Sociobiology
An international journal on social insects

RESEARCH ARTICLE - ANTS

Effects of Eight Years of Collecting on the Persistence of *Liometopum apiculatum* Ant Nests in Rangelands of Charcas, San Luis Potosí, Mexico

Julio César Zavala-Sánchez[1], Juan Antonio Reyes-Agüero[2], Priscila Lara-Juárez[3], Pedro Castillo Lara[2]
Alicia Grajales-Lagunes[4], Juan Rogelio Aguirre-Rivera[2]

1 - Posgrado en Ciencias Agropecuarias, Facultad de Agronomía y Veterinaria, Universidad Autónoma de San Luis Potosí, Soledad de Graciano Sánchez, SLP, México
2 - Instituto de Investigación de Zonas Desérticas, Universidad Autónoma de San Luis Potosí, San Luis, SLP, México
3 - Instituto Tecnológico de Estudios Superiores de Monterrey, Campus San Luis Potosí, San Luis, SLP, México
4 - Facultad de Ciencias Químicas, Universidad Autónoma de San Luis Potosí, San Luis, SLP, México

Article History

Edited by
Gilberto M. M. Santos, UEFS, Brazil
Received 17 July 2023
Initial acceptance 07 March 2024
Final acceptance 10 April 2024
Publication date 15 May 2024

Keywords
Escamoles, ant pupae, dead and live ant nests.

Corresponding author
Juan Antonio Reyes-Agüero
Instituto de Investigación de Zonas Desérticas, Universidad Autónoma de San Luis Potosí, Altaír 200, Col. del Llano, 78377 San Luis, SLP, México.
E-Mail: reyesaguero@uaslp.mx

Abstract

In Mexico, the pupae of the reproductive castes of the ant *Liometopum apiculatum*, *escamoles*, are highly valued in traditional and gourmet cuisine in the country's central region. *Escamoles* are collected during the dry season of the year. The recommended collecting process is to open the ant nest by removing soil until the rearing chamber and the trabeculae with attached *escamoles* are found. A well-managed ant nest can be collected repeatedly for approximately 12 to 40 years. In Charcas municipality, San Luis Potosí, Mexico, 400 ant nests were located and checked under two land tenure conditions: the Laguna Seca private ranch and the Pocitos communal ejido. The exploitation of *escamoles* on both tenures was characterized by recording the number of dead and live ant nests. This work evaluated the condition of the ant nests registered in 2012 after eight years. The hypothesis was that ant nests' survival would be greater in the private than in the communal land. The percentage of living ant nests on the ejido decreased by 35.67%. In contrast, on the ranch, it was 26.88%. The percentage of relocated ant nests was lower on the ejido, 37.43%, compared to the ranch, which was 48.1%. The number of dead ant nests on the ejido increased to 33.51% and on the ranch 15.0%. As predicted by the hypothesis, ant nest survival was higher on the private ranch than on the communal ejido lands because of stronger control of the extraction process.

Introduction

In Mexico, five species of ants are known to be used as food (Ramos-Elorduy et al., 1984; Ramos-Elorduy & Pino, 1989; Ramos-Elorduy & Levieux, 1992); one of them is *Liometopum apiculatum* Mayr, 1870. The pupae of the reproductive castes (for insects with complete metamorphosis, pupae are the stage before adulthood), known as escamoles, are highly valued in traditional and gourmet cuisine in the country's central region. The commercial demand for *escamoles* is growing, with attractive prices for gatherers, which has increased the pressure on the ant nests of this species. Consequences of this are the expansion of traditional gathering areas from central Mexico to other regions of the country where this species is naturally distributed, such as in the state of San Luis Potosí (Lara-Juárez, 2013; Lara-Juárez et al., 2015; 2018). Increased demand has also caused the excessive and unattended extraction of the ant nests to obtain

maximal profit with the least effort (Dinwiddie et al., 2013) by omitting procedures that reduce the disturbance caused by extraction and protect the nest from external environmental conditions and predators.

The *L. apiculatum* ant nests are underground or under rocks, dead logs, or at the base of *Yucca* spp. or *Agave* spp. plants (Wheeler, 1905; Gregg, 1963; Miller, 2007; Hoey-Chamberlain et al., 2013; Cruz-Labana et al., 2014; Lara-Juárez et al., 2015). *Escamoles* are gathered during the year's dry season, from the second half of February to the latter weeks of May (Ramos-Elorduy, 2006; Miranda et al., 2011; Lara-Juárez et al., 2015; 2018). During that period the gatherers look for and follow the paths of the worker ants. An ant nest is usually found where four or five paths cross (Lara-Juárez et al., 2015). The recommended extraction process follows (Reyes-Agüero et al., 2020). The ant nest is opened by removing the soil until the rearing chamber and the trabeculae with attached *escamoles* are reached. The trabeculae are extracted and shaken to detach the pupae (Miranda et al., 2011; Lara-Juárez et al., 2018). The trabeculae are easily destroyed (Gulmahamad, 1995). The *escamoles* are placed in a container. Before covering the ant nest, dry debris consisting of prickly pear cactus (*Opuntia* spp.) or maguey (*Agave* spp.) pads and dry or fresh grass is placed inside the chamber to accelerate the formation of new trabeculae, and then the ant nest is closed and covered with flat stones, soil, and thorny plant materials (Miranda et al., 2011; Lara-Juárez et al., 2015; Reyes-Agüero et al., 2020). A well-managed ant nest can last up to 40 years but more commonly lasts four to 12 years (Ramos-Elorduy y Lévieux, 1992).

Inexperience, overuse, and irresponsibility when extracting the *escamoles* can cause the disappearance or death of the ant nests (Ambrosio, 2013; Lara-Juárez, 2013). This problem is intensified when the utilization of communal resources is carried out individually because, as pointed out by Aguirre (1982), the main reason for the damage of communal arid zones is the users themselves and their inappropriate exploitation practices, which directly impact the resource and its environment.

In 2012, Lara-Juárez (2013) located and checked 400 ant nests, 200 on the private ranch Laguna Seca and 200 on the nearby ejido, Pocitos, in Charcas, SLP, Mexico. She registered the number of dead and live ant nests at both venues. In the dead ant nests, those without any sign of living ants, she found evidence of excessive disturbance due to unsuitable exploitation practices. Thus, the present work aimed to evaluate the condition of the ant nests registered in 2012, eight years later. The hypothesis was that the survival of ant nests would be greater on the private ranch than on the ejido.

Materials and Methods

The study was carried out in the municipality of Charcas in the northern part of the state of San Luis Potosí, in two neighboring areas where *escamoles* are collected, the private ranch Laguna Seca (23° 16′ 08″ N and 101° 04′ 07″ W) and Ejido Pocitos (23° 10′ 24″ N and 100° 58′ 06″ W), whose common rangelands are individually utilized. From the Lara-Juárez (2013) data, the coordinates of each of the 400 ant nests were obtained and processed in QGIS 3.16.0 (QGIS, 2002) and transferred to a Garmin Oregon® GPS using Garmin BaseCamp Version 4.7.3. From October 22 to 31, 2020, these ant nests were located again in the field to determine their current status. For each ant nest, the following data were registered: whether there was evidence of it being active, if it was dead, or if the ant nest had been relocated by a few meters. This field data was compared with the data obtained by Lara-Juárez (2013), and preliminary results were presented on November 13, 2020, at a meeting with 18 *escamol* gatherers from Ejido Pocitos so that they could give their opinions on the differences in mortality and survival between the two rangelands.

Results

In 2020, only 339 of the 400 ant nests registered by Lara-Juárez (2013) were located, and of the remaining 61, no trace was found (Table 1).

Table 1. Live, dead, and relocated ant nests of *Liometopum apiculatum* after eight years of utilization in rangelands of an ejido and a private ranch in Charcas, SLP, Mexico.

Ant nests	Ejido Pocitos, communal usufruct				Laguna Seca Ranch, private property			
	2012		2020		2012		2020	
	Number	%	Number	%	Number	%	Number	%
Alive	185	92.5	52	29.05	186	93.0	59	36.87
Relocated*			67	37.43			77	48.13
Dead	15	7.5	60	33.52	14	7.0	24	15.00
Total	200	100.0	179	100.00	200	100.0	160	100.00

*According to the *escamol* gatherers, a poorly exploited ant nest may die or may be moved to a nearby location.

On Ejido Pocitos, the percentage of living ant nests had decreased by 38.37% in eight years (reduced from 185 to 119, including relocated nests); in contrast, on Laguna Seca ranch, the reduction of living ant nests was 26.88% (from 186 to 136). In other words, the percentage of dead ant nests in the Pocitos ejido increased by 4.5 times (from 7.5% to 33.52%) and in the private ranch only doubled (from 7.0% to 15.0%).

For the 2020 sample, the "relocated ant nests" category was necessary. The gatherers have observed that an ant nest that is poorly collected or attacked by a predator may die or relocate; this means that the ants abandon the disturbed ant nest and move it deeper in the same location, or 1 to 10 meters away from the original nest. The gatherers noticed this because there were no trabeculae in the original rearing chamber, but an intense activity of ants continued in the surrounding area. In contrast, there are neither trabeculae nor active ants in dead ant nests. On Ejido Pocitos, the percentage of relocated ant nests (37.43%) was much lower than on the Laguna Seca ranch (48.13%).

During the presentation of the above results to the 18 gatherers from Pocitos, they were asked to explain the sharp decline of their living ant nests. Their answers were natural causes, such as the queen ant's death or the ant nests' predation by wild animals. Still, they also recognize unsustainable collecting methods by the gatherers as a cause of mortality (inappropriate opening, total and repeated extraction of *escamoles* during the same season, damage or accidental extraction of the queen, not putting plant material into the chamber for the reconstruction of the trabeculae, and defective closure of the ant nest). The gatherers emphasized that the main explanation for poor collecting technique is the lack of organization of those who work in the communal rangelands, because they consider that everyone has the same right to open any ant nest, without respecting the proper season or whether another gatherer previously opened it. To back up their statement, they state that those who have ant nests on their plot or in their back yard say that an ant nest can remain active and produce *escamoles* for 20 years or more. They commented that the disorganization among the gatherers is taken advantage of by those who do not carry out the correct procedure for opening or closing the ant nests, are reluctant to attend the workshops on gathering *escamoles* that have been held and are only interested in fast money. These people extract all of the *escamoles* from the ant nests, expose the ants extracted with the trabeculae to sunlight, and also "to not waste time," they do not insert plant material to help the ants replenish the trabeculae, leaving the ant nests open or not correctly closed (Fig 1). Middlemen who buy the *escamoles*, usually people outside the ejido, incentivize this behavior by encouraging the gatherers to obtain the greatest amount of *escamoles* in the least time possible.

Upon further inquiry of the gatherers of the Laguna Seca ranch about the higher percentages of ant nest survivals, they explained that the collecting is better organized there. The owner of the ranch assigned a respected person with extensive experience in collecting *escamoles* as captain for this activity; the ranch is then divided into zones, and each zone is permanently assigned to one gatherer, who is the only one who can extract the *escamoles* from his area. This encourages the gatherers to work correctly the ant nests under their responsibility or since improper collecting is to their detriment. In addition, gatherers who open ant nests in other areas or do a poor job on the ones assigned to them are excluded from the group of gatherers.

Fig 1. A- Unclosed nest. B- when this nest was closed, plants with thorns were not placed to protect it, and a predatory mammal opened it, causing the death of the ant nest.

Discussion

As stated by the gatherers of Charcas, SLP, there are several reasons why ant nests may disappear. The persistence of an ant nest depends on disturbances in its environment and the resources available to be used as food, habitat, and resting areas by the worker ants, in addition to variations in climate, particularly extreme rainfall and temperature (Lara-Juárez, 2013).

An ant nest disappears when the queen ant dies or stops producing worker ants (Kaspari, 2003); it is still unknown whether *L. apiculatum* ant nests, which can last up to 40 years, as estimated by Ramos-Elorduy and Lévieux (1992), are maintained continuously by the same queen ant or whether at least one younger queen can replace her, as is the case with the fire ant *Solenopsis invicta* Buren, 1972 (Tschinkel & Howard, 1978). Predators of the *escamol* ant include invertebrate animals such as *Dinardilla* spp. and *Sceptobius* sp. beetles (Danoff-Burg, 2002) and *Myrmecophila* spp. crickets (del Toro et al., 2009), but it is likely that the animals that most endanger ant nests in the study region are vertebrates, such as the snake *Toluca* sp., and several mammals, such as coyotes, skunks, and possums (Cuadriello, 1980; Lara-Juárez et al., 2015). Gatherers say a possum can eat an ant's nest in a few hours. Therefore, to deter them, the gatherers cover the ant nests with branches or plants with thorns after closing them (Lara-Juárez et al., 2015). Although it is still unknown how much ant nest mortality is due to predators and other natural causes and how much to human causes, the gatherers believe that most of the mortality is caused by some gatherers due to careless collecting. The initial opening of the ant nest, the trabecula extraction, protecting the ants from excess sun, selecting and arranging the correct plant material for reconstruction of the trabeculae, and properly closing and protecting the nest against predators, are the main elements of sustainable collecting of the ant nests. If these actions are not done correctly, the survival and development of the ant nests are put at risk, as well as the repopulation of ant nests of this species (Lara-Juárez, 2013; Reyes-Agüero et al., 2020).

One reason that is not mentioned by the gatherers when they explain the lower number of living ant nests in the ejido is the condition of their rangelands. In the Altiplano Potosino, the rangelands in communal use tend to be more damaged than private rangelands (Aguirre et al., 2020). When Lara-Juárez et al. (2016) compared the location and condition of the rangelands concerning the density of ant nests, it was found that in the ejido, the density of plant species was less than half the density in the private ranch. In the ejido there was less presence of plant species favorable to ants (*Bouteloua gracilis* (Kunth) Lag. ex Griffiths, *Menodora coulteri* A. Gray, *Hilaria cenchroides* Kunth, *Leptochloa dubia* (Kunth) Nees, *Muhlenbergia villosa* Swallen, and *Parthenium incanum* Kunth); in contrast, in the ejido the dominant plant was *Larrea tridentata* Sessé & Moc. ex DC., a species characteristic of heavily overgrazed rangelands. In addition, there was on average, twice the area of bare soil on the ejido than on the private ranch and less than 30% of the amount of mulch as recorded on the ranch (Lara-Juárez et al., 2016).

The persistence of an optimally collected ant nest could be up to 40 years, but the most common lifespan is four to 12 years (Ramos-Elorduy and Lévieux, 1992). The ant nests that some gatherers in Pocitos have on their properties are still in the 12 to 40-year range. In contrast, based on Ramos-Elorduy and Lévieux (1992), most of the ant nests registered in 2012 may disappear within about four more years (2024), when they will have been registered as alive for 12 years. This does not necessarily imply the local extinction of the species because it is necessary to consider the annual repopulation of the ant nests that occurs at the beginning of the rainy season (Lara-Juárez et al., 2016) when a total and continued extraction of the *escamoles* has not taken place yet that year. The good condition of the rangelands is favorable to their repopulation.

Berumen (2018) estimated the extinction risk of *L. apiculatum* with SRAM (species risk assessment method) based on four criteria (size of the distribution area, habitat status, biological vulnerability, and impact of human activity) and concluded that the *escamol* should be subject to special protection under the NOM-059 standard (Secretaría del Medio Ambiente y Recursos Naturales [SEMARNAT], 2010). This author confirmed that improper collecting of the species populations is one of the main factors that puts *L. apiculatum* populations at risk.

In the region of Teotihuacán, Mexico State, Ambrosio (2013) found that the decrease in *escamol* ant nests, estimated to be 80%, is directly related to a reduction of the *L. apiculatum* habitat since several rangeland areas with *escamol* ant nests have been cleared for crop production. But as in Pocitos, SLP, in the Teotihuacán region, a significant problem for the prevalence of the ant nests is the *escamol* gatherers because they are not concerned about conserving the ant population, and their only interest is immediate profit. When extracting the escamoles, these people destroy the nest and compromise the continuity of the ant nest so that the population may disappear (Ambrosio, 2013).

Another factor that jeopardizes the prevalence of *L. apiculatum* is the reluctance of some gatherers in the Pocitos ejido to receive training on the correct collecting of the ant nests. A similar situation was recorded by Barrios-Díaz et al. (2016) in the community of Cuapancingo, Tetela de Ocampo, Puebla, where gatherers showed no interest in receiving training on the sustainable extraction process. Dinwiddie et al. (2013) worked with suburban gatherers of *escamoles* in two localities in San Juan del Río, Querétaro, Mexico. They recorded that after the extraction of the *escamoles*, only 68% of the gatherers closed the ant nest properly, while the rest left it open or improperly closed. This study also recorded that those who left the ant nests open did so out of ignorance or disinterest, as they were only occasional or opportunistic gatherers. However, some other gatherers, dedicated to gathering and selling the *escamoles*, argue that they do not cover the nests in order "not to waste time" and thus can spend more time finding more ant nests and more *escamoles*. Some of these gatherers also had the prospect of migrating to work outside their locality, so they expressed disinterest in the persistence of the ant nests.

Concerning changes in the location of ant nests caused by excessive perturbation, Hölldobler and Wilson (1990)

found that migration or movement of the ant nests is due to stress factors such as flood, predation, and competition. Also, the disturbance generated by light and wind entering the rearing chambers provokes an immediate retreat by the queen and workers. Thus, it can be affirmed that the displacement of the analyzed ant nests in the Charcas, SLP region is mainly caused by disturbance derived from poor practices of the *escamol* gatherers when opening and closing the ant nests.

The ant nests that were not located after eight years could have died, and their traces could have been erased during the period between the two evaluations, which is facilitated by the better condition of the rangelands of the ranch, where the number of unlocated ant nests was higher. The greater mobility of ant nests on the ranch could be due to the greater abundance of predatory vertebrates, which is also associated with the better condition of the rangelands.

Conclusions

In agreement with the initial hypothesis, more ant nest survival was found on the private Laguna Seca ranch than in the communal lands of the Pocitos ejido because of stronger control of the collecting process and the better condition of its rangelands. In the 2020 survey, the relocation of ant nests was attributed to disturbance provoked mainly by deficient collecting techniques.

Acknowledgments

Rocío Reyes wrote the first English version, and Margaret Schroeder proofread the English writing. Anonymous referees made necessary suggestions to improve their understanding of the article. The first author had a CONACYT scholarship (Num. 736382) for master's studies. The financial support for this paper came from the project "Integration of processes for the management, characterization, conservation, and commercialization of *escamoles* (*Liometopum apiculatum*) in the region of the highlands of Potosí", code B-S-3804, of the SAGARPA-CONACYT Sector Fund, administered by Dr. Alicia Grajales-Lagunes.

Authors' Contribution

JCZS conceptualization, investigation, writing: original draft, writing: review & editing.
JARA: supervision, investigation, writing: review & editing.
PLJ: investigation, writing: review & editing.
PCL: supervision, investigation, writing: review & editing.
AGL: conceptualization, investigation, funding, writing: review & editing.
JRAR: conceptualization, writing: review & editing.

References

Aguirre R., J.R., Negrete S., L.O. & Castro R.,R. (2020). Efectos de 20 años de la parcelación sobre la condición del agostadero comunal de un ejido mexicano. Revista de la Facultad de Ciencias Agrarias, Universidad Nacional de Cuyo, 52: 189-203.

Aguirre R., J.R. (1982). Sobre los problemas de las comunidades rurales del altiplano potosino-zacatecano. Salinas de Hidalgo, San Luis Potosí. México: Centro Regional para Estudios de Zonas Áridas y Semiáridas, Colegio de Postgraduados, 12 p.

Ambrosio A., G.A. (2013). La recolección de escamoles (*Liometopum apiculatum* M.) en el corredor gastronómico del municipio de Teotihuacán, Estado de México. Unpublished master's thesis. Toluca, Estado de México, México: Universidad Autónoma del Estado de México, 101 p.

Barrios-Díaz, B., González-Vázquez, J.A., Márquez-Pérez, G., Ojeda-Martínez, A., Vázquez-Huerta, G. & Barrios-Díaz, J.M. (2016). Situación actual de la recolección de la hormiga escamolera *Liometopum apiculatum* (Formicidae: Dolichoderinae) en Tetela de Ocampo, Puebla. Entomología Mexicana, 3: 142-145.

Berumen J., M. (2018). Evaluación de riesgo de extinción de *Liometopum apiculatum* Mayr y descripción de las etapas de recolección, limpieza-lavado-drenado y almacenamiento de sus larvas. Unpublished master's thesis. Salinas de Hgo., San Luis Potosí, México: Colegio de postgraduados, 83 p.

Cruz-Labana, J.D., Tarango-Arámbula, L.A., Alcántara-Carbajal, J.L., Pimentel-López, J., Ugalde-Lezama, S., Ramírez-Valverde, G. & Méndez-Gallegos, S.J. (2014). Uso de hábitat por la hormiga escamolera (*Liometopum apiculatum* Mayr) en el centro de México. Agrociencia, 48: 569-582.

Cuadriello A., J.I. (1980). Consideraciones biológicas y económicas acerca de los escamoles (Hymenoptera: Formicidae). Unpublished Bachelor Thesis. México, DF.: Facultad de Ciencias, Universidad Nacional Autónoma de México, 106 p.

Danoff-Burg, J.A. (2002). Evolutionary liability and phylogenetic utility of behavior in a group of ant-guest Staphylinidae beetles. Annals of Entomological Society of America, 95: 143-155. https://doi.org/10.1603/0013-8746(2002)095[0143:ELAPUO]2.0.CO;2

Del Toro, I., Pacheco, J.A. & Mackay, W.P. (2009). Revision of the ant genus *Liometopum* (Hymenoptera: Formicidae). Sociobiology, 53: 299-369.

Dinwiddie, M.L., Jones, R.W., Roitman-Genoud, P., Tarango-Arámbula, L.A. & Malda-Barrera, G.X. (2013). Estudio etnoentomológico de la hormiga escamolera (*Liometopum apiculatum*) en dos localidades del estado de Querétaro. Agroproductividad, 6: 27-35.

Gregg, R.E. (1963). The ants of Colorado, with reference to their ecology, taxonomy, and geographic distribution. Denver, CO.: University of Colorado, 792 p.

Gulmahamad, H. (1995). The genus *Liometopum* Mayr (Hymenoptera: Formicidae) in California, with notes on nest architecture and structural importance. The Pan-Pacific Entomologist, 71: 82-86.

Hoey-Chamberlain. R., Rust, M.K. & Klotz, J.H. (2013). A review of the biology, ecology and behavior of velvety tree ants of North America. Sociobiology, 60: 1-10. https://doi.org/10.13102/sociobiology.v60i1.1-10

Hölldobler, B. & Wilson, E.O. (1990). The Ants. Cambridge: Harvard University Press, 732 p. https://doi.org/10.1007/978-3-662-10306-7

Kaspari, M. (2003). Introducción a la ecología de las hormigas. In: F. Fernández (Ed.), Introducción a las hormigas de la región neotropical (pp. 97-112). Bogotá, Colombia: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Lara-Juárez, P., Aguirre R., J.R., Castillo L., P. & Reyes-Agüero, J.A. (2018). Collecting pupae (escamoles) of *Liometopum apiculatum* (Hymenoptera, Formicidae, Dolichoderinae) in the San Luis Potosí High Plain, Mexico. Interciencia, 43: 763-769.

Lara-Juárez, P. (2013). Etnobiología de escamoles (*Liometopum apiculatum*) en el altiplano potosino. Unpublished master's thesis. San Luis Potosí, México: Universidad Autónoma de San Luis Potosí, 103 p.

Lara-Juárez, P., Aguirre R., J.R., Castillo L., P. & Reyes-Agüero, J.A. (2015). Biología y aprovechamiento de la hormiga de escamoles, *Liometopum apiculatum* Mayr (Hymenoptera: Formicidae). Acta Zoológica Mexicana, 42: 251-264.

Lara-Juárez, P., Castillo L., P., Tristán-Patiño, F.D.M., Rendón-Huerta, J.A. & Aguirre R., J.R. (2016). Efectos del sitio y la condición de agostadero en la densidad de hormigueros de escamoles (*Liometopum apiculatum* Mayr). Revista Chapingo serie Ciencias Forestales y del Ambiente, 22: 285-302. https://doi.org/10.5154/r.rchscfa.2015.04.016

Miller T., E.X. (2007). Does having multiple partners weaken the benefits of facultative mutualism? A test with cacti and cactus-tending ants. Oikos, 116: 500-512. https://doi.org/10.1111/j.2007.0030-1299.15317.x

Miranda R., G., Quintero B., S., Ramos R., B. & Olguín-Arredondo, H.A. (2011). La recolección de insectos con fines alimenticios en la zona turística de Otumba y Teotihuacán, Estado de México. Pasos, 9: 81-100. https://doi.org/10.25145/j.pasos.2011.09.008

QGIS (2002). QGIS Geographic Information System. Geospatial Foundation Project. https://qgis.org. (accessed date 7 June 2020).

Ramos-Elorduy, J. (2006). Threatened edible insects in Hidalgo, Mexico and some measures to preserve them. Journal of Ethnobiology and Ethnomedicine, 2 :51-61. https://doi.org/10.1186/1746-4269-2-51

Ramos-Elorduy, J. & Lévieux, J. (1992). Détérmination des caracteristiques spatiales des aires de prospection des plusieurs societés de fourmis mexicaines *Liometopum apiculatum* et *L. occidentale* (Hymenoptera Formicidae). Bulletin de la Société Zoologique de France, 117: 21-30.

Ramos-Elorduy, J., Pino M., J.M., Márquez M. C., Rincón V., F., Alvarado P.M., Escamilla P., E. & Bourges R., H. (1984). Protein content of some edible insects in Mexico. Journal of Ethnobiology, 4: 61-72.

Ramos-Elorduy, J. & Pino M., J.M. (1989). Los insectos comestibles en el México antiguo. México D.F.: Diana, 108 p.

Reyes-Agüero, J.A., Zavala S., J.C., Castillo L. P., Aguirre R., J.R. & Grajales L., A. (2020). Manual para recolectar escamoles en el altiplano potosino. San Luis Potosí, México: Universidad Autónoma de San Luis Potosí, 71 p.

Secretaría del Medio Ambiente y Recursos Naturales [SEMARNAT]. (2010). Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental, especies nativas de México de flora y fauna silvestres, categorías de riesgo y especificaciones para su inclusión, exclusión o cambio. México. Ciudad de México: Diario Oficial de la Federación, 78 p.

Tschinkel, W.R. & Howard, D.F. (1978). Queen replacement in orphaned colonies of the fire ant, *Solenopsis invicta*. Behavioral Ecology and Sociobiology, 3: 297-310. https://doi.org/10.1007/BF00296315

Wheeler, W.M. (1905). The North American ants of the genus *Liometopum*. Bulletin of the American Museum of Natural History, 21: 321-333.