect on the wild habitats and the subsequent transition to the agricultural habitats.

Keywords: NDVI, Migration, Northwest of Mexico, agroecosystems.

Introduction

The order Chiroptera comprises almost 25% of the living species of mammals. It is one of the oldest, most diverse, cosmopolitan, and highly ecologically relevant groups of vertebrates (Banerjee et al. 2019; Hutson and Mickleburgh, 2001). Bats have developed both morphological and physiological adaptations (such as the ability to fly and echolocation) that lead them to selectively fix different eating behaviors (as insectivores, frugivores, nectarivores, carnivores, and hematophagous) and, of course, to be nocturnal animals (Wilson et al. 1996).

From different perspectives, bats have been present in human activities throughout a significant part of our history. For example, they have been artistical and ritual inspiration in many cultures, and in some regions of the world, they are included in the human diet (Kasso and Balakrishnan, 2013; Sieradzki and Mikkola, 2022; Villa and Canela, 1988). Agriculturally, their feces (guano) are used as a natural fertilizer. Additionally, in the pharmaceutical industry, it is suggested that desmoteplase (a molecule obtained from a hematophagous bat species) could be used as an antithrombotic agent (Gallant et al. 2020; Low et al. 2021; Mickleburgh et al. 2009; Schleuning, 2001). However, the most relevant contributions of bats are observed in the ecosystem since they contribute to the control of populations of insects, dispersal of seeds, and pollination of an

important diversity of plant species (Boyles et al. 2011; Kunz et al. 2011). When migratory species contribute in this way, a large amount of energy, nutrients, and pathogens are transferred in a widescale among different ecosystems where they develop each part of their life cycle (Fleming, 2019).

Of all the existing bat species, only a small proportion performs migratory movements (Fleming et al. 2003). Thus, only 87 species belonging to 10 different families perform regional movements or long-distance migrations (Fleming, 2019; Krauel and McCracken, 2013; Welbergen et al. 2020). This behavior could be differentiated among bat populations, which show certain plasticity in the proportion of individuals that will seek winter shelter, or they will get dispersed regionally in a way that their departure coincides with better environmental conditions (Bisson et al. 2009, Jonasson, 2017; Russell et al. 2005).

According to Baker (1978), this differentiation is known as facultative and forced migration. In the first situation, individuals are sensitive to specific local changes in resource availability. In the second situation, they are less sensitive to these changes, and most individuals will migrate even though this availability is still present (Krauel and McCracken, 2013).

The particularities of the bat's biological cycle (e.g., reproduction, hibernation, latitudinal and altitudinal migrations) are strongly shaped by the environmental conditions and resource availability (Barclay, 2012; Burles et al. 2009; Frick et al. 2010; Jonasson and Guglielmo, 2019; Racey et al. 1982). For example, the reproductive stages of most of the bat species are shaped by the rainfall season since this induces the abundance of the necessary resources to obtain the energy of the reproductive stage (Hoying and Kunz, 1998; Hutson and Mickleburgh, 2001). These conditions allow the female to provide parental care to the offspring until they achieve their first flight or until their flying and foraging skills are developed enough (Kohles et al. 2018; Kunz and Hood, 2000). However, the reproductive stage duration could vary among the members of the same bats family, even between the same genera at the same latitude (Racey et al. 1982). Mexican free-tailed bats (*Tadarida brasiliensis* Geoffroy Saint-Hilaire, 1824) are a classic example of a facultative migratory species, sensitive to local variations (e.g., availability of resources). Their population can develop wide variations on their migratory behavior, sexual segregation, distance per movement, and direction with a wide variation between them (Krauel and McCracken, 2013). Furthermore, partial migration has been described in this species, in which some populations are sedentary while others are migratory (Fleming, 2019). *T. brasiliensis* is broadly distributed throughout the

American continent, from the USA, Mexico, and Central America up to South America, including Brazil, Chile, and Argentina (Gannon et al. 2005; Nabte et al. 2016; Wilkins, 1989).

This species shows a general migratory pattern: the North American populations spend winter in central Mexico and successively move to the north of Mexico and the south of the United States during summer (Kunz et al. 1995; McCracken and Gassel, 1997) to mate and find shelter in caves, abandoned mines, bridges, and different types of constructions offering stable and secure conditions (Kunz, 1982; Wilkins, 1989).

Foraging of this species begins at sunset and is performed during the night until sunrise, covering about 400 km² (Lee and McCracken, 2005). As a generalist predator, the *T. brasiliensis* diet includes a great variety of insects (11 orders and 38 families), of which abundance and availability vary widely between seasons (Kunz et al. 1995; McCracken et al. 2008; McWilliams, 2005).

During the reproductive season of *T. brasiliensis*, reproductive females (pregnant and breastfeeding) cover their high energetic demand (30 - 60 %), consuming mainly nocturnal butterflies (5 to 10 adults per night); In non-reproductive females and males, this rate is lower at 32 % (Cleveland et al. 2006; Federico et al. 2008; McCracken et al. 2012; Lee and McCracken, 2005).

The presence of Lepidoptera in the *T. brasiliensis* diet (a plague insect well known in agriculture) suggests that this bat could be an important ally in agriculture as plague control since they can modulate the population growth of potentially damaging insects to diverse crops, like corn (McCracken et al. 2012; Tuttle and Moreno, 2005).

If nocturnal butterflies become a plague on agriculture, 1.5 females of *T. brasiliensis* would prevent the presence of 5 larvae, reducing the crops damage (Cleveland et al. 2006; Sansone and Smith, 2001). This ecosystem service occurs for various types of plague insects, crops, and agroecosystems, and it is provided by insectivore bats (which are most of the chiropteran species) worldwide.

The abundance of prey (clothes moths) is modulated by the rainy season in the Northeast of Mexico (Krauel et al. 2015). In Sinaloa State, the reproductive season of the *T. brasiliensis* and the commercial agricultural season do not converge. However, this and other bat species exploit the available insect species in their natural habitat (Gillespie et al. 1944). In this case, the tropical dry forest (TDF), once the dominant vegetation of the actual extended agroecosystems of maize and the current source of feeding for insectivorous bats, which is complemented with the TDF patches distributed along the landscape.

Among several vegetation indices (De Pauw et al. 2021; Wan et al. 2018; Wang et al. 2004), the most accepted for the analysis of the recuperation of the vegetation cover is the Normalized Difference Vegetation Index (NDVI; Huete, 1997; Juang et al. 2006). Even though this index is very useful in ecology, its most significant benefit comes from yielding access to the primary production dynamics at a large scale through time (Pettorelli et al. 2011).

High values of NDVI have been correlated with the abundance of insects and birds (Bailey et al. 2004). Pettorelli et al. (2011) contemplated that the temporal resolution of the NDVI helps to study the movement of the fauna since the information about the vegetation productivity could be linked to the data of the location of the individuals simultaneously.

Since food sources (e.g., moths and other insects) inside the maternal colony shelter depend on the productivity of the vegetation outside the shelter, i) the NDVI was used to determine the productivity of all the vegetation types around the colony of bats, and ii) the vegetation productivity was related with population parameters of the maternity colony of *T. brasiliensis* during the most significant environmental stress season of the vegetation and its implication for insects abundance.

Materials and methods

Study area

This fieldwork was performed in the northern region of the state of Sinaloa, Mexico (25°48'53" N and 109°1'32" W), in 100 km radius surrounding the *T. brasiliensis* maternity colony, which is located at Cueva de El Maviri in ejido Topo Viejo, Ahome. This natural cave is protected as a municipal sanctuary for the protection of bats (Gobierno del Estado de Sinaloa, 2003), also is part of the Gulf of California Islands federal wildlife protection area (Presidencia de la República, 1978; CONANP, 2000), located north of the Port of Topolobampo, Ahome, Sinaloa (Figure 1). This region includes different habitats, from the coastal line towards the maize cropland in the communities of Chinobampo, San Lazaro, Capomos, and Las Chunas, all belonging to the municipality of El Fuerte (Table 1). All the sites were included to describe the community of insectivore bats (particularly the presence of the *T. brasiliensis*) and complement the field work developing bat acoustic monitoring and evaluating and characterizing insect crop damage.

Individuals were captured during sunrise when the bats returned from the foraging journey to the diurnal roost, which hosts around 250,000 specimens (Wiederholt et al. 2013). The bats

were captured using a nylon mist net of 3 x 2.4 m and kept separated in clean cloth bags during a time capture effort of 1 hour. All the specimens were processed by taking their morphometric measures (weight and tarsus), age, gender, and reproductive state (females: Non-Reproductive (NR), Pregnant (P), Breast Feeding (L) and Post Breast Feeding (PL); males: Non-Reproductive (NR) or Reproductive (E)). Immediately after being processed, we released them in situ. Twenty-nine captures were made by sampling two mornings every month during the reproductive season of 2015 (June to October) since this is the period of major activity of *T. brasiliensis* in the region. The captured individuals, handling, registries, and samples are under the SGPA/DGVS /02567/15 collection permit.

Climatic Data

We used the climatic information available from 22 meteorologic stations from the region (Table 1) to characterize the precipitation patterns in the study area, which were obtained from an online platform (<http://localhost/system-clima/schubert>) belonging to the Research Center for Nutrition and Development (CIAD, Unit Culiacán). These stations cover six municipalities from the north of Sinaloa State (Ahome, Angostura, El Fuerte, Guasave, Mocorito, and Sinaloa de Leyva).

Vegetation Productivity

The vegetation productivity was calculated using the Normalized Difference Vegetation Index (NDVI) using the following array: $NIR-RED/NIR+RED$, where NIR is the close infrared wavelength, RED is the visible infrared wavelength captured by the satellite sensor.

The images MOD13Q1 (Moderate Resolution Imaging Spectroradiometer MODIS) for the estimation of the NDVI were obtained from the webpage of the National Aeronautics and Space Administration (NASA, search.earthdata.nasa.gov). These images included a composition of 16 days with a spatial resolution of 250 m, one atmospheric correction, and one at the ground level.

The computational remote platform Google Earth Engine (GEE) was used to process MOD13Q1-NDVI. The data from the NDVI from May to October 2015 (12 layers) were downloaded. MOD13Q1 was reprojected out of a sinusoid projection to WGS84 UTM 12 N.

The series of V ground coverage was uploaded to the GEE provided by INEGI (the National Institute for Statistics and Geography from Mexico) to extract the NDVI from all the types of coverage inside a buffer of 120 kms around the maternity colony of bats. Afterwards, the values

for NDVI were extracted for the vegetation coverage. The most common types of vegetation from the region were selected, which include mangrove, tropical dry forest, irrigation agriculture, seasonal agriculture, halophytic vegetation, tropical dry forest secondary vegetation, and scrub. The pixel values of the NDVI for each coverage (each 16 days) were calculated, and the median values were calculated in Excel Software (Microsoft). The NDVI values were processed to identify correlations with climate and productivity.

Statistical Analysis

The relationship between reproductive phenology and environmental conditions was analyzed using a generalized linear model (GLM), where the response variable (y) is the proportion of breastfeeding females and weather (accumulated precipitation and maximum temperature), and vegetation type (mangrove swamps, tropical dry forest, irrigation agriculture, seasonal agriculture, halophytic vegetation, tropical dry forest secondary vegetation and scrub) are the predicting variables in the model. The generalized linear models used the approximation of penalized quasi-likelihood (link to a quasi-distribution and identity) (Crawley, 2007; Faraway, 2005). The analysis was performed in the software R (2017) using the MASS package (Ripley et al. 2016). ANOVA was used to compare and select between the models including all the variables and interactions between the predicting variables (Crawley, 2007).

Results and discussion

The models indicate a significant relationship between the breastfeeding females from the reproductive season 2015 and the productivity of the dry tropical forest. Likewise, a negative relation with the productivity obtained in that period in the mangrove, irrigation agriculture, and the thorny scrub distributed in a radius of 100 effective km of foraging for the *T. brasiliensis* females (Table 1).

Table 1. Relationship between the proportion of lactating females of *T. brasiliensis* and the productivity of the different types of vegetation in northern Sinaloa, Mexico.

| | β | <i>t</i> | <i>P</i> |
|---------------------|---------|----------|----------|
| Intercept | 9.909 | 6.948 | 0.002 |
| Mangrove | -12.342 | -7.221 | 0.001 |
| I. Agriculture | -9.004 | -5.067 | 0.007 |
| Shrub | -3.830 | -3.223 | 0.032 |
| Tropical Dry Forest | 8.743 | 15.514 | <0.001 |

The GLMs also indicated a significant relationship between the proportion of male bats in the maternity colony and the productivity of the irrigation agricultural fields and accumulated rainfall (Table 2). Similarly, the scrub productivity and the halophile vegetation present a significant relationship with the estimated abundance of *T. brasiliensis* (Table 3).

Table 2. Relationship between the proportion of male *T. brasiliensis* and the productivity of irrigated agricultural fields and accumulated rainfall.

| | β | t | P |
|---------------------------|--------------|--------------|--------------|
| Intercept | -3.089 | -3.907 | 0.005 |
| I. Agriculture | 7.382 | 3.863 | 0.006 |
| Accumulated precipitation | 0.004 | 3.129 | 0.016 |

Table 3. Relationship between the abundance of *T. brasiliensis* in the maternity colony of El Maviri, Sinaloa and the productivity of the scrub and halophytic vegetation.

| | β | t | P |
|-----------------------|--------------|--------------|--------------|
| Intercept | -3.089 | -3.907 | 0.005 |
| Shrub | 7.382 | 3.863 | 0.006 |
| Halophilic vegetation | 0.004 | 3.129 | 0.016 |

In this study, several phenological characteristics of the *T. brasiliensis* maternity colony were related with the productivity of the different vegetation types that surround the foraging range of the individuals that use that site. Our results suggest that the productivity of the surrounding landscape vegetation is closely related to three characteristic variables in a bat maternity colony: the proportion of lactating females (in the reproductive state), the proportion of present males (gender), and the abundance of individuals. A possible explanation for the positive relationship between breastfeeding females and the tropical dry forest is two-fold: a) the maximum energetic demand increase between breastfeeding and the weaning stage (Barclay, 1989; Kunz, 1974), which motivates the females to find food sources, and b) its synchrony with the summer rains (during the monsoon season) falling in the tropical dry forest, fostering the productivity in the forest and the subsequent abundance of preys (e.g. Lepidoptera; Bailey et al. 2004; Marimuth, 1996).

The tropical dry forest has a higher relevance for the reproductive colony than other components of the studied landscape. This suggests the most critical foraging habitat, even before its productivity peak. This is probably since the Sinaloa tropical dry forest is the largest extension of the tropical dry forest in Mexico and one of the five largest eco-regions in America (Portillo-Quintero and Sánchez-Azofeifa, 2010).

In the last half of the century at the State of Sinaloa, vast extensions of the forest were transformed into large agricultural projects with irrigation systems (Gallardo et al. 2006; González-Medina et al. 2009). Due to irrigation agriculture, this large extension of landscape has high seasonal variations in the NDVI (Leveau et al. 2018), imputable to the loss in most of the vegetative coverage in the harvest, which is fundamental for the presence and survival of insects like the fall armyworm (*Spodoptera frugiperda*; Huang et al. 2020). The lowest productivity levels for irrigation agriculture coincide with the highest energetic demand of the females breastfeeding their young.

Our study suggests a negative relationship between the mangrove, irrigation agriculture, and the scrub with the breastfeeding female bats in the maternity colony. This ratio reflects the homogeneity of the productivity in this type of vegetation. The mangrove extension in the lagoon systems near the maternity colony does provide an important number of preys to the female bats in their maximum peak of caloric demand due to the breastfeeding. Even though their high productivity and the intermedium diversity of Lepidoptera (Hassan et al. 2021; Yeo et al. 2021), despite their theoretically high productivity, the lagoon systems and its mangrove found within the foraging range are not home to populations of insects with a high impact on the *T. brasiliensis* diet.

In that same sense, one of the most extensive landscape elements is thorn scrubs. The foraging range of the maternity colony of *T. brasiliensis* is nestled in a wide extension of the south borderline of the Sonora Desert (Búrquez et al. 1999), which exhibits productivity parameters highly linked to the rainfall (Méndez-Barroso et al. 2014), neither rainfall regime nor the thorn scrub vegetation productivity overlaps on the high energetic demand of the lactating bats from the Maviri maternity colony.

The presence of male adults in a maternity colony is expected since the males are looking for reproductive opportunities before and after the maternity colonies are established (French and Lollar, 1998), with sexually active males in September and October in colonies of Texas (Scales and Wilkins, 2007) coinciding with the observed in El Maviri. The abundance of males increased when the rainfall levels reached their maximum. This could be related to the Lepidoptera migration in the summer and its importance as a prey (Krauel et al. 2018; Russel et al. 2005), responding to the productivity increase in the agricultural irrigation zones surrounding the maternity colony (280,000 hectares; Ibanez Castillo and Chávez Morales, 1990; Nboyine et al. 2020).

The halophilic vegetation and the scrub are the landscape elements supporting the largest number of individuals that the maternity colony accommodated during our study. Landscape

productivity shapes the presence of insects that bats include on their diet (Lee and McCracken, 2002). Both vegetation types are abundant in the cave contiguity with the scrubs highly linked to the rainfall (Méndez-Barroso et al. 2014) and with the halophile vegetation that, even though does not tend to be very abundant, it presents a relevant productivity (Pérez González and García Rodríguez, 2005). Both types of vegetation support high abundance coinciding with the rainfall and the scrubs response and with the constant abundance of insects in the halophile vegetation (Mouhoubi et al. 2019). Hence, the high abundance of individuals matches with the first summer rainfalls and the first pups exploring the landscape to learn how to forage (Allen et al. 2010; Cumming and Bernard, 1997; Lee and McCracken 2002; Russell et al. 2005).

Conclusions

This work seeks to contribute to understanding the phenology of a maternity colony of insectivore bats in the landscape of northern Sinaloa. This region is characterized by nestled noticeable agroecosystems, standing out large technified extensions (irrigation agriculture, mainly maize, in small proportion potato, sugarcane, leafy vegetables, among others) and the resilience of those who still plant (beans, squash, watermelon, melons, cucumbers, sesame seeds, and mainly maize) depending on the seasonal rainfall.

Some potentially damaging populations of insects, like some lepidopterous species which larvae find in the commercial corn one of its most essential burrows, susceptible and attacked (Blanco et al. 2014; Casmuz et al. 2010, García-Gutiérrez et al. 2012; González Maldonado et al. 2015; Rangel et al. 2014; Sena Jr. et al. 2003), are also naturally distributed in the agroecosystems of seasonal maize (Delfín-González et al. 2007; Hernández-Mendoza et al. 2008). In the northern latitudes, the origin of the Lepidoptera population that attacks the maize crops is clear (Westbrook, 2008; Westbrook et al. 2016), but wild population samples are required to determine its segregation (Nagoshi et al. 2015). These species and their effects in the fall and winter agricultural seasons (Cortez-Mondaca et al. 2012) are well established. However, since we do not know the seasonality (in Sinaloa) of its reproductive cycle (Cruz-Esteban et al. 2017), the ecosystem service effect of the maternity colony of *T. brasiliensis* is unclear. In this sense, the plant species in the surrounding ecosystems, remaining species extensively harvested (e.g., maize), and other agricultural species that are not typical burrows should be described in the ecological context and the cycle of life of the insects that tend to become plagues (Malo and Hore, 2020; Montezano et al. 2018).

The native maize plants start developing in the agricultural ecosystems of seasonal harvest at the same time as the beginning of the rainfall season. This makes them vulnerable to the populations of plague insects. This type of agriculture depends totally on the rainfall season and generally are developed in the TDF, an agroecosystem shaped by the phenology of the wild organisms that form it (weeds, insects, and some vertebrates such as birds and mammals; Altieri and Letourneau, 1982; Altieri and Trujillo, 1987; Leal-Sandoval et al. 2020; Mayamba et al. 2021; Peisley et al. 2015; Perfecto and Vandermeer, 2008; Tooker et al. 2020).

Even though the scope of our study is limited, and the direct effect of the insect population cannot be established, our results do suggest *T. brasiliensis* diet includes various species of Lepidoptera, which can be harmful to agriculture (Cleveland et al. 20026; Federico et al. 2008; Krauel et al. 2018; Lee and McCracken, 2005). The productivity explosion in the TDF coincides with the highest energetic demand of breastfeeding females, which suggests that the preys are abundant in it.

Further studies will contribute to understanding the predators' effect on the fall and winter agricultural seasons in the wild habitats and the subsequent transition to the agricultural habitats. The complexity of this process highlights the relevance of the ecosystem services. It demands the preservation and study of the bat community, which influences in some way the abundance and incidence of plague insects in agricultural valleys at a landscape scale.

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References

- Allen, L.C., Richardson, C.S., McCracken, G.F., and Kunz, T.H. 2010. *Birth size and postnatal growth in cave-and bridge-roosting Brazilian free-tailed bats*. Journal of Zoology 280: 8-16.
- Altieri, M.A., and Letourneau, D. K. 1982. *Vegetation management and biological control in agroecosystems*. Journal of Crop Protection 1: 405-430.

- Altieri, M.A., and Trujillo, J. 1987. *The Agroecology of Corn Production in Tlaxcala, Mexico*. Human Ecology 15: 189-220.
- Bailey, S.A., Horner-Devine, M.C., Luck, G., Moore, L.A., Carney, K.M., Anderson, S., Betrus, C., and Fleishman, E. 2004. *Primary productivity and species richness: relationships among functional guilds, residency groups and specie vagility classes at multiple spatial scales*. Ecography 27: 207-217.
- Baker, R.R. 1978. *The evolutionary ecology of animal migration*. Holmes & Meier Publishers, New York, USA. 1102 pp.
- Barclay, R.M.R. 1989. *The effect of reproductive condition on the foraging behavior of female hoary bats, Lasiurus cinereus*. Behavioral Ecology and Sociobiology 24: 31-37.
- Barclay, R.M.R. 2012. *Variable variation: annual and seasonal changes in offspring sex ratio in a bat*. PLoS One 7(5): e36344.
- Banerjee, A., Kulcsar, K., Misra, V., Frieman, M., and Mossman, K. 2019. *Bats and coronaviruses*. Viruses 11: 1-25.
- Bisson, I.A., Safi, K., and Holland, R.A. 2009. *Evidence for repeated independent evolution of migration in the largest family of bats*. PLoS One, 4 (10): e7504.
- Blanco, C.A., J.G. Pellegaud, U. Nava-Camberos, D. Lugo-Barrera, P. Vega Aquino, J. Coello, A.P. Terán-Vargas, and J. Vargas-Camplis. 2014. *Maize pests in Mexico and challenges for the adoption of integrated pest management programs*. Journal of Integrated Pest Management 5: 1-9.
- Boyles, J.G., Cryan, P.M., McCracken, G.F., and Kunz, T.H. 2011. *Economic importance of bats in agriculture*. Science 332: 41-42.
- Burles, D.W., Brigham, R.M., Ring, R.A., and Reimchen, T. E. 2009. *Influence of weather on two insectivorous bats in a temperate Pacific Northwest rainforest*. Canadian Journal of Zoology 87: 132-138.
- Búrquez, A., Martínez-Yrizar, A., Felger, R. S., and Yetman, D. 1999. *Vegetation and habitat diversity at the southern edge of the Sonoran Desert. Ecology of Sonoran Desert plants and plant communities*. 36-67. In: Robichaux, R. H. 1999. Ecology of Sonoran Desert plants and plant communities. University of Arizona Press. Tucson, USA. 295 pp.
- Casmuz, A, Juárez, M.L., Socías, M.G., Murúa, M.G., Prieto, S., Medina, S., Willink, E., and Gastaminza, G. 2010. *Revisión de los hospederos del gusano cogollero del maíz, Spodoptera frugiperda Lepidoptera: Noctuidae*. Revista de la Sociedad Entomológica Argentina 69: 209-231.

- Cleveland, C.J., Betke, M., Federico, P., Frank, J.D., Hallam, T.G., Horn, J., López Jr, J.D., McCracken, G.F., Medellín, R.A., and Moreno-Valdez, A., et al. 2006. *Economic value of the pest control service provided by Brazilian free tailed bats in south-central Texas*. *Frontiers in Ecology and the Environment* 4: 238-243.
- CONANP - Comisión Nacional de Áreas Naturales Protegidas. 2000. Programa de Manejo del Área de Protección de Flora y Fauna Islas del Golfo de California. México. SEMARNAP.
- Cortez-Mondaca, E., Pérez-Márquez, J., and Bahena-Juárez, F. 2012. *Control biológico natural de gusano cogollero 1 Lepidoptera: Noctuidae en maíz y en sorgo, en el norte de Sinaloa, México*. *Southwest Entomology* 37: 423-428.
- Crawley, M.J. 2007 *The R Book*. John Wiley, New York, USA.
- Cruz-Esteban, S., Rojas, J.C., and Malo, E.A. 2017. *Calling behavior, copulation time, and reproductive compatibility of corn-strain fall armyworm Lepidoptera: Noctuidae from populations in Mexico*. *Environmental Entomology* 46: 901-906.
- Cumming, G.S., and Bernard, R.T.F. 1997. *Rainfall, food abundance and timing of parturition in African bats*. *Oecologia* 111: 309-317.
- De Pauw, K., Meeussen, C., Govaert, S., Sanczuk, P., Vanneste, T., Bernhardt-Römermann, M., Bollmann, K., Calders, K., and Cousins, S. A. O., M., Hedwall, P., Iacopetti, G., Lenoir, J., Lindmo, S., Orczewska, A., Ponette, Q., Plue, Jan., Selvi, F., Spicher, F., Verbeeck, H., Vermeir, P., Zellweger, F., Verheyen, K., Vangansbeke, P., and De Frenne, P. 2021. *Taxonomic, phylogenetic and functional diversity of understorey plants respond differently to environmental conditions in European forest edges*. *Journal of Ecology* 109: 2629-2648.
- Delfín-González, H., Bojórquez-Acevedo, M., and Manrique-Saide, P. 2007. *Parasitoids of fall armyworm Lepidoptera: Noctuidae from a traditional maize crop in the Mexican State of Yucatan*. *Florida Entomology* 90: 759-761.
- Faraway, J.J. 2005. *Extending the linear model with R: generalized linear, mixed effects and nonparametric regression models*. Chapman and Hall/CRC. Boca Raton, USA.
- Federico, P., Hallam, T.G., McCracken, G.F., Purucker, S.T., Grant, W.E., Correa-Sandoval, A.N., Westbrook, J.K., Medellín, R.A., Cleveland, C.J., and Sansone, C.G. 2008. *Brazilian free-tailed bats as insect pest regulators in transgenic and conventional cotton crops*. *Ecological Applications* 18: 826-837.
- French, B., and Lollar, A. 1998. *Observations on the reproductive behavior of captive Tadarida brasiliensis mexicana Chiroptera: Molossidae*. *Southwestern Naturalist* 43: 484-490.

- Frick, W.F., Reynolds, D.S., and Kunz, T.H. 2010. *Influence of climate and reproductive timing on demography of little brown Myotis lucifugus*. *Journal of Animal Ecology* 79: 128-136.
- Fleming, T.H. 2019. Bat Migration. 605-610. En: Choe, J. C. (Ed.). *Encyclopedia of animal behavior*. Academic Press. Oxford, U.K. 623 pp.
- Fleming, T.H., Eby, P., Kunz, T.H., and Fenton, M.B. 2003. *Ecology of bat migration*. 164-65. En: Fenton, M. B., and Kunz, T. H. (Eds.). *Bat ecology*. University of Chicago Press. Chicago, USA. 798 pp.
- Gallant, L.R., Grooms, C., Kimpe, L.E., Smol, J.P., Bogdanowicz, W., Stewart, R.S., Claree, E.L., Fenton, B., and Blais, J.M. 2020. *A bat guano deposit in Jamaica recorded agricultural changes and metal exposure over the last 4300 years*. *Palaeogeography, Palaeoclimatology, Palaeoecology* 538: 109470.
- Gallardo, H.F., Bustamante, W.O., and Ibarra, E.S. 2006. *Estudio retrospectivo de la sequía en el norte de Sinaloa*. *MultiCIENCIA* 1 (3): 15-20.
- Gannon, M., A. Kurta, A. Rodríguez-Duran, and Willig, M. 2005. *Bats of Puerto Rico: An Island Focus and a Caribbean Perspective*. The University of the West Indies Press. Lubbock, USA. 224 pp.
- García-Gutiérrez, C., González-Maldonado, M.B., and Cortez-Mondaca, E. 2012. *Uso de enemigos naturales y biorracionales para el control de plagas de maíz*. *Ra Ximhai* 8: 57-71.
- Gillespie, T.W., Ostermann-Kelm, S., Dong, C., Willis, K.S., Okin, G.S., and Linsley E. 1944. *Natural sources, habitats, and reservoirs of insects associated with stored food products*. *Hilgardia* 16 (4):185-224.
- Gobierno del Estado de Sinaloa. 2003. Decreto Municipal No. 14. *Diario Oficial del Estado de Sinaloa*. Lunes 15 de septiembre de 2003.
- González-Maldonado, M.B., Gurrola-Reyes, J.N., and Chaírez-Hernández, I. 2015. *Biological products for the control of Spodoptera frugiperda Lepidoptera: Noctuidae*. *Revista Colombiana de Entomología* 41: 200-204.
- González-Medina, E., Angulo-Gastélum, U.T., Castillo-Guerrero, J. A., Guevara-Medina, M. 2009. *Distribución y abundancia relativa invernal del Vireo de cabeza negra Vireo atricapilla en Sinaloa, México*. *Ornitología Neotropical* 20: 291-298.
- Hassan, M. U., Bagaturov, M. F., Tariq, G., and Faiz, L. Z. (2019). *Diversity of Moths in some selected areas of district Bagh, Azad Jammu & Kashmir (Pakistan)*. *Journal of Bioresource Management* 6(1): 3.

- Hernández-Mendoza, J.L., López-Barbosa, E.C., Garza-González, E., and Mayek-Perez, N. 2008. *Spatial distribution of Spodoptera frugiperda* Lepidoptera: Noctuidae in maize landraces grown in Colima, México. *International Journal of Tropical Insect Science* 28: 126-129.
- Hoying, K.M., and Kunz, T.H. 1998. *Variation in size at birth and post-natal growth in the insectivorous bat Pipistrellus subflavus* Chiroptera: Vespertilionidae. *Journal of Zoology* 245: 15-27.
- Huang, Y., Dong, Y., Huang, W., Ren, B., Deng, Q., Shi, Y., Bai, J., Ren, Y., Geng, Y., and Ma, H. 2020. *Overwintering distribution of fall armyworm Spodoptera frugiperda in Yunnan, China, and influencing environmental factors*. *Insects* 11: 805.
- Huete, A.R., Liu, H. Q., Batchily, K.V., and Van Leeuwen, W.J.D.A. 1997. *A comparison of vegetation indices over a global set of TM images for EOSMODIS*. *Remote Sensing of Environment* 59: 440-451.
- Hutson, A.M., Mickleburgh, S.P., and Racey, P.A. Comp. 2001. *Microchiropteran bats: global status survey and conservation action plan*. IUCN/SSC Chiroptera Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. 258 pp.
- Ibanez Castillo, L.A., and Chávez Morales, J. 1990. *Metodología para la planeación de la operación de los distritos de riego de los Valles del Fuerte y Del Carrizo, Sinaloa*. *Agrociencia* 1: 77-99.
- Jiang, Z., Huete, A.R., Chen, J., Chen, Y., Li, J., Yan, G., y Zhang, X. 2006. *Analysis of NDVI and scaled difference vegetation index retrievals of vegetation fraction*. *Remote Sensing of Environment* 101: 366-378.
- Jonasson, K.A., 2017. *The effects of sex, energy, and environmental conditions on the movement ecology of migratory bats*. Ph.D. thesis. The University of Western Ontario, Canada. 146 pp.
- Jonasson, K.A., and Guglielmo, C.G. 2019. *Evidence for spring stopover refueling in migrating silver-haired bats Lasiurus noctivagans*. *Canadian Journal of Zoology* 97: 961-970.
- Kasso, M., and Balakrishnan, M. 2013. *Ecological and economic importance of bats Order Chiroptera*. *International Scholarly Research Notices Biodiversity*, 2013: 1-9.
- Kohles, J. E., Page, R. A., Dechmann, D. K., and O'Mara, M. T. 2018. *Rapid behavioral changes during early development in Peters' tent-making bat Uroderma bilobatum*. *PloS One* 13 (10): e0205351.
- Krauel, J.J., and McCracken, G.F. 2013. *Recent Advances in Bat Migration Research*. In: Adams, R., Pedersen, S. (Eds.) *Bat Evolution, Ecology, and Conservation*. Springer, New York, USA. 293-313.

- Krauel, J.J., Ratcliffe, J.M., Westbrook, J.K., and McCracken, G.F. 2018. *Brazilian free-tailed bats Tadarida brasiliensis adjust foraging behavior in response to migratory moths*. Canadian Journal of Zoology 96: 513-520.
- Krauel, J.J., Westbrook, J.K., and McCracken, G.F. 2015. *Weather-driven dynamics in a dual-migrant system: moths and bats*. Journal of Animal Ecology 84: 604-614.
- Kunz, T.H. 1974. *Feeding ecology of a temperate insectivorous bat Myotis velifer*. Ecology 55: 693-711.
- Kunz, T.H. 1982. *Roosting ecology*. In: Kunz T. H. (Ed.) Ecology of bats. Plenum Publishing Corporation, New York, USA. 1-46 pp.
- Kunz, T.H., Braun de Torrez, E., Bauer, D., Lobova, T., and Fleming, T.H. 2011. *Ecosystem services provided by bats*. Annals of the New York Academy of Sciences 1223: 1-38.
- Kunz, T.H., and Hood, W.R. 2000. *Parental Care and Postnatal Growth in the Chiroptera*. In: Crichton, E. G., & Krutzsch, P. H. (Eds.). Reproductive Biology of Bats. Academic Press, San Diego, USA. 415-468 pp.
- Kunz, T.H. and Robson, S. 1995. *Postnatal growth and development in the Mexican free-tailed bat. Tadarida brasiliensis mexicana: birth size, growth rates, and age estimation*. Journal of Mammalogy 76: 769-783.
- Leal-Sandoval, A., Tepatlán-Vargas, A., López-Segoviano, G., Omer Linares-Holguín, O., Sánchez-Peña, P., and López-Hoffman, L. 2020. *Acoustic records of Promops centralis Thomas, 1915 Chiroptera, Molossidae in corn agroecosystems of northwestern Mexico*. Check List 16: 1269-1276.
- Lee, Y-F, and McCracken, G.F. 2002. *Foraging activity and food resource use of Brazilian free-tailed bats, Tadarida brasiliensis Molossidae*. Écoscience 9: 306-313.
- Leveau, L.M., Isla, F I., and Bellocq, M.I. 2018. *Predicting the seasonal dynamics of bird communities along an urban-rural gradient using NDVI*. Landscape and Urban Planning 177: 103-113.
- Low, M.R., Hoong, W.Z., Shen, Z., Murugavel, B., Mariner, N., Paguntalan, L.M., Tanalgo, K., Aung, M.M., Sheherazade and Bansa, L.A., et al. 2021. *Bane or Blessing? Reviewing Cultural Values of Bats Across the Asia-Pacific Region*. Journal of Ethnobiology 41: 18-34.
- Malo, M., and Hore, J. 2020. *The emerging menace of fall armyworm KJE Smith in maize: A call for attention and action*. Journal of Entomology and Zoology Studies 8: 455-465.
- Marimuthu, G. 1996. *Foraging behaviour in bats*. In: Ramamurthi, R. Readings in Behaviour. New Age International. Delhi, India. 103 pp.

- Mayamba, A., Byamungu, R.M., Leirs, H., Moses, I., Makundi, R.H., Kimaro, D.N., Massawe, A.W., Kifumba, D., Nakiyemba, A., Mdangi, M.E., Isabirye, B.E. and Mulungu, L.S. 2021. *Population and breeding patterns of the pest rodent: Mastomys natalensis in a maize dominated agroecosystem in Lake Victoria crescent zone, Eastern Uganda*. Journal of African Zoology 56: 76-84.
- McCracken, G.F., and Gassel, M.F. 1997. *Genetic structure in migratory and nonmigratory populations of Brazilian free-tailed bats*. Journal of Mammalogy 78; 348-357.
- McCracken, G.F., Gillam, E.H., Westbrook, J.K., Lee, Y-F., and Jenson, M.L., Balsley B.B. 2008. *Brazilian free-tailed bats Tadarida brasiliensis: Molossidae, Chiroptera at high altitude: links to migratory insect populations*. Integrative and Comparative Biology 48: 107.
- McCracken, G.F., Westbrook, J.K. Brown, V.A. Eldridge, M., Federico, P., and Kunz, T.H. 2012. *Bats Track and Exploit Changes in Insect Pest Populations*. Plos One 7(8): e43839.
- McWilliams, L.A. 2005. *Variation in diet of the Mexican free tailed bat Tadarida brasiliensis mexicana*. Journal of Mammalogy 86: 599-605.
- Méndez-Barroso, L.A., Vivoni, E.R., Robles-Morua, A., Mascaro, G., Yépez, E.A., Rodríguez, J.C., Watts, C.J., Garatuza-Payán, J. and Saíz-Hernández, J.A. 2014. *A modeling approach reveals differences in evapotranspiration and its partitioning in two semiarid ecosystems in Northwest Mexico*. Water Resources Research 50: 3229-3252.
- Mickleburgh, S., Waylen, K., and Racey, P. 2009. *Bats as bushmeat: a global review*. Oryx 43: 217-234.
- Montezano, D.G., Sosa-Gómez, D.R., Specht, A., Roque-Specht, V.F., Sousa-Silva, J.C., Paula-Moraes, S.V., Peterson J.A. and Hunt, T.E. 2018. *Host plants of Spodoptera frugiperda Lepidoptera: Noctuidae in the Americas*. African Entomology 26; 286-300.
- Mouhoubi, D., Djenidi, R., and Bounechada, M. 2019. *Contribution to the study of diversity, distribution, and abundance of insect fauna in salt wetlands of Setif region, Algeria*. International Journal of Zoological Research 2019: 1-11.
- Nabte, M.J., Andrade, A., Monjeau, A., Hernández, J.L., Vaquero, D., and Saba, S.L. 2016. *Mammalia, Chiroptera, Molossidae, Tadarida brasiliensis I. Geoffroy, 1824: Distribution extension*. Check List 7: 142-143.

- Nagoshi, R.N., Rosas-García, N.M., Meagher, R.L., Fleischer, S.J., Westbrook, J.K., Sappington, T.W., Hay-Roe, M., Thomas, J.M.G. and Murúa, G.M. 2015. *Haplotype profile comparisons between Spodoptera frugiperda Lepidoptera: Noctuidae populations from Mexico with those from Puerto Rico, South America, and the United States and their implications to migratory behavior.* Journal of Economic Entomology 108: 135-144.
- Nboyine, J.A., Kusi, F., Abudulai, M., Badii, B.K., Zakaria, M., Adu, G.B., Haruna, A., Seidu, A., Osei, V., Alhassan, S.S. and Yahaya, A. 2020. *A new pest, Spodoptera frugiperda JE Smith, in tropical Africa: Its seasonal dynamics and damage in maize fields in northern Ghana.* Journal of Crop Protection 127: 104960.
- Peisley, R.K., Saunders, M.E., and Luck, G.W. 2015. *A systematic review of the benefits and costs of bird and insect activity in agroecosystems.* Springer Science Reviews 3: 113-125.
- Pérez González, M.A., and García Rodríguez, M.P. 2005. *Discriminación visual y digital de suelos de baja calidad agrícola a partir de imágenes Landsat.* Geographicalia 46: 99-115.
- Perfecto, I., and Vandermeer, J. 2008. *Biodiversity conservation in tropical agroecosystems: a new conservation paradigm.* Annals of the New York Academy of Sciences 1134: 173-200.
- Pettorelli, N., Ryan, S., Mueller, T., Bunnefeld, N., J., drzejewska, B., Lima, M., and Kausrud, K. 2011. *The Normalized Difference Vegetation Index NDVI: unforeseen successes in animal ecology.* Climate Research 46: 15-27.
- DOF - Diario Oficial de la Federación. 1978. Decreto por el que se establece una zona de reserva y refugio de aves migratorias y de la fauna silvestre, en las islas que se relacionan, situadas en el Golfo de California. México. Presidencia de la República.
- Portillo-Quintero, C.A., and Sánchez-Azofeifa, G.A. 2010. *Extent and Unforeseen conservation of tropical dry forests in the Americas.* Biological Conservation 143: 144-155.
- Racey, P., Speakman, R., and Swif, S.M. 1982. *Reproductive adaptations of heterothermic bats at the northern borders of their distribution.* South African Journal of Science 83: 636-638.
- Rangel, N.J.C., Vázquez R.M.F. and Del Rincón, C.M.C. 2014. *Caracterización biológica y molecular de cepas exóticas de baculovirus SfNPV, con actividad bioinsecticida hacia una población mexicana del gusano cogollero del maíz Spodoptera frugiperda Lepidoptera: Noctuidae.* Interciencia 39: 320-326.
- Ripley, B., Venables, B., Bates, D.M., Hornik, K., Gebhardt, A. and Firth, D. 2016. *MASS: Support functions and datasets for venables and Ripley's MASS. R package version 7.3-45.* Available at: <https://cran.r-project.org/web/packages/MASS/>

- Russell, A., and McCracken, G.F. 2006. *Population genetic structure of very large populations: the Brazilian free-tailed bat, Tadarida brasiliensis*. En: Zubaid A, McCracken G, Kunz T. (Eds.). *Functional and Evolutionary Ecology of Bats*. Oxford University Press. New York, USA. 227-247 pp.
- Russell, A.L., Medellín, R.A., and McCracken, G.F. 2005. *Genetic variation and migration in the Mexican free-tailed bat Tadarida brasiliensis mexicana*. *Molecular Ecology* 14: 2207-2222.
- Sansone, C., and Smith, J. 2001. *Natural mortality of Helicoverpa zea Lepidoptera: Noctuidae in short-season cotton*. *Biological Control* 30: 113-122.
- Sieradzki, A and Mikkola, H.J. 2022. *Bats in Folklore and Culture: A Review of Historical Perceptions around the World*. 3-22 Pp. En: Mikkola, H. J. (Ed.) *Bats Disease-Prone but Beneficial*. Intechopen, London, UK. 134 pp.
- Schleuning, W.D. 2001. *Vampire bat plasminogen activator DSPA-alpha-1 desmoteplase: a thrombolytic drug optimized by natural selection*. *Pathophysiology of Haemostasis and Thrombosis* 31: 118-122.
- Scales, J.A., and Wilkins, K.T. 2007. *Seasonality and fidelity in roost use of the Mexican free-tailed bat, Tadarida brasiliensis, in an urban setting*. *Western North American Naturalist* 67: 402-408.
- Sena Jr., D.G., Pinto, F.A.C., Queiroz, D.M., and Viana, P.A. 2003. *Fall armyworm damaged maize plant identification using digital images*. *Biosystems Engineering* 85: 449-454.
- Tooker, J.F., O'Neal, M.E., and Rodríguez-Saona, C. 2020. *Balancing disturbance and conservation in agroecosystems to improve biological control*. *Annual Review of Entomology* 65: 81-100.
- Tuttle, M. D., and Moreno, A. 2005. *Murciélagos cavernícolas del norte de México su importancia y problemas de conservación*. Bat Conservation International, Inc. Austin, USA. 49 pp.
- Villa, C, B., and Canela, R, M. 1988. *Man, Gods, and Legendary Vampire Bat*. In *Natural History of Vampire Bats*. Pp. 233-240. En: Greenhall, A. M. (Ed.). *Natural History of Vampire Bats* 1st ed. CRC Press. Boca Raton, USA. 261 pp.
- Wan, L., Li, Y., Cen, H., Zhu, J., Yin, W., Wu, W., Zhu, H., Sun, D., Zhou, W., and He, Y. 2018. *Combining UAV-based vegetation indices and image classification to estimate flower number in oilseed rape*. *Remote Sensing of Environment* 10: 1484.
- Wang, D., Wan, B., Qiu, P., Su, Y., Guo, Q., Wang, R., Sun, F., and Wu, X. 2018. *Evaluating the performance of sentinel-2, landsat 8 and pléiades-1 in mapping mangrove extent and species*. *Remote Sensing of Environment* 10: 1468.

- Wiederholt, R., López-Hoffman, L., Cline, J., Medellín, R.A., Cryan, P., Russell, A., McCracken, G., Diffendorfer, J. and Semmens, D. 2013. *Moving across the border: modeling migratory bat populations*. *Ecosphere* 4: 1-16.
- Welbergen, J.A., Meade, J., Field, H.E., Edson, D., McMichael, L., Shoo, L.P., Praszczalek, J., Smith, C., and Martin, J.M. 2020. *Extreme mobility of the world's largest flying mammals creates key challenges for management and conservation*. *BMC Biology* 18: 1-13.
- Westbrook, J.K. 2008. *Noctuid migration in Texas within the nocturnal aeroecological boundary layer*. *Integrative and Comparative Biology* 48: 99-106.
- Westbrook, J.K., Nagoshi, R.N., Meagher, R.L., Fleischer, S.J., and Jairam, S. 2016. *Modeling seasonal migration of fall armyworm moths*. *International Journal of Biometeorology* 60: 255-267.
- Wilkins, K.T. 1989. *Tadarida brasiliensis*. *Mammalian species* 331: 1-10.
- Wilson, D.E., C.F. Ascorra and S. Solari. 1996. *Bats as indicators of habitat disturbance*. 577-592 pp. In: Wilson, D.E., and Sandoval, A. (Eds.). *Manu, the Biodiversity of Southeastern Peru*. Smithsonian Institution - Ed. Horizonte, Lima, Perú.
- Yeo, D., Srivathsan, A., Puniamoorthy, J., Maosheng, F., Grootaert, P., Chan, L., Guénard, B., Damken, C., Wahab, R.A., Yuchen, A., and Meier, R. 2021. *Mangroves are an overlooked hotspot of insect diversity despite low plant diversity*. *BMC Biology* 19: 1-17.

Cita

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