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Monitoring of *Orthotomicus erosus* (Coleoptera: Curculionidae) using pheromone trap in pine forests of western Tehran

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Abstract. The Mediterranean pine engraver, *Orthotomicus erosus* (Wollaston) (Col.: Curculionidae: Scolytinae), is a destructive bark beetle in pine forests worldwide. Regarding the recent outbreak of *O. erosus* in Iran, its flight activity and popu113lation density were monitored in four contaminated sites in western Tehran. These four sampling sites included Tabiat Park, Khargush Darreh Forest Park, Chitgar Park behind Bam Riding Club as well as Chitgar Park 9th Aghaghiya Street (western Tehran). Two pheromone traps (ECONEX ORTHOTOMICUS EROSUS 60 DAYS pheromone, Spain) were installed in each sampling site at a height of 2.5 m in the south direction of the pine trees. The number of trapped adults was recorded at 10-day intervals from April 2019 to March 2020. In total, 8514 adults of *O. erosus* were collected using pheromone traps during the sampling period. The results showed that the adult flight started in April in four sampling sites. The flight periods of adults continued until November in Tabiat Park, Khargush Darreh Forest Park, and Chitgar Park, behind Bam Riding Club. Differently, the last adults were collected in October in Chitgar Park, 9th Aghaghiya Street. In addition, the flight peaks of *O. erosus* occurred in August in Tabiat Park, Khargush Darreh Forest Park, and Chitgar Park, behind Bam Riding Club. However, the highest numbers of adults were trapped in July in Chitgar Park, 9th Aghaghiya Street. Based on our results, the number of trapped adults was significantly different in sampling sites. The mean number of trapped adults was the highest (183.25 ± 0.11) in Chitgar Park, 9th Aghaghiya Street, and lowest (106.32 ± 0.07) in Tabiat Park during the whole monitoring experiment. These findings on flight activity and population fluctuation of *O. erosus* in local conditions could be helpful to establish an efficient and successful management program for this destructive pest.

Keywords: Bark beetle, Coniferous forest, Flight activity, Geographic variables

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Introduction

Different abiotic factors such as global warming, repeated heatwaves and, drought have caused stress and weakened the defense of pine trees, resulting in forest decline in many parts of the world. Based on research, unfavorable environmental conditions have been interconnected with biotic factors including bark beetles (Scolytinae), viral, bacterial as well as fungal pathogens would accelerate coniferous forest destruction worldwide (Ayres & Lombardero, 2000; Zhou *et al.*, 2001; Romon *et al.*, 2007; Sanguesa-Barreda *et al.*, 2015). It should be noted that although more scolytine species have been considered as secondary pests on weakened and felled

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trees, some species are destructive pests representing continuous threats to healthy living pine trees (Ayres & Lombardero, 2000; Pernek *et al.*, 2019). The Mediterranean pine engraver, *Orthotomicus erosus* (Wollaston), is among the most abundant species on pine trees. This bark beetle belongs to the tribe Ipini native to Eurasia, has been introduced to South Africa and America and reported on different coniferous species (Mendel & Halperin, 1982; Haack, 2004; Lee *et al.*, 2008; Gomez & Martinez, 2013). Based on Mendel & Halperin (1982) and Baylis *et al.* (1986), *O. erosus* killed the weak *Pinus* species after drought and fire in Asia and Africa. On the other hand, Jiang *et al.* (1992) reported that *O. erosus* infested healthy pine trees and caused a 20% loss of standing *P. massoniana* Lambert in China.

The conifer, *Pinus eldarica* Medw., can tolerate drought conditions and has been planted in semi-arid regions of Iran. Currently, there is a high density of this coniferous in Chitgar Park and 29 other parks (about 400 hectares) located in western Tehran (Arkani *et al.*, 2018). Despite the drought tolerance potential, it seems that *P. eldarica* trees have been infested by the Mediterranean pine engraver in many parts of Iran including Tehran, Isfahan, Guilan, Kerman, and Kermanshah provinces (Amini *et al.*, 2013; Ahadiyat & Akrami, 2015; Salehi-Jouzani *et al.*, 2016; Arkani *et al.*, 2018). According to Salehi-Jouzani *et al.* (2016), more than 80% of pine destructions have been attributed to *O. erosus* in Isfahan. It should be noted that besides direct injury, *O. erosus* can transmit and inoculate several important phytopathogens and nematodes (Zhou *et al.*, 2001; Arias *et al.*, 2005; Jamaa *et al.*, 2007; Romon *et al.*, 2007). Zhou *et al.* (2001) detected the spores of *Ophiostoma ips* (Rumb.) and *Leptographium lundbergii* Lagerb. & Melin (Family: Ophiostomataceae) on adult beetles transmitting the pathogens to the trunks of *Pinus* species.

There are multiple factors contributing to the high destruction potential of *O. erosus,* including the difficulty of infection detection, wide host plant range, high ability of adults to disperse, multiple generations, sap flow disruption due to primarily feeding on inner bark (phloem), transferring pathogens as well as complicated management (Kirisits, 2004; Raffa *et al.*, 2005; Haack, 2006; Arkani *et al.*, 2018).

Because of severe economic and ecological damage to coniferous species, kinds of research have been dedicated to the biology, host preference, and population fluctuation of *O. erosus* in forests as well as urban/suburban areas (Mendel & Halperin, 1982; Tribe, 1990; Walter *et al.*, 2010; Pernek *et al.*, 2019). The observation of the head capsule indicated that the larvae developed through three instars, lasting 29 and 6.5 days at 18 and 36°C, respectively (Mendel & Halperin, 1982). The preadult developmental times ranged from 30 to 75 days in summer and winter, respectively (Mendel, 1983). Adult sexual maturation occurred after feeding in the breeding hosts or new trees depending on the gallery moisture (Mendel & Halperin, 1982). According to research, the male was joined by 1–3 females in the nuptial chamber. Then, the mated female constructed egg galleries and laid 26–75 eggs (Lee *et al.*, 2005). According to Giesen *et al.* (1984) and Faccoli *et al.* (2020), first *O. erosus* was attracted by the primary signal of weak host trees (alpha-pinene and ethanol) and then an aggregation pheromone was released for colonization and establishment.

Based on the phenological research, the number of generations per year varied from 4–7 generations in Asia (Mendel *et al.*, 1982; Sarikaya *et al.*, 2013). Moreover, 3–4 generations in Tunisia and South Africa were reported (Lee *et al.*, 2005). The adult facultatively overwintered from mid-October to February (Mendel, 1983). However, Sarikaya *et al.* (2013) recorded the adult flight activity from the first week of March until October in Turkey. According to the population fluctuations recorded by pheromone traps, *O. erosus* had six generations in Tehran in 2015, wherein the mean total capture per trap during spring, summer, and autumn were 401, 1159, and 114 adults, respectively (Arkani *et al.*, 2018).

Different factors including host species, elevation and, climatic conditions could affect the population density of *O. erosus* (Walter *et al.*, 2010; Kausrud *et al.*, 2012; Sarikaya *et al.*, 2013). Taylor *et al.* (2006) stated that the pest outbreak occurred in forests located at elevations 800 to 1400 m in western Canada. Sarikaya *et al.* (2013) found five generations in the forests that had the lowest elevation (120 m) in Turkey. However, there were four generations in other sites (at higher elevations) in Izmir province. In other research, the host preference of *O. erosus* on five conifer species was different, wherein, *P. resinosa* Aiton, and, *Picea glauca* (Moench), was accepted by adults and also suitable for reproduction (Walter *et al.*, 2010). Despite the widespread distribution of *O. erosus* in Iran, little research has been done on the population and flight activity

of the pest. Findings on the population fluctuation of *O. erosus* would be crucial to provide suitable control strategies based on accurate predictions. So, the main objective of the current study was the population monitoring of *O. erosus* in the west pine forest of Tehran.

Materials and methods

Study areas

Experiments were carried out in pine forests of District 21 Tehran (latitude 35.7189 N, longitude 51.1531E, elevation 1199 m) and Chitgar Forest Park (latitude 35.7388 N, longitude 51.2077E, elevation 1283 m) located in District 22 (western Tehran) during 2019-2020. The sampling sites were selected taking to initially captured adults in traps and field observations. The coordinates of contaminated areas were recorded using the GPS device, and these points were drawn on the park map. Four infested areas (50 × 50 m including 10 rows of 10 *P. eldarica* trees) were considered for population fluctuation of *O. erosus* adults. These four sampling sites included Tabiat Park, Khargush Darreh Forest Park, Chitgar Park, behind Bam Riding Club, and Chitgar Park, 9th Aghaghiya Street (Table 1). The number of trees per surface unit, the age of trees (20-25 cm in diameter) and high stand density were similar among sampling sites. In four sampling sites, similar management tactics were applied wherein the conifers were irrigated once a month, and no fertilizer was used. After extensive sampling, the scolytine species were identified by valid keys (Wood, 1986; LaBonte & Valley, 2019), and the species was confirmed by the Iranian Research Institute of Plant Protection.

Pheromone traps

Two pheromone traps were used for monitoring of *O. erosus* population density placed at a height of 2.5 m from the ground in the south direction of the pine trees in each sampling site (Salehi-Jouzani *et al.*, 2016; Arkani *et al.*, 2018; Sanidad Agricola Econex, 2020). The traps were made of transparent plates (30 × 30 cm tarpaulin plates) coated with glue on both sides (Fig. 1). The aggregation pheromone of the pine bark beetle (ECONEX ORTHOTOMICUS EROSUS 60 DAYS pheromone composed of ipsdienol, methylbutenol, and cis-verbenol from the Spanish company Econex) was attached to each plate. The pheromone capsules were replaced every 60 days. The numbers of trapped *O. erosus* collected from pheromone traps were recorded at 10-day intervals from April 2019 to March 2020.

Data analysis

The counted number of trapped adults of *O. erosus* in different sampling sites were analyzed using SPSS, 19. Two factors of sampling site and time were considered. First, the normality of data was checked using Kolmogorov-Smirnova normality test ($P < 0.01$). In the absence of normal distribution, the data were transformed using Ln (x + 1). Multiple comparisons among different sampling sites were evaluated by Tukey's ($P < 0.01$).

Results

According to records from *O. erosus* sampling, the total numbers of trapped bark beetles at different sampling sites ranged from 1487 to 2673 adults during 2019-2020. Based on data analysis, the investigation of trap catches showed that the mean number of beetles in pheromone traps was significantly different among sampling sites ($P < 0.0001$, $df = 3$, Table 2), wherein the highest (183.25 ± 0.11) and lowest (106.32 ± 0.07) mean catches were recorded in Chitgar Park, 9th Aghaghiya Street, and Tabiat Park, respectively.

Based on the coordinates of sampling areas, the density of trapped adults was highest in Chitgar Park, 9th Aghaghiya Street with high latitude and elevation (35.7433N, 51.2062E, and 1296 m). A positive relationship based on correlation analysis was observed between the mean number of trapped *O. erosus* with latitude and elevation of sampling sites ($r = 0.85$, Fig. 2). The number of trapped adults decreased in other sampling areas with lower latitudes and elevations. The monthly fluctuation of the mean number of trapped adults is presented in Fig. 3.

Table 1. Locations and characteristics of sampling sites for monitoring of *Orthotomicus erosus*

Elevation (m)	Geographical position	Tehran district	Sampling sites	No.
1194	35.7162N, 51.1529E	21	Tabiat Park	Site 1
1259	35.7163N, 51.2559E	22	Khargush Darreh Forest Park	Site 2
1273	35.7320N, 51.1973E	22	Chitgar Park, behind Bam Riding Club	Site 3
1296	35.7433N, 51.2062E	22	Chitgar Park, 9th Aghaghiya Street	Site 4

Monthly average of counted *O. erosus* was significantly different in pheromone traps ($P < 0.0001$, $df = 7$). However, there was no significant difference in the interaction between time and sampling site ($P = 0.932$, $df = 21$), therefore, the population fluctuation trends were the same in the sampling sites as shown in Fig. 3. The results showed that the emergence of flying adults started from April in four sampling sites. In addition, the flight activity lasted until November and no adult was trapped from December in Tabiat Park, Khargush Darreh Forest Park, and Chitgar Park, behind Bam Riding Club. However, the catches of pheromone traps in Chitgar Park, 9th Aghaghiya Street showed that the last trapped adults occurred one month sooner in October and after that, no adult was counted in the trap (Fig. 3).

The results of monthly catches showed that the density of trapped adults in Tabiat Park, Khargush Darreh Forest Park, and Chitgar Park, behind Bam Riding Club, gradually increased and reached to peak in August. Differently, the highest catches of *O. erosus* occurred in July in Chitgar Park, 9th Aghaghiya Street. According to Fig. 3, the highest trapped adults of *O. erosus* were 142.67, 189.67, 226.67, and 246.00 adults in Tabiat Park, Khargush Darreh Forest Park, Chitgar Park, behind Bam Riding Club and Chitgar Park, 9th Aghaghiya Street, respectively. Although the number of adults in Tabiat Park was the lowest in April (the first sampling date), the highest catch was recorded on the last sampling date (November) in this sampling site compared to other areas (Fig. 3).

Discussion

A recent significant increase in the population of *O. erosus* has led to great concern in pine forests (Pernek *et al.*, 2019). Based on research, the geographical factors (latitude, elevation and etc.) as well as climatic conditions and host tree availability, would affect the flight activity period and population density of *O. erosus* (Logan & Powell, 2001; Fettig *et al.*, 2007; Lee *et al.*, 2008; Pernek *et al.*, 2019; Zabihi *et al.*, 2021). So that the findings on population fluctuations of *O. erosus* could be helpful to better understand the biodiversity of the pest.

Fig.1. Trap made of transparent plate and hanged ECONEX ORTHOTOMICUS EROSUS 60 DAYS pheromone

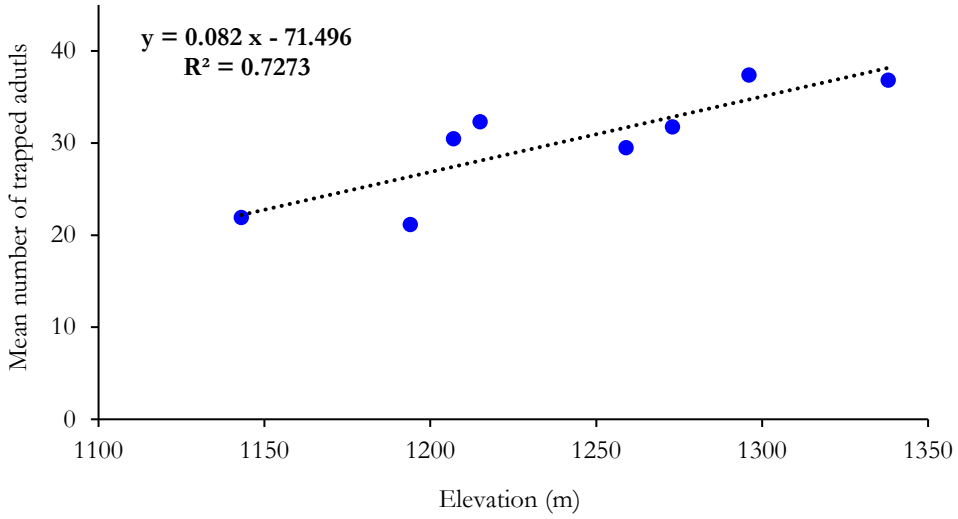

Fig.2. Correlation of sampling site elevation and the trapped adults of *Orthotomicus erosus*

According to the analysis of variance, *O. erosus* adults started to fly in April in four experimental sites (Tehran, Iran). However, in Isfahan province (Iran), Salehi-Jouzani *et al.* (2016) revealed that the flight activity of *O. erosus* occurred from March to December. Mendel (1983) stated that the spring flight of overwintering adults started during March-April in Aleppo pine plantations at Kesalon. Furthermore, *O. erosus* adults were trapped in the first week of March in sampling sites in Izmir province (Turkey) (Sarikaya *et al.*, 2013). The current results showed that the flight periods continued until October and November in different sampling sites. It seems that the lower temperature and higher elevation in Chitgar Park, 9th Aghaghiya Street resulted in a shortening flight period which lasted until October on this site. However, in three other sampling sites, the last catches by pheromone traps occurred in November. On the other hand, Arkani *et al.* (2018) demonstrated that the adult flight activity started in early April and continued until mid-December during 2015-2017.

The flight monitoring indicated that the highest number of adults were trapped in July in Chitgar Park, 9th Aghaghiya Street. Differently, the highest density of trapped adults was delayed until August in Tabiat Park, Khargush Darreh Forest Park, and Chitgar Park, behind Bam Riding Club, which had lower elevation and latitude. According to Sarikaya *et al.* (2013), the flight periods and the number of generations varied due to the different elevations of sampling sites in Izmir province and the highest flight peak in the Urla experimental site (the lowest elevation, 120 m) occurred in August. Similarly, Arkani *et al.* (2018) found that the highest mean capture of *O. erosus* by cross trap was recorded in August 2015-2017.

Our results showed that there was a positive correlation (r = 0.85) between the mean capture of the trap with latitude and elevation of sampling sites. According to our findings, the number of trapped adults (2673 adults) in Chitgar Park, 9th Aghaghiya Street (highest latitude and elevation) was higher than other sampling sites. Sarikaya *et al.* (2013) observed the highest number of beetles per trap in the Menderes-Catalca sampling site which had a higher elevation (850 m) compared to five other sites in Turkey. Furthermore, Acer *et al.* (2021) studied Scolytinae species at eight experimental sites in Turkey and revealed that the number of species and individuals was high at an elevation of 1164 m.

Table 2. Number of *Orthotomicus erosus* captured in sampling sites of western Tehran during 2019-2020

Sampling sites	No.	Number of adults		Total number of adults	Mean number of trapped adults
		Trap 1	Trap 2		
Tabiat Park	72	746	741	1487	106.32 ± 0.07d
Khargush Darreh Forest Park	72	1063	1016	2079	135.26 ± 0.10c
Chitgar Park, behind Bam Riding Club	72	1131	1144	2275	153.17 ± 0.22b
Chitgar Park, 9th Aghaghiya Street	72	1326	1347	2673	183.25 ± 0.11a

The means followed by different letters in the same column are significantly different (P < 0.01).
No. is the number of sampling data for two traps at 10-day intervals during 12 months.
Mean number of trapped adults is for two traps in each sampling site during the whole monitoring experiment.

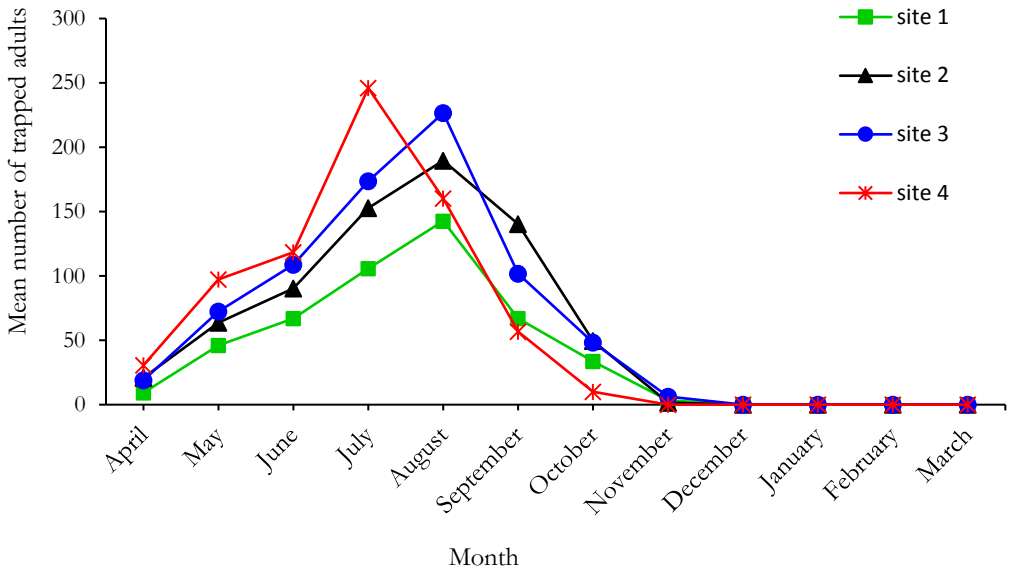

Fig. 3. Flight activity of *Orthotomicus erosus* adults in sampling sites of western Tehran during 2019-2020. Site 1: Tabiat Park, Site 2: Kharghush Darreh Forest Park, Site 3: Chitgar Park, behind Bam Riding Club, Site 4: Chitgar Park, 9th Aghaghiya Street

Since survival and population increase of bark beetle is influenced by thermal conditions, water stress, and coniferous resistance, their outbreaks have been directly/indirectly correlated with temperature and precipitation shifts (Logan & Powell, 2001). Mendel & Halperin (1982) studied the developmental rates at different constant temperatures (14-42°C) and revealed that no hatching occurred at <16°C and >40°C. Moreover, survival and developmental rates of *O. erosus* decreased at temperatures higher than 36°C (Mendel & Halperin, 1982). Despite adaptation to high temperatures, *O. erosus* adults might prefer to fly at temperatures as low as 12-18°C (Tribe, 1990; Gomez *et al.*, 2020) and so that they might disperse to higher latitudes and elevations (northwards) as mentioned in many other bark beetle species (Bentz *et al.*, 2010; Hill *et al.*, 2011). Previously, Ungerer *et al.* (1999) found that an increase of 3°C in minimum annual temperature might extend the northern distribution of other bark beetle species, *Dendroctonus frontalis* Zimm in forests of the south-eastern United States. In addition, Taylor *et al.* (2006) demonstrated the outbreak severity of *D. ponderosae* Hopk. was less at lower elevations (400-800 m) and the majority of these bark beetle outbreaks occurred at elevations of 800 to 1400 m. Therefore, the higher density of trapped adults in Chitgar Park, 9th Aghaghiya Street might be justified by the lower temperature (especially the lower summer temperature) in this station.

In total, 8514 adults of *O. erosus* were collected from pheromone traps in four sampling sites in western Tehran. Although *O. erosus* adults were monitored for seven months (from April to October) in Chitgar Park, 9th Aghaghiya Street, the total number of trapped adults (2673 adults) in this site was the highest compared to three other sampling sites (eight months of adult catches). In fact, the density of collected adults in pheromone traps was approximately twice higher in Chitgar Park, 9th Aghaghiya Street than in Tabiat Park (1487 adults). Similar results were reported during 2012 in Turkey where the number of adults per trap at an elevation of 850 m (the Menderes-Catalca site) was 132493 individuals. While in the Ulra site (elevation 120 m), the number of trapped adults was evaluated to be 69023 individuals (Sarikaya *et al.*, 2013).

Findings on population fluctuation and flight periods of *O. erosus* across different geographical locations would be a critical step in the distribution prediction of this destructive pest. The recent losses of pine trees by different bark beetle species in the Mediterranean countries and the Middle East such as Iran, emphasizes the need for a detailed understanding of abiotic variable effects on important interactions of pine forest resiliency and stability. It should be considered that in future climate change scenarios, successful distribution predictions of *O. erosus* in different geographical areas will be necessary for the establishment of a sustainable management program in planted and natural pine forests.

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پایش سوسک پوستخوار *Orthotomicus erosus* (Coleoptera: Curculionidae) با استفاده از تله فرومونی در جنگل‌های کاج غرب تهران

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چکیده

سوسک پوستخوار مدیترانه‌ای، *Orthotomicus erosus* (Wollaston) (Col.: Curculionidae: Scolytinae)، آفت مخرب جنگل‌های کاج در سراسر جهان است. به دلیل طغیان‌های اخیر *O. erosus* در ایران، فعالیت پروازی و تراکم جمعیت آفت در چهار منطقه آلوده در غرب تهران پایش شد. چهار منطقه نمونه‌برداری شامل پارک طبیعت، پارک جنگلی خرگوش دره، پشت باشگاه سوارکاری بام در پارک چیتگر و خیابان اقاقیای نهم در پارک چیتگر بودند. در هر منطقه نمونه‌برداری، دو تله فرومونی (فرومون ۶۰ روزه شرکت ECONEX اسپانیا) در ارتفاع ۲/۵ متری در قسمت جنوبی درخت نصب شد. تعداد حشرات بالغ در تله در فواصل ۱۰ روزه از فروردین ۱۳۹۸ تا اواخر اسفند ۱۳۹۸ شمارش شدند. طی نمونه‌برداری، تعداد ۸۵۱۴ حشره بالغ توسط تله‌های فرومونی جمع آوری شد. نتایج نشان داد که خروج حشرات بالغ در هر چهار منطقه نمونه‌برداری از فروردین ماه آغاز شد. دوره فعالیت پروازی حشرات بالغ در سه منطقه پارک طبیعت، پارک جنگلی خرگوش دره و پشت باشگاه سوارکاری بام پارک چیتگر تا اوایل آذر ماه ادامه داشت. به طور متفاوتی، آخرین حشرات بالغ در خیابان اقاقیای نهم پارک چیتگر در اوایل آبان‌ماه جمع‌آوری شدند. علاوه براین، اوج پرواز حشرات بالغ *O. erosus* در سه منطقه نمونه‌برداری پارک طبیعت، پارک جنگلی خرگوش دره و پشت باشگاه سوارکاری بام پارک چیتگر در مردادماه اتفاق افتاد. در حالی که در خیابان اقاقیای نهم پارک چیتگر بیش‌ترین حشرات بالغ در تیرماه به تله افتادند. بر اساس نتایج، میانگین حشرات بالغ به دام افتاده در مناطق مختلف نمونه‌برداری اختلاف معنی‌دار داشت. بیش‌ترین میانگین حشرات بالغ در تله (۰/۱۱ ± ۱۸۳/۲۵) در خیابان اقاقیای نهم پارک چیتگر و کم‌ترین آن (۰/۰۷ ± ۱۰۶/۳۲) در پارک طبیعت طی کل دوره نمونه‌برداری بود. یافته‌های حاضر در مورد فعالیت پروازی و نوسان جمعیت سوسک پوستخوار *O. erosus* در شرایط محلی می‌تواند در ایجاد یک برنامه مدیریتی کارآمد برای این آفت خطرناک مفید باشد.

کلمات کلیدی: سوسک پوستخوار، جنگل سوزنی‌برگ، فعالیت پروازی، متغیرهای جغرافیایی

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