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Seed removal by the squirrel *Notocitellus adocetus* (Rodentia: Sciuridae) in Western México

Daniel Flores-Alta[1]; ⓘD https://orcid.org/0000-0002-1464-5868
Francisco Alberto Rivera-Ortiz[2]; ⓘD https://orcid.org/0000-0002-5487-4817
Ana María Contreras González[1]*; ⓘD https://orcid.org/0000-0003-4509-7865

1. Laboratorio de Ecología. Unidad de Biotecnología y Prototipos, Facultad de Estudios Superiores Iztacala. Avenida de los Barrios 1, Los Reyes Iztacala, Tlalnepantla, Estado de México, México; danielfloresalta@gmail.com; *amcontre-rasg@comunidad.unam.mx (*Correspondence).
2. Laboratorio de Ecología Molecular y Evolución. Unidad de Biotecnología y Prototipos, Facultad de Estudios Superiores Iztacala. Avenida de los Barrios 1, Los Reyes Iztacala, Tlalnepantla, Estado de México, México; francisco.rivera@iztacala.unam.mx

ABSTRACT

Introduction: Seed dispersal and seed predation have important impacts on plant diversity and community structure. Rodents participate in both of these types of interactions.

Objectives: To evaluate the removal of the seeds of *Crescentia alata*, *Randia capitata*, and *Zea mays* by the squirrel *Notocitellus adocetus* to determine how it affects these plant species, by dispersing or preying on their seeds.

Methods: We studied 14 individuals for *C. alata,* 24 for *R. capitata*, and for *Z. mays* 35 individuals. We observed foraging and used camera traps to determine the part of the fruit (seed and/or pulp) consumed by the squirrels and the amount of fruit or seed consumed. We also placed fine sand traps (FST) to measure the percentage of seed removal. We quantified the fruits produced by the plant species studied and the percentage of damage caused by *N. adocetus* throughout the plots.

Results: *Notocitellus adocetus* feeds on the seeds and pulp of *C. alata* and *Z. mays*. The species with the highest removal rate and the highest percentage of damage was *C. alata*. *Zea mays* was the plant species that had the highest percentage of removal from FST, the largest number of fruits, and the lowest percentage of damage. On FST, *R. capitata* had the lowest seed remotion.

Conclusions: *Notocitellus adocetus* is considered a seed predator; however, due to its behavior and the characteristics of the fruits of *C. alata* and *R. capitata*, this rodent could make the seeds available to secondary seed dispersers.

Key words: tropical ground squirrel; *Crescentia alata*; *Randia capitata*; *Zea mays*; seed dispersal; seed predation; tropical deciduous forest.

RESUMEN

Remoción de semillas por la ardilla *Notocitellus adocetus* (Rodentia: Sciuridae) en el oeste de México.

Introducción: La dispersión y depredación de semillas tienen efectos importantes en la diversidad de plantas y estructura de las comunidades. Los roedores participan en estos tipos de interacciones.

Objetivos: Evaluar la remoción de semillas de *Crescentia alata*, *Randia capitata* y *Zea mays* por la ardilla *Notocitellus adocetus*, para determinar su efecto en estas especies de plantas, dispersando o depredando semillas.

Métodos: Estudiamos 14 individuos de *C. alata*, 24 para *R. capitata* y 35 individuos para *Z. mays.* Observamos el forrajeo y usamos cámaras trampas para determinar la parte del fruto (semilla y/o pulpa) consumida y la intensidad de consumo por las ardillas. También colocamos trampas de arena fina (FST) para medir el porcentaje de remoción de semillas. Cuantificamos los frutos producidos por las especies estudiadas y el porcentaje de daño ocasionado por *N. adocetus,* mediante parcelas.

Resultados: *Notocitellus adocetus* se alimenta de las semillas y pulpa de *C. alata* y *Z. mays*. La especie que tuvo mayor tasa de remoción y mayor porcentaje de daño fue *C. alata.* La especie con mayor porcentaje de remoción, mayor número de frutos y menor daño en las FST fue *Z. mays*. En las trampas de arena fina, *R. capitata* tuvo la menor remoción de semillas.

Conclusiones: *Notocitellus adocetus* es considerada depredadora de semillas, no obstante, por su comportamiento y las características de los frutos de *C. alata* y *R. capitata*, este roedor podría dejar disponibles las semillas a dispersores secundarios de semillas.

Palabras clave: ardilla tropical del suelo; *Crescentia alata*; *Randia capitata*; *Zea mays*; dispersión de semillas; depredación de semillas; bosque tropical caducifolio.

INTRODUCTION

Ecological interactions can have positive, negative, or neutral effects for the species involved in them, and they play a crucial role in the structure and organization of communities (Bertness & Callaway, 1994; Perea et al., 2013). In the dispersal cycle of plants, there are positive interactions with animals such as seed dispersal, and negative interactions such as seed predation (Howe, 1986; Howe & Small-wood, 1982; Janzen, 1971b). These interactions can affect the plant and animal populations involved; on the one hand, they play a role in maintaining the seed bank and, therefore, in seed distribution in the environment, so that the interactions have impact the recruitment of plants and thus affect their fitness. While on the other, animals depend on the resource provided by plants for their survival (Howe & Small-wood, 1982; Janzen, 1971b; Louda, 1989). These interactions occur with very high frequency, so their effects have consequences on plant demography and genetic diversity and are critical in the maintenance and plant diversity (Calvino-Cancela, 2007; Howe & Smallwood, 1982; Janzen, 1971b; Jordano & Godoy, 2000; Wang & Smith, 2002).

Animals, as small invertebrates to large mammals, are agents involved in seed removal (Howe & Smallwood, 1982;. Janzen, 1971b; Martínez-Orea et al., 2009). Rodents are considered seed dispersers (Acevedo-Quintero & Zamora-Abrego, 2016; Ouden et al., 2005; Sunyer et al., 2013; Xiao et al., 2006), and seed predators (DeMattia et al., 2006; Galetti et al., 2015a; Ibáñez & Soriano, 2005; Janzen, 1971b; Traveset et al., 2009). Rodents are important in communities; by excavating and building their burrows, they provide benefits to ecosystems, such as water infiltration, improved soil texture, and changing the level of available nutrients, making soils more heterogeneous (Ewacha et al., 2016; Reichman & Seabloom, 2002; Zhang et al., 2003), increasing landscape variability, and maintenance of species richness in changing environments (Brown et al., 2001; Davidson & Lightfoot, 2008; Reichman & Seabloom, 2002; Valkó et al., 2021; Zhang et al., 2003).

However, the environment has a problem around the world, which is the high social importance (Blackie et al., 2014), as a land-use change that caused habitat fragmentation and altered the original vegetation structure (Emer et al., 2018; Haddad et al., 2015). Approximately 90 % of the tropical deciduous forest (TDF) in the world has been altered by agriculture or ranching (Banda et al., 2016), which increase rodent densities, since these organisms obtain their food more efficiently in farmlands (Castillo-Castillo & González-Romero, 2010; Galetti et al., 2015a), where they can be considered pests (Elias & Valencia, 1984; Villar-González, 2000). In México, for example, crops including corn, sorghum, rice,

beans, sugarcane, coconut, and squash are affected by rodents (Bello & Hidalgo, 2009; Brooks & Fiedler, 2001; Panti-May et al., 2017; Villar-González, 2000). The land-use change causes species loss due to migrations to vegetation patches or agricultural areas and even the local extinction of native species. In addition, this species loss induces a decrease in ecological functions, including interactions between plants and animals (Bolger et al. , 1997; Galetti et al., 2015b; Marjakangas et al., 2020).

In Western México, *Notocitellus adocetus* is a terrestrial squirrel, an endemic rodent species (Flores-Alta et al., 2019; Valdés & Ceballos, 2014), considered a pest by people who refer that squirrels cause damage to their crops; for this reason, they kill individuals of this species. This human activity can change community structure and ecological functions derived from land-use change; therefore, it is essential to know the role of the *N. adocetus* in the environment to determine conservation strategies for this species. So, the question for this work was, what role does *N. adocetus* play in seed removal on three plant species? Then the aim of the present study was to evaluate the removal by *N. adocetus* of *C. alata*, *R. capitata*, and *Z. mays* seeds to determine whether this squirrel species participates in seed dispersal and/or seed predation. Also, evaluate the rodents impact on these plant species to know the importance of this species on the environment.

MATERIALS AND METHODS

Species: *Notocitellus adocetus* belongs to the Sciuridae family, has terrestrial habits and is known locally as the "cuinique", it is commonly referred to as the tropical ground squirrel and is endemic to Western México (Flores-Alta et al., 2019; Valdez, 2003).

The three plant species studied were chosen because they are the most consumed by *N. adocetus* in the locality of Cuambio, Guerrero (Flores-Alta et al., 2019). Also, in TDF only these species had fruit during the study. The seed of *Z. mays* is an important seed consumed by humans, to which *N. adocetus* causes economic losses, for this reason the people kill them.

Crescentia alata and *R. capitata* are wild TDF species, whose fruit production occurs during the dry season. *Zea mays* is the most cultivated species in the region (Duque, 2016 personal communication) and produce fruit at the end of the rainy season.

Crescentia alata (Bignoniaceae) (Cirián/ Mexican Calabash) is a tree from 6.96 ± 0.92 height (Table 1), has an indehiscent fleshy fruit measuring 7 to 15 cm diameter, with a hard shell, has seeds from 0.6 to 1 cm long (Briones-Salas et al., 2006; CONABIO, 2020; Flores-Alta, 2018; Janzen & Martin, 1982). The fruits of this species are consumed by rodents (*Liomys salvi*) in Costa Rica (Janzen, 1982). *Randia capitata* (Rubiaceae) (Tecuche or Cruceta) is a tree from 3.67 ± 0.15 m height (Table 1), has indehiscent globose berry fruits measuring 5 cm in diameter, with a hard shell (Felger et al., 2012; Flores-Alta, 2018), has seeds from 0.79 ± 0.03 cm long and 0.63 ± 0.2 cm wide (Obs. pers.). *Zea mays* (Poaceae) (corn) is an herb with caryopsis-type fruits that together form an ear; the seed size measure 0.55 to 0.95 cm long and 0.3 to 0.7 cm wide (Espinosa-García & Sarukhán, 1997; Quiroz, 2019).

Study area: The study site is in the Northwest of the state of

TABLE 1

Number and size of individuals of *C. alata* and *R. capitata* in tropical dry forest plots.

Species	Number of individuals	Height (m)	DBH (cm)	Coverage individual (m²)	Coverage (m²)	Coverage (%)
C. alata	0.33 ± 0.16	6.96 ± 0.92	51.82 ± 92.61	49.75 ± 27.01	83.13 ± 22.93	2.77
R. capitata	11.66 ± 2.56	3.67 ± 0.15	5.39 ± 0.52	4.84 ± 0.89	262.16 ± 0.62	8.73

DBH = Diameter at breast height.

Guerrero, in the municipality of Zirándaro de Los Chávez in the locality of Cuambio, at coordinates (18°26'28.54"-18°26'06.63" N & 101°01'21.68"-100°59'39.56" W), between 209 and 324 m.a.s.l. (Flores-Alta et al., 2019). The mean annual temperature is 28.4 °C, and the mean annual rainfall is 977.2 mm, with a dry season lasting eight months (CONAGUA, 2020). The vegetation type is TDF, with areas that have suffered land-use change on the alluvial terraces. Some sites are used to farm seasonal and irrigation-based crops including corn, sorghum, sesame, and to a lesser extent, mango, watermelon, plum, pumpkin, cucumber, tomato, chili, hibiscus, and beans. In the same way, there are areas dedicated to cattle grazing (Mendoza, *in prep.*). The extension of the study area in the TDF was 6.45 ha, while in the corn crops was 7.45 ha, and the distance between the two areas was 1.9 km.

For each plant species, we carried out one sampling period during each sampling month, which were selected based on when fruits are produced. For *Z. mays*, this was in September and October 2016, for *C. alata* in January, March, and May 2017, and in January and March 2017 for *R. capitata*. Each sampling lasted three days at two sites. For each of the plant species, we made direct observations at fixed points daily (Altmann, 1974) during the peak activity periods of *N. adocetus* (9:00-14:00 h) (Flores-Alta et al., 2019). Three observers remained still at different points at a distance of ten to 15 m from the focal plants so as not to disturb the activity of the squirrels and observed their behavior using 10X42 binoculars (Bushnell and Alpen). Each observer attended from one to three focal individuals of *C. alata* (1.32 ± 0.09 individuals), with 14 individuals observed in total, for *R. capitata* we observed five to nine individuals (6 ± 1.77 individuals), with 24 individuals observed in total, and for *Z. mays* for each observer was attended from seven to ten individuals with 35 individuals observed in total (8.3 ± 0.88 individuals).

The total observation time for each species was 32.25 h for *C. alata*, 50.06 h for *R. capitata*, and 49.66 h for *Z. mays*. The lower total observation time of *C. alata* is due to the lower number of individuals (Table 1) in the study area.

To complement the foraging observations, we placed three digital camera traps (Bushnell Trophy cam HD, Essential E2) near three focal individuals of each of the plant species for three consecutive days (Trolliet et al., 2014). The cameras were focused on open fruits located on the ground in the case of *C. alata* and *R. capitata*, while in the case of *Z. mays*, we placed fruits on the ground. The cameras were programmed to film 60 s videos, which were reviewed in the laboratory. During the foraging observations and videos, we noted the part of the fruit consumed (pulp and/or seeds), stage of development (ripe or immature), number of feeding observations recorded, number of seeds consumed, number of individuals of *N. adocetus* feeding per event, time foraging (Contreras-González & Arizmendi, 2014), foraging behavior (consumption of seeds in situ or storage in cheek pouches), as well as their behavior and movements after feeding (e.g. to their burrows or places with better visibility, such as rocks).

To quantify the number of seeds that *N. adocetus* removes and determine its impact on the three plant species studied, we quantified the percentage of seed removal. For this, we placed six fine sand traps (FST) per species per sample close to the parent plant (1.5 m distance), with a minimum of 15 m between traps. We set the traps before the squirrel's activity period in the morning, and we checked them at the end of this activity for two consecutive days. The trapping method consisted of clearing a 1m^2 area of litter and vegetation for each trap and placing a layer of fine sand so that the squirrels would leave tracks in the sand when removing the seeds (Giraldo & Moreno, 2011). We put 40 seeds previously obtained from mature fruits at the center of each FST. For FST containing *N. adocetus* tracks, we quantified the number of seeds removed for each plant species and expressed these data as a percentage. We identified *N. adocetus* tracks by comparing tracks left in the FST to the tracks

of Mexican Ground Squirrel (*Spermophilus mexicanus*) and Rock Squirrel (*S. variegatus*) in the Mexican wild mammal tracking guide (Aranda, 2012; *N. adocetus* are not described in the guide). There is little chance of misidentifying tracks as belonging to *N. adocetus,* since no similar squirrels are distributed in the area.

Fruit abundance and damage: Because the abundance of resources available in the environment influences seed removal (Izhaki, 2002; Ortiz-Pulido et al., 2007; Wästljun, 1989), we quantified the resources available for *N. adocetus*. During each sampling in the TDF, we randomly placed three 50 x 20 m plots in which we quantified the number of individuals and the number of fruits per individual of each of the two plant study species. When fruits were too numerous to efficiently count directly, we estimated the number of fruits by multiplying the average fruit count from three branches by the total number of branches per individual (Chapman et al., 1992; Contreras-González et al., 2009). In addition, to know the height, coverage, and space occupied by the individuals of *C. alata* and *R. capitata*, we measured the diameter at breast height (DBH), the height of the individuals, and the coverage for each individual using the ellipse formula to estimate the percentage that each species occupies in the sampled space, since these variables influence fruit production (Chapman et al., 1992). In the case of *Z. mays*, we reduced the plot size to 5 x 5 m due to the high density of plants. We quantified the total number of individuals and the number of fruits per individual.

We also quantified the number of fruits with damage caused by *N. adocetus* (bites, partially opened fruits, or partially consumed fruits; Fig. 1), identifying the source of damage with the help of a person from the Cuambio locality who has observed squirrel activity for many years. We estimate the percentage of damage by dividing the number of damaged fruits by the total fruits in the plot.

We applied Shapiro-Wilk normality tests to all the data obtained to determine whether the data conformed to parametric assumptions
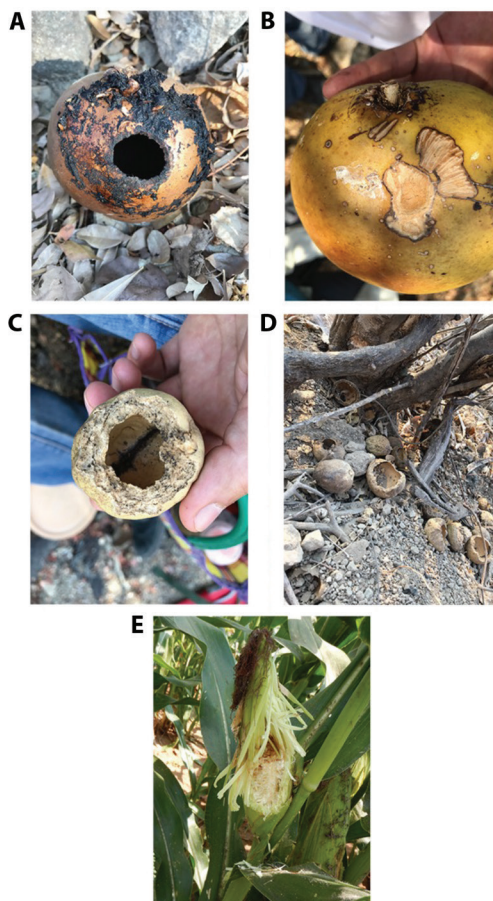

Fig. 1. Fruits of *C. alata* **A.** and **B.** *R. capitata*, **C.** and **D.** and *Z. mays*, **E.** damaged by *N. adocetus*.

(Zuur et al., 2009). Because we did not observe *N. adocetus* feeding on *R. capitata* in direct observations or camera trap videos, analyses of some data included only *C. alata* and *Z. mays*.

We applied a Wilcoxon test to determine whether the number of squirrels feeding on the fruits differed between *C. alata* and *Z. mays*. We calculated the rate of seed removal to evaluate the intensity with which a squirrel consumes the seeds from *C. alata* and *Z. mays* by dividing the number of seeds consumed by the time that squirrels spent foraging. We used a generalized linear model (GLM) test with a Poisson error distribution to determine whether the rate of seed removal of *N. adocetus* differed between these species (Zuur et al., 2009).

To evaluate the differences in the percentage of seeds removed in the FST among the three species studied in the different months sampled, we used a generalized linear mixed model (GLMM) with a Poisson distribution (Zuur et al., 2009), with percentage of seed removed as the dependent variable, and time and species as independent variables. We analyzed the wild TDF species separately from the corn crops because human management influences fruit production in corn crops (Nadal, 1999). For this analysis, we used a linear mixed model (LMM) for the TDF species, with fruit abundance as the dependent variable, and time and species as independent variables and a GLM with a Poisson distribution for the corn crops (Zuur et al., 2009), with crop size as dependent variable, and time as independent variable. In addition, due to pseudoreplication, we applied a GLMM analysis with a Poisson distribution to examine differences in the percentage of damaged fruits between the studied species (Zuur et al., 2009).

RESULTS

We found that *N. adocetus* feeds on the pulp and seeds of ripe and immature fruits of *C. alata* and *Z. mays* (Table 2). We did not record squirrels feeding on *R. capitata*, though we did observe fruits of *R. capitata* and *C. alata* with marks from *N. adocetus* (Fig 1A, Fig. 1B, Fig. 1C, Fig. 1D). Also, we observed individuals of *N. adocetus* opening fruits of *C. alata* by making a hole in the hard shell, from which they extracted pulp and seeds. Squirrels fed on

seeds of *C. alata* and *Z. mays in situ*, taking seeds with their hands, opening them with their teeth and consuming the embryo, leaving only the seed coat. Some seeds were carried in the cheek pouches to their burrows or to later feed in areas with greater visibility (e.g., on rocks, protruding roots, or dry logs). We observed 1.14 (± 0.06) individuals feeding on 6.47 (± 1.15) seeds of *C. alata* per visit, while for *Z. mays* we observed 1.02 (± 0.02) individuals feeding (Wilcoxon = 381, P > 0.05). Squirrels removed more *C. alata* (removal rate) (13.60 ± 0.24 seeds / minute) seeds per minute than *Z. mays* seeds (10.42 ± 0.84 seeds / minute) (X^2 = 2.55, d.f. = 22, P < 0.05; Table 2).

In the FST, *N. adocetus* removed seeds from all three study species. The highest seed removal was from *Z. mays* (43.43 ± 4.88 %; X^2= 14.89, d.f. = 122, P < 0.05), followed by *C. alata* (29.5 ± 6.15 %), and finally *R. capitata* (23.17 ± 8.41 %) (Table 2).

In terms of resource abundance, in the TDF plots *C. alata* had higher height and DBH and more coverage than *R. capitata* (Table 2). However, in the sampled area, *C. alata* occupied a lower percentage of the area than *R. capitata* (2.77 % and 8.73 %, respectively) and there were fewer individuals of *C. alata* than *R. capitata* (0.33 ± 0.16 and 11.66 ± 2.56 individuals respectively (Table 2). For *C. alata*, we found a larger number of fruits per hectare than for *R. capitata*. *C. alata* had higher fruit abundance in March than in January and May, while *R. capitata* had similar fruit abundance between January and March, and we did not record fruits in May (Fig. 2A, LMM = 11.68, d.f. = 74,

TABLE 2
Species eaten by *N. adocetus* in TDF and corn crops.

Species	Part eaten and stage of ripeness[a]	FOR	SF	FT (min)	CR (seed/min)	RFST %	Month
C. alata	rp, pl, se	103	1.14 ± 0.06	6.47 ± 1.15	13.06 ± 0.24	29.5 ± 6.15	Jan, Mar, May 2017
R. capitata	rp, pl, se	0	0	UN	UN	23.17 ± 8.41	Jan, Mar 2017
Z. mays	rp, unrp, dr, pl, se	6	1.02 ± 0.02	UN	10.42 ± 0.84	43.43 ± 4.88	Sep, Oct 2016

In part eaten and stage of ripeness: rp = ripe, unrp = unripe, dr = dry, pl = pulp, se = seed; FOR = number of feeding observations records; SF = number of squirrels feeding per event; FT = time foraging per event observed; CR= consumption rate; RFST = percentage seed removal in fine sand traps; UN = unidentified).
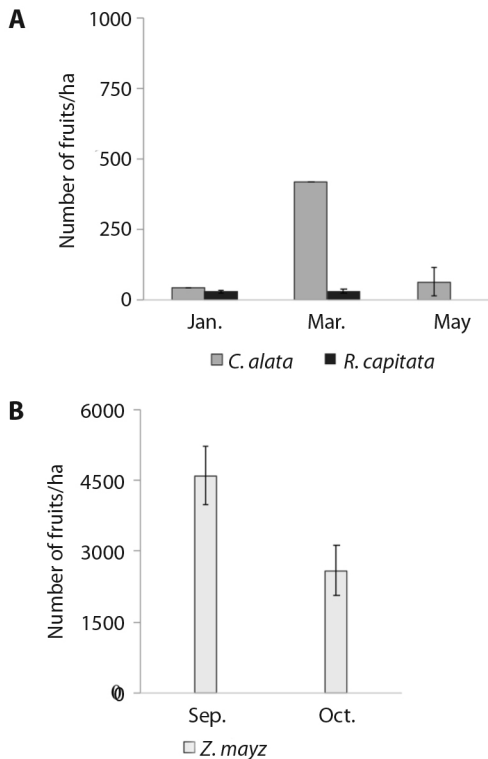
Fig. 2. Abundance of fruits per hectare in study plots in *C. alata* and *R. capitata* in tropical dry forest plots **A.** and in **B.** *Z. mays* in plots in corn fields.

P < 0.05). In the corn crops we recorded more fruits in September than in October (Fig. 2B, $X^2 = 6.07$, d.f. = 14, P < 0.05).

Based on the number of available fruits of the studied plant species, we found that the percentage of fruits damaged by *N. adocetus* was highest for *C. alata* (38.74 ± 11.92 %), while for *R. capitata* it was 10.34 % (± 5.75) and for *Z. mays* was 5.16 % (± 2.55; GLMM= 1.82, d.f. = 74, P > 0.05).

DISCUSSION

Notocitellus adocetus feeds on the pulp and embryo of the seeds of *C. alata* and *Z. mays*, which indicating that this rodent is a seed predator (Janzen, 1971b), as is the case of the other squirrels in tropical forests (*Notosciurus*

granatensis, *Sciurus variegatoides, S. colliaei* y *S. ingrami*) (Acevedo-Quintero et al., 2018; Henn, et al. 2014; Herrerías-Diego et al., 2008; Janzen, 1971a). In addition, when *N. adocetus* fed on *C. alata*, it scared away reptiles and birds, and some members of these groups are considered seed dispersers (Howe & Smallwood, 1982; Valido & Olesen, 2007). However, when squirrels feed on *C. alata*, the iguana *Ctenosaura pectinata* scares them away. Members of the Iguanidae family have been described as seed dispersers, increasing the reproductive success of some plants (Traveset, 1990; Vásquez-Contreras & Ariano-Sánchez, 2016), which can influence the seed dispersal from *C. alata*.

One of the feeding behaviors we observed was that *N. adocetus* made a hole in the tough outer shell of *C. alata* through which it extracted the pulp and seeds. This behavior has also been described in the squirrel *S. variegatorides* in Costa Rica, which can spend up to 15 min making the hole in the fruit, then extracts the pulp in pieces and feeds on the seeds (Janzen, 1982). The characteristics of *C. alata* and *R. capitata* fruits, such as a thick, hard covering, make it difficult for other organisms to access the seeds. In addition, when the fruits of *C. alata* fall to the ground and mature, the seeds can die due to desiccation when not opened (Janzen, 1982). Therefore, *N. adocetus*, by breaking the fruits of *C. alata* and *R. capitata*, plays an important role since it makes the seeds available to seed dispersers, as occurs for the plant species *Heteroflorum sclerocarpum* (Urrea-Galeano & Andresen, 2018). Similar dynamics have been described for the squirrels *S. granatensis*, *Microsciurus mimulus*, and the rat, *Proechymys* sp., which make the seeds of *Oenocarpus bataua* available to seed dispersers (Rojas-Robles et al., 2012).

Notocitellus adocetus removed a higher percentage of *C. alata* seeds in the FST, influencing negatively on this plant species (Vander-Wall et al., 2005). However, this rate of removal is lower than chipmunks *Tamias amoenu*, which can consume a seed per second (Vander-Wall, 1994). Seed removal by *N. adocetus* in the TDF

and the corn crops is lower compared to other rodent species, since has been described seed removal by rodents for the forest 96 % of seed removal, and in agroforestry systems 76 % (Escobar et al., 2020; Li & Zhang, 2007). This indicates that the effects of *N. adocetus* on the plant species consumed are likely less severe than other rodent species, which can be useful for conservation programs for this species.

Individuals from *N. adocetus* feed on fruits and seeds of *C. alata* and *Z. mays in situ*. However, some seeds are carried in their cheek pouches to their burrows or to places with better visibility to continue feeding. This behavior could lead to some seeds being dispersed when they are dropped during transport or feeding (Gottfried, 1987). Moreover, outside burrows of *N. adocetus*, we found empty fruits of *R. capitata* with holes (Fig. 1D); the same feeding behavior has been reported for this squirrel species when it feeds on *H. sclerocarpum* (Urrea-Galeano & Andresen, 2018). Squirrels can store seeds temporarily in their burrows, which can even germinate when squirrels fail to find and eat all of the seeds they have cached (Steele et al., 2015; Vander-Wall, 1994; Vander-Wall, 2003; Zong et al., 2010). However, the absence of large seed dispersers due to fragmentation has led to a loss of ecological interactions and an increase in rodent populations, such that seeds are deposited mainly in an aggregate manner (Marjakangas et al., 2020; Rojas-Robles et al., 2012), which may affect plant populations (Hulme, 1998; Hulme, 2002).

We found that *Z. mays* had the highest abundance of fruits of the three species studied, which influences that more seeds of this species are removed (Elmouttie, 2009; Kelrick et al., 1986). There is a higher density of squirrels in the corn crops (Flores-Alta et al., 2019), which increases the intensity of seed predation (Gharnit et al., 2020; Minor & Koprowski, 2015). This is similar to what occurs with the mouse *Peromyscus leucopus*, in which seed predation increases with increasing population density (Ostfeld et al., 1997). In addition, when resource abundance is high in a small area, rodents do not have to move long distances to acquire resources, so they are less exposed to predators (Hannon et al., 2006).

Although total seed removal was higher in corn crops than in the forest species, the percent damage in plots of *Z. mays* was low. Conversely, *C. alata* had higher percent damage, although the density of squirrels is lower (Flores-Alta et al., 2019). Nevertheless, in sub-deciduous forests, the intensity of seed predation by rodents is less intense than in fragmented sites (Fleury & Galetti, 2006), since fragmented areas do not present the appropriate conditions for the rodents' predators. In addition, squirrels have better visibility to detect predators when they feed in fragmented areas than in forests (Fleury & Galetti, 2006; Hannon et al., 2006; Herrerías-Diego et al., 2008).

Due to the interactions present in the environment, it is necessary to observe the ecological and evolutionary history of the plant species. Unfortunately, there is no information for *R. capitata*. However, *C. alata* has been described as having a rare adaptation to survive and avoid seed predation which makes the fruit inaccessible to most animals. Members of the now extinct proboscidean family Gomphotheriidae were proposed as their previous dispersers (Janzen & Martin, 1982). Once the members of this family became extinct, other organisms, such as horses, dispersed the seeds (Janzen, 1982). However, these organisms could not be considered seed dispersers in the study area in the TDF since their distribution is restricted to farmlands and grazing lands and is hardly found in the TDF. So that is necessary to carry out studies from seed dispersal for both species.

We conclude that *N. adocetus* is a seed predator of the three species studied, which can decrease or regulate the populations of these plant species; however, the intensity of seed predation is not a result of the number of fruits. Nevertheless, the characteristics of sites in TDF, such as the proximity to areas dedicated to farmland and grazing land can influence seed predation, so it would be essential to carry out a study that quantifies the predation of seeds in conserved areas far from disturbed areas.

Ethical statement: the authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgements section. A signed document has been filed in the journal archives.

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REFERENCES

Acevedo-Quintero, J. F., & Zamora-Abrego, J. G. (2016). Papel de los mamíferos en los procesos de dispersión y depredación de semillas de *Mauritia flexuosa* (Arecaceae) en la Amazonía colombiana. *Revista de Biologia Tropical*, *64*(1), 5–15. https://doi.org/10.15517/rbt.v64i1.18157

Acevedo-Quintero, J. F., Zamora-Abrego, J. G., & Ortega-León, Á. M. (2018). The prickles of *Astrocaryum malybo* as a structural defense to avoid seed predation. *Food Webs*, *16*, 1–3. https://doi.org/10.1016/j.fooweb.2018.e00088

Altmann, J. (1974). Observational study of behavior: sampling methods. *Behavior*, *49*, 227–267.

Aranda, J. M. (2012). *Manual para el rastreo de mamíferos silvestres de México*. CONABIO. https://doi.org/10.5962/bhl.title.113211

Banda, K., Delgado-Salinas, A., Kyle, G. D., Linares-Palomino, R., Oliveira-Filho, A., Prado, D., Pullan, M., Quintana, C., Riina, R., Rodríguez, G. M., Weintritt, J., Acevedo-Rodríguez, P., Adarve, J., Álvarez, E., Aranguren, A., Arteaga, J. C., Aymard, G., Castaño, A., Ceballos-Mago, N., … Pennington, T. (2016). Plant diversity patterns in neotropical dry forests and their conservation implications. *Science, 353*, 383–1388.

Bello, G. J., & Hidalgo, M. M. G. (2009). *Estudio que permita el método de control de la ardilla en el cultivo de cocotero avalado por la SEMARNAT*. Universidad Juárez Autónoma de Tabasco.

Bertness, M. D., & Callaway, R. (1994). Positive interactions in communities. *Trends in Ecology & Evolution*, *9*, 191–193.

Blackie, R., Baldauf, C., Gautier, D., Gumbo, D., Kassa, H., Parthasarathy, N., Paumgarten, F., Sola, P., Pulla, S., & Waeber, P. (2014). *Tropical dry forests: The state of global knowledge and recommendations for future research*. Center for International Forestry Research.

Bolger, D. T., Alberts, A. C., Sauvajot, R. M., Potenza, P., McCalvin, C., Tran, D., Mazzoni, S., & Soulé, M. E. (1997). Response of Rodents to Habitat Fragmentation in Coastal Southern California. *Ecological Applications*, *7*(2), 552–563.

Briones-Salas, M., Sánchez-Cordero, V., & Sánchez-Rojas, G. (2006). Multi-species fruit and seed removal in a tropical deciduous forest in México. *Canadian Journal of Botany*, *84*(3), 433–442. https://doi.org/10.1139/B06-020

Brooks, J. E., & Fiedler, L. A. (2001). Vertebrate: post-harvest operations. In D. Mejia & B. Lewis (Eds.), *Vertebrate pests: post harvest operations* (pp. 1–26). Food and Agriculture Organization of United Nations.

Brown, J. H., Ernest, S. K. M., Parody, J. M., & Haskell, J. P. (2001). Regulation of diversity: maintenance of species richness in changing environments. *Oecologia*, *126*, 321–332.

Calvino-Cancela, M. (2007). Seed and microsite limitations of recruitment and the impacts of post-dispersal seed predation at the within population level. *Plant Ecology, 192*(1), 35–44. https://doi.org/10.1007/sll258-006-9223-3

Castillo-Castillo, C., & González-Romero, A. (2010). Áreas de actividad de la ardilla endémica de Perote *Xerospermophilus perotensis*. *Therya*, *1*(1), 69–74. https://doi.org/10.12933/therya-10-6

Chambers, J. C., & MacMahon, J. A. (1994). A day in the life of a seed: Movements and fates of seeds and their implications for natural and managed systems. *Annual Review of Ecology and Systematics*, *25*, 263–292. https://doi.org/10.1146/annurev.es.25.110194.001403

Chapman, C., Chapman, L., Wangham, R., Hunt, K., Gebo, D., & Gardner, L. (1992). Estimators of fruits abundance of tropical trees. *Biotropica*, *24*, 527–531.

CONABIO. (2020). *Crescentia alata.* http://www.conabio.gob.mx/conocimiento/info_especies/arboles/doctos/10-bigno1m.pdf

CONAGUA. (2020). *Información climatológica*. https://smn.conagua.gob.mx/es/informacion-climatologica-por-estado?estado=gro

Contreras-González, A. M., & Arizmendi, M. D. C. (2014). Pre-dispersal seed predation of the columnar cactus

(*Neobuxbaumia tetetzo*, Cactaceae) by birds in central México. *Ornitologia Neotropical*, *25*(4), 373–387.

Contreras-González, A. M., Rivera-Ortíz, F. A., Soberanes-González, C. A., Valiente-Banuet, A., & Arizmendi, M. del C. (2009). Feeding ecology of military macaws (*Ara militaris*) in a semi-arid region of Central México. *The Wilson Journal of Ornithology*, *121*, 384–391. https://doi.org/10.1676/08-034.1

Davidson, A. D., & Lightfoot, D. C. (2008). Burrowing rodents increase landscape heterogeneity in a desert grassland. *Journal of Arid Environments*, *72*(7), 1133–1145. https://doi.org/10.1016/j.jaridenv.2007.12.015

DeMattia, E. A., Rathcke, B. J., Curran, L. M., Aguilar, R., & Vargas, O. (2006). Effects of small rodent and large mammal exclusion on seedling recruitment in Costa Rica. *Biotropica*, *38*(2), 196–202. https://doi.org/10.1111/j.1744-7429.2006.00117.x

Elias, D. J., & Valencia, D. G. (1984). La agricultura latinoamericana y los vertebrados plaga. *Interciencia*, *9*, 223–229.

Elmouttie, D. (2009). *Utilisation of seed resources by small mammals: a two-way interaction*. Queensland University of Technology.

Emer, C., Galetti, M., Pizo, M. A., Guimarães, P. R., Moraes, S., Piratelli, A., & Jordano, P. (2018). Seed-dispersal interactions in fragmented landscapes – a metanetwork approach. *Ecology Letters*, *21*(4), 484–493. https://doi.org/10.1111/ele.12909

Escobar, S., Razafindratsima, O. H., Montúfar, R., & Balslev, H. (2020). Post-dispersal seed removal in a large-seeded palm by frugivore mammals in Western Ecuador. *Tropical Conservation Science*, *13*, 1–14. https://doi.org/10.1177/1940082920947041

Espinosa-García, F. J., & Sarukhán, J. (1997). *Manual de malezas del Valle de México*. Ediciones Científicas Universitarias UNAM-Fondo de Cultura Económica.

Ewacha, M. V. A., Kaapehi, C., Waterman, J. M., & Roth, J. D. (2016). Cape ground squirrels as ecosystem engineers: Modifying habitat for plants, small mammals and beetles in Namib Desert grasslands. *African Journal of Ecology*, *54*, 68–75. https://doi.org/10.1111/aje.12266

Felger, R. S., Wilder, B. T., & Romero-Morales, H. (2012). *Plant Life of a Desert Archipelago: Flora of the Sonoran Islands in the Gulf of California*. University of Arizona Press.

Fleury, M., & Galetti, M. (2006). Forest fragment size and microhabitat effects on palm seed predation. *Biological Conservation*, *131*(1), 1–13. https://doi.org/10.1016/j.biocon.2005.10.049

Flores-Alta, D. (2018). *Interacción planta-animal de Notocitellus adocetus (Sciuridae) con algunas especies de bosque tropical caducifolio y zonas de cultivo de Zirándaro de los Chávez, Guerrero.* Universidad Nacional Autónoma de México.

Flores-Alta, D., Rivera-Ortíz, F. A., & Contreras-González, A. M. (2019). Record of a population and description of some aspects of the life history of *Notocitellus adocetus* in the north of the state of Guerrero, México. *Mastozoología Neotropical*, *26*(1), 175–181. https://doi.org/10.31687/SAREMMN.19.26.1.0.02

Galetti, M., Guevara, R., Galbiati, L. A., Neves, C. L., Rodarte, R. R., & Mendes, C. P. (2015a). Seed predation by rodents and implications for plant recruitment in defaunated Atlantic forests. *Biotropica*, *47*(5), 521–525. https://doi.org/10.1111/btp.12246

Galetti, M., Guevara, R., Neves, C. L., Rodarte, R. R., Bovendorp, R. S., Moreira, M., Hopkins III, J. B., & Yeakel, J. D. (2015b). Defaunation affect population and diet of rodents in Neotropical rainforests. *Biological Conservation*, *190*(2015), 2–7. https://doi.org/10.1016/j.biocon.2015.04.032

Gharnit, E., Bergeron, P., Garant, D., & Réale, D. (2020). Exploration profiles drive activity patterns and temporal niche specialization in a wild rodent. *Behavioral Ecology*, *31*(3), 772–783. https://doi.org/10.1093/beheco/araa022

Giraldo, A., & Moreno, X. (2011). *Protocolos de investigación en ecosistemas terrestres, intermareales, submareales y pelágicos para el Parque Nacional Natural Gorgona*. Universidad del Valle.

Gottfried, G. J. (1987). Regeneration of pinyon. In R. L. Everett (Ed.), *Proceedings- Pinyon-Juniper Conference* (pp. 249–254). Intermountain Research Station.

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., Lovejoy, T. E., Sexton, J. O., Austin, M. P., Collins, C. D., Cook, W. M., Damschen, E. I., Ewers, R. M., Foster, B. L., Jenkins, C. N., King, A. J., Laurance, W. F., Levey, D. J., Margules, C. R., … Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, *1*(2), 1–10. https://doi.org/10.1126/sciadv.1500052

Hannon, M. J., Jenkins, S. H., Crabtree, R. L., & Swanson, A. K. (2006). Visibility and vigilance: behavior and population ecology of uinta ground squirrels (*Spermophilus armatus*) in different habitats. *Journal of Mammalogy*, *87*, 287–295. https://doi.org/10.1644/05-MAMM-A-081R2.1

Henn, J. J., McCoy, M. B., & Vaughan, C. S. (2014). Beach almond (*Terminalia catappa*, Combretaceae) seed production and predation by scarlet macaws (*Ara macao*) and variegated squirrels (*Sciurus variegatoides*). *Revista de Biologia Tropical*, *62*(3), 929–938. https://doi.org/10.15517/rbt.v62i3.14060

Herrerías-Diego, Y., Quesada, M., Stoner, K. E., Lobo, J. A., Hernández-Flores, Y., & Sanchez-Montoya, G. (2008). Effect of forest fragmentation on fruit and seed predation of the tropical dry forest tree *Ceiba aesculifolia*. *Biological Conservation*, *141*(1), 241–248. https://doi.org/10.1016/j.biocon.2007.09.017

Howe, H. F. (1986). *Seed dispersal.* Academic Press.

Howe, H. F., & Smallwood, J. (1982). Ecology of seed dispersal. *Annual Review of Ecology and Systematics*, *13*, 201–228.

Hulme, P. E. (1998). Post-dispersal seed predation: consequences for plant demography and evolution. *Perspectives in Plant Ecology, Evolution and Systematics*, *1*(1), 32–46. https://doi.org/10.1078/1433-8319-00050

Hulme, P. E. (2002). Seed-eaters: seed dispersal, destruction and demography. In D. J. Levey, W. R. Silva, & M. Galetti (Eds.), *Seed dispersal and frugivory: ecology, evolution and conservation* (pp. 257–273). CABI Publishing.

Ibáñez, J., & Soriano, P. (2005). Hormigas, aves y roedores como depredadores de semillas en un ecosistema semiárido andino de Venezuela. *Ecotropicos, 17*, 38–51.

Izhaki, I. (2002). The role of fruit traits in determining fruit removal in east Mediterranean ecosystems. In D. J. Levey, W. R. Silva, & M. Galetti (Eds.), *Seed dispersal and frugivory: ecology, evolution and conservation* (pp. 161–175). CABI Publishing.

Janzen, D. H. (1971a). Escape of juvenile *Dioclea megacarpa* (Leguminosae) vines from predators in a deciduous tropical forest. *The American Naturalist*, *105*(942), 97–112. https://doi.org/10.1086/282709

Janzen, D. H. (1971b). Seed predation by animals. *Annual Review of Ecology and Systematics*, *2*, 465–492.

Janzen, D. H. (1982). Fruit traits, and seed consumption by rodents, of *Crescentia alata* (Bignoniaceae) in Santa Rosa National Park, Costa Rica. *American Journal of Botany*, *69*, 1258–1268. https://doi.org/10.2307/2442750

Janzen, D. H., & Martin, P. S. (1982). Neotropical anachronisms: The fruits the gomphotheres ate. *Science*, *215*(4528), 19–27. https://doi.org/10.1126/science.215.4528.19

Jordano, P., & Godoy, J. A. (2000). RAPD variation and population genetic structure in *Prunus mahaleb (*Rosaceae), an animal-dispersed tree. *Molecular Ecology*, *9*(9), 1293–1305. https://doi.org/10.1046/j.1365-294X.2000.01009.x

Kelrick, M. I., MacMahon, J. A., Parmenter, R. R., & Sisson, D. V. (1986). Native seed preferences of shrub-steppe rodents, birds and ants: the relationships of seed attributes and seed use. *Oecologia*, *68*(3), 327–337. https://doi.org/10.1007/BF01036734

Li, H., & Zhang, Z. (2007). Effects of mast seeding and rodent abundance on seed predation and dispersal by rodents in *Prunus armeniaca* (Rosaceae). *Forest Ecology and Management*, *242*(2–3), 511–517. https://doi.org/10.1016/j.foreco.2007.01.063

Louda, S. M. (1989). Predation in the dynamics of seed regeneration. In M. A. Leck, V. Parker & R. L. Simpson (Eds.), *Ecology of soil seed bank* (pp. 25–51). Academic Press.

Marjakangas, E. L., Abrego, N., Grøtan, V., de Lima, R. A. F., Bello, C., Bovendorp, R. S., Culot, L., Hasui, E., Lima, F., Lara, M. R., Brandão, N. B., Oliveira, A. A., Pereira, L. A., Prado, P. P., Stevens, R. D., Vancine, M. H., Ribeiro, M. C., Galetti, M., & Ovaskainen, O. (2020). Fragmented tropical forests lose mutualistic plant–animal interactions. *Diversity and Distributions*, *26*(2), 154–168. https://doi.org/10.1111/ddi.13010

Martínez-Orea, Y., Castillo-Argüero, S., & Guadarrama-Chávez, P. (2009). La dispersión de frutos y semillas y la dinámica de comunidades. *Ciencias*, *96*, 38–41.

Mendoza, O. M. S. (In prep.). *Efecto del cambio de uso/cobertura del suelo sobre la biomasa y el almacén de carbono en la selva baja caducifolia de Zirándaro, Guerrero* (Tesis doctoral). Universidad Nacional Autónoma de México, México.

Minor, R. L., & Koprowski, J. L. (2015). Seed removal increased by scramble competition with an invasive species. *PLoS ONE*, *10*(12), 1–10. https://doi.org/10.1371/journal.pone.0143927

Nadal, A. (1999). *Maize in México: Some Environmental Implications of the North American Free Trade Agreement (NAFTA)*. NAFTA.

Ortiz-Pulido, R., Albores-Barajas, Y. V., & Díaz, S. A. (2007). Fruit removal efficiency and success: Influence of crop size in a neotropical treelet. *Plant Ecology*, *189*(1), 147–154. https://doi.org/10.1007/s11258-006-9175-7

Ostfeld, R. S., Manson, R. H., & Canham, C. D. (1997). Effects of rodents on survival of tree seeds and seedlings invading old fields. *Ecology*, *78*(5), 1531–1542. https://doi.org/10.1890/0012-9658(1997)078[1531:EOROSO]2.0.CO;2

Ouden, J., Jansen, P. A., & Smit, R. (2005). Jays, Mice and Oaks: Predation and dispersal of *Quercus robur* and *Q. petraea* in North-western Europe. In P. M. Forget, J. E. Lambert, P. E. Hulme, & S. B. Vander Wall (Eds.), *Seed fate* (pp. 223–239). CAB international.

Panti-May, J. A., Sodá-Tamayo, L., Gamboa-Tec, N., Cetina-Franco, R., Cigarroa-Toledo, N., Machaín-Williams, C., & Hernández-Betancourt, S. F. (2017).

Perceptions of rodent-associated problems: an experience in urban and rural areas of Yucatan, México. *Urban Ecosystems*, *20*(5), 983–988. https://doi.org/10.1007/s11252-017-0651-8

Perea, R., Delibes, M., Polko, M., Suárez-Esteban, A., & Fedriani, J. M. (2013). Context-dependent fruit-frugivore interactions: Partner identities and spatiotemporal variations. *Oikos*, *122*(6), 943–951. https://doi.org/10.1111/j.1600-0706.2012.20940.x

Quiroz, I. (2019). *Efecto del despanoje y defoliación sobre el rendimiento de grano de la línea de alta endogamia de maíz amarillo duro Zea mays L. (Poaceae) CML 297* (Tesis de grado). Universidad Privada Antenor Orrego, Perú.

Reichman, O. J., & Seabloom, E. W. (2002). The role of pocket gophers as subterranean ecosystem engineers. *Trends in Ecology and Evolution*, *17*(1), 44–49. https://doi.org/10.1016/S0169-5347(01)02329-1

Rojas-Robles, R., Gary Stiles, F., & Muñoz-Saba, Y. (2012). Frugivoría y dispersión de semillas de la palma *Oenocarpus bataua* (Arecaceae) en un bosque de los Andes colombianos. *Revista de Biología Tropical*, *60*(4), 1445–1461.

Steele, M. A., Rompré, G., Stratford, J. A., Zhang, H., Suchocki, M., & Marino, S. (2015). Scatterhoarding rodents favor higher predation risks for cache sites: The potential for predators to influence the seed dispersal process. *Integrative Zoology*, *10*(3), 257–266. https://doi.org/10.1111/1749-4877.12134

Sunyer, P., Muñoz, A., Bonal, R., & Espelta, J. M. (2013). The ecology of seed dispersal by small rodents: A role for predator and conspecific scents. *Functional Ecology*, *27*(6), 1313–1321. https://doi.org/10.1111/1365-2435.12143

Traveset, A., Nogales, M., Alcover, J. A., Delgado, J. D., López-Darias, M., Godoy, D., Igual, J. M., & Bover, P. (2009). A review on the effects of alien rodents in the Balearic (western Mediterranean Sea) and Canary islands (Eastern Atlantic ocean). *Biological Invasions*, *11*(7), 1653–1670. https://doi.org/10.1007/s10530-008-9395-y

Traveset, A. (1990). *Ctenosaura similis* gray (Iguanidae) as a seed disperser in a Central American deciduous forest source. *The American Midland Naturalist*, *123*(2), 402–404.

Trolliet, F., Huynen, M. C., Vermeulen, C., & Hambuckers, A. (2014). Use of camera traps for wildlife studies. A review. *Biotechnology, Agronomy, Society and Environment*, *18*(3), 446–454.

Urrea-Galeano, L. A., & Andresen, E. (2018). Importancia de las interacciones semilla-mamífero para *Heteroflorum* (Leguminosae), un género monoespecífico endémico. *Revista Mexicana de Biodiversidad*, *89*, 497–506.

Valdez, M. (2003). Las Ardillas de México. *Biodiversitas*, *8*(51), 1–7.

Valdés, A. M., & Ceballos, G. (2014). *Tropical ground squirrel*. The Johns Hopkins University Press.

Valido, A., & Olesen, J. M. (2007). The importance of lizards as frugivores and seed dispersers. In A. J. Dennis, E. W. Schupp, R. J. Green, & D. A. Westcott (Eds.), *Seed Dispersal: Theory and Its Application in a Changing World* (pp. 124–147). CAB International.

Valkó, O., Tölgyesi, C., Kelemen, A., Bátori, Z., Gallé, R., Rádai, Z., Bragina, T. M., Bragin, Y. A., & Deák, B. (2021). Steppe Marmot (*Marmota bobak*) as ecosystem engineer in arid steppes. *Journal of Arid Environments*, *184*, 104244. https://doi.org/10.1016/j.jaridenv.2020.104244

Vander-Wall, S. B. (1994). Seed fate pathways of antelope bitterbrush: Dispersal by seed-caching yellow pine chipmunks. *Ecology*, *75*(7), 1911–1926. https://doi.org/10.2307/1941596

Vander-Wall, S. B. (2003). Effects of seed size of wind-dispersed pines (*Pinus*) on secondary seed dispersal and the caching behavior of rodents. *Oikos*, *100*(1), 25–34. https://doi.org/10.1034/j.1600-0706.2003.11973.x

Vander-Wall, S. B., Kuhn, K. M., & Beck, M. J. (2005). Seed removal, seed predation, and secondary dispersal. *Ecology*, *86*(3), 801–806. https://doi.org/10.1890/04-0847

Vásquez-Contreras, A., & Ariano-Sánchez, D. (2016). Endozoochory by the Guatemalan Black Iguana, *Ctenosaura palearis* (Iguanidae), as a germination trigger for the Organ Pipe Cactus *Stenocereus pruinosus* (Cactaceae). *Mesoamerican Herpetology*, *3*(3), 661–668.

Villar-González, D. (2000). Principales vertebrados plaga en México : Situación actual y alternativas para su manejo. *Chapingo Serie Ciencias Forestales y del Ambiente*, *6*(1), 41–54.

Wang, B. B., & Smith, T. (2002). Closing the seed dispersal loop. *Trends in Ecology & Evolution*, *17*, 379–385.

Wästljun, U. (1989). Effects of crop size and stand size on seed removal by vertebrates in hazel *Corylus avellana*. *Oikos*, *54*(2), 178–184.

13

Xiao, Z., Jansen, P. A., & Zhang, Z. (2006). Using seed-tagging methods for assessing post-dispersal seed fate in rodent-dispersed trees. *Forest Ecology and Management*, *223*(1–3), 18–23. https://doi.org/10.1016/j.foreco.2005.10.054

Zhang, Y., Zhang, Z., & Liu, J. (2003). Burrowing rodents as ecosystem engineers: The ecology and management of plateau zokors *Myospalax fontanierii* in alpine meadow ecosystems on the Tibetan Plateau. *Mammal Review*, *33*(3–4), 284–294. https://doi.org/10.1046/j.1365-2907.2003.00020.x

Zong, C., Wauters, L. A., Van Dongen, S., Mari, V., Romeo, C., Martinoli, A., Petroni, D., &Tosi, G. (2010). Annual variation in predation and dispersal of Arolla pine (*Pinus cembra* L.) seeds by Eurasian red squirrels and other seed-eaters. *Forest Ecology and Management*, *260*(5), 587–594. https://doi.org/10.1016/j.foreco.2010.05.014

Zuur, A. F., Ieno, E. N., Walker, N. J., Saveliev, A. A., & Smith, G. M. (2009). *Mixed effects models and extensions in ecology with R*. Springer.