IMPACT OF HIKING TRAIL DISTURBANCE ON ANTS` DIVERSITY AT MOUNT SINAI, ST. KATHERINE PROTECTORATE, EGYPT

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ABSTRACT

Saint Katherine Protectorate (SKP) is one of the most important regions for biodiversity in Egypt. Tourism and its associated activities has become the main economic driver in SKP which might have negative impacts on biodiversity. Ants are effective biological indicators, since ant species diversity correlates with the assembly of other invertebrate fauna of particular habitats. The current study aimed at assessing the impact of some anthropogenic activities along the touristic hiking trail passing through Mount Sinai area on ants` diversity. A total of 583 individuals belonging to nine ant species, three subfamilies, from (Family: Formicidae; Order: Hymenoptera) were recorded within the study localities in Mount Sinai. Our study showed that the hiking trail disturbance had a negative environmental impact on the species richness and abundance of ants within the study localities in Mount Sinai. Based on our results it is advisable to move the hiking trails to slopes of Mount Sinai away from its current location within the basins (farshs). More studies are needed to assess the impact of hiking trails and associated human activities on other biodiversity elements in SKP.

Keywords: Biodiversity, St Katherine, ant species, anthropogenic activities, tourism, Sinai, Egypt

INTRODUCTION

St. Katherine Protectorate (SKP) is a unique area for biodiversity. The biological resources of Saint Katherine protectorate have an important economic value, and its biodiversity is of great scientific interest. It includes Egypt's highest mountains, which support a unique collection of high altitude ecosystems, with a high diverse fauna and flora (Baha El Din, 2006) and a relatively high representation of endemic species (St. Katherine protectorate management plan (SKP-M.P.), 2003).

Mount Sinai (Mousa Mountain) is considered one of the highest peaks of Egypt with an altitude ≃ 2280m above sea level (SKP-M.P., 2003). It contains the most important biodiversity rich spots in St. Katherine area such as Farsh Elias, Farsh El Losa, Farsh Shoeab and Farsh El Hemar. A major hiking trail about 2 km long passes through these spots and is used by tourists and local inhabitants during their visits to the area.

Protected areas as biodiversity standards allow a separation of the direct effects of human impact on biodiversity from those of other environmental changes (Sinclair *et al.,* 2002). Accordingly, these regions present ideal systems for evaluating the impact of human activities. SKP faces severe threats to their conservation status (Fouda *et al.,* 2006). Some threats are global such as climate change and international tourism, whilst others arise from local socio-economic issues and necessities (e.g. the over-harvesting of wild resources) (Grainger and Gilbert, 2008). Nature-based tourism and recreation activities such as hiking, wildlife viewing, and cycling within and close to protected areas might had negative impacts on animal communities

and biodiversity within protected areas (Knight and Cole, 1995; Huhta and Sulkava, 2014). The use of hiking trails is one of the most important recreational activities that have widespread impacts on ecosystems (Queiroz *et al.*, 2014).

Ants are effective biological indicators, since ant species diversity correlates with the assembly of other invertebrate fauna of particular habitats (Majer, 1983). Ants have been used as indicator species in a number of studies (Gollan *et al.*, 2011; Schmidt *et al.*, 2013; Fisher *et al.*, 2014; Berberich *et al.*, 2016). Ants are diverse and abundant in most ecosystems (Roth *et al.*, 1994), and have a community structure that reflects the nature of the area in which they occur (Majer, 1983; Hoffmann, 2010; Gollan *et al.*, 2011).

Although hiking trail is certainly less harmful than a road, it may have an impact on small invertebrates; even a narrow hiking trail could fragment their habitat. A maintained hiking trail could act as a barrier to dispersal of non-flying species (Mader, 1984). Kwon (2015) reported that the impact of trails on ants is complex, requires thorough research. Shepherd (2010) in her study in SKP about the role of ants in conservation of the sinai baton blue butterfly, found four ant species belonging to the subfamily Formicinae and three ant species belonging to the subfamily Myrmicinae in Farsh Shoeab only.

Accordingly, this study aimed at assessing the impact of some anthropogenic activities along the touristic trail passing through Mount Sinai area (Farsh Elias, Farsh El Losa, Farsh Shoeab and Farsh El Hemar) on ants`

diversity. The study also aimed at identifying and quantifying ant species within the study localities in Mount Sinai.

MATERIALS AND METHODS

Study area:

St. Katherine protectorate expands over virtually the entire mountain massif of South Sinai with an area of 4,350 km² (SKP-M.P. 2003). SKP is characterized by the highest mountains in Egypt and a dense Wadi system. It was declared as a protected area in 1996 due to its cultural and biological values (SKP-M.P. 2003). SKP is characterized by a Saharo-Mediterranean climate. Summers are relatively hot, and winters are relatively cold (SKP-M. P. 2003). Its arid climate with little rains in winter reflected as a unique flora and fauna (Semida, 2006). SKP is the coolest area in Sinai due to its high elevation (1500–2641 m above sea level). According to SKP weather station, the lowest monthly mean minimum temperature ranges between 4 °C and 10 °C, while the highest monthly mean maximum temperature varies between 28 °C and 32 °C. The mean temperatures ranged from 9 °C to 26.5 °C while mean monthly relative humidity ranging between 29.4 and 54.5%. Annual precipitation for the 4-year period (2013–2016) averaged about 8 mm, occurring mainly in January, February, March, and December.

SKP is one of the richest spots for flora diversity in the Middle East; from which ≃ 472 plant species have been recorded (Fayed and Shaltout, 2004). Twinty six endemic plant species were recorded in SKP which comprise 42.6% of Egypt endemic plant species. These endemic species were mainly located in four main mountains namely: St. Katherine Mountain,

Serbal Mountain, Sinai (Musa) Mountain, and Umm Shaumer Mountain (Ramadan *et al.*, 2009).

In this study, four localities namely, Farsh Elias, Farsh El Losa, Farsh Shoeab and Farsh El Hemar were selected for monitoring and sampling of ants` species in SKP (Table 1; Fig. 1& 2).. These localities represent the main farshs (basins) above Mount Sinai. The vegetation structure among these localities was more or less the same.

Table 1: Geographic attributes of four study localities in Saint Katherine protectorate

Locality	Longitude (North)	Latitude (East)	Altitude (m) Above sea level
Farsh Elias	28.5462	33.9742	2045
Farsh El Losa	28.5487	33.9712	2000
Farsh Shoeab	28.5526	33.9669	2014
Farsh El Hemar	28.54646	33.96774	2030

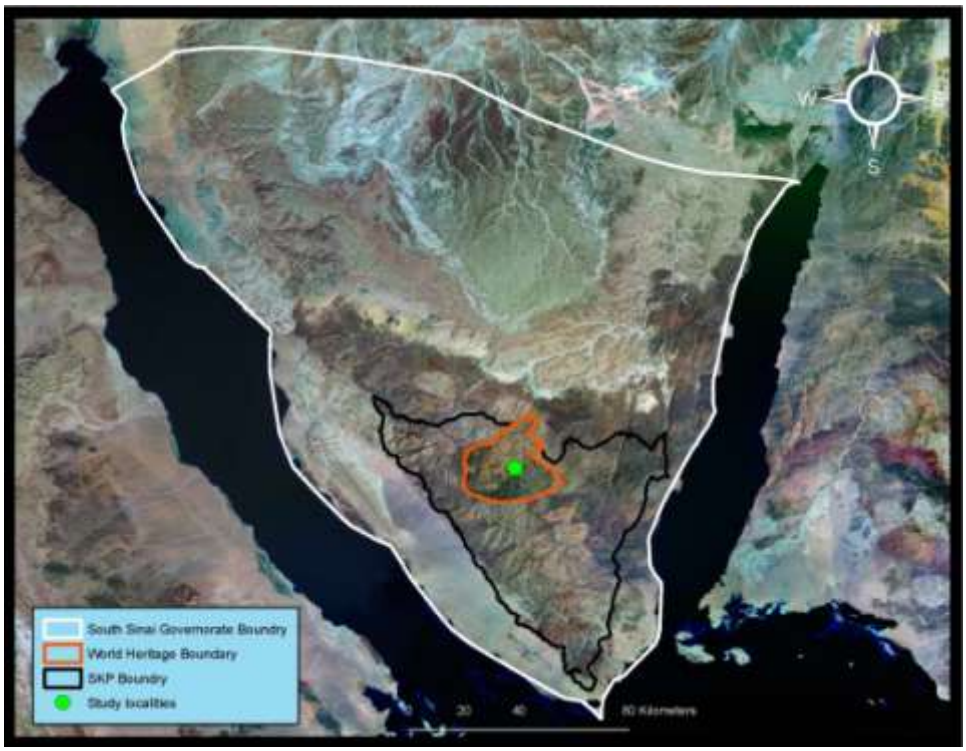

Fig. 1. Location map showing boundaries of South Sinai Governorate, World Heritage Site, and St. Katherine protectorate. (Map source: SKP, GIS unit & google map – https://www.google.com.eg/maps/@28.9319362,34.2174414,8z).

Fig. 2. Hiking trail passing through the four study localities. (**.**) Sampling points along the hiking trail
Map source: google map https://www.google.com.eg/maps/@28.5373631,33.977581,15z

Monitoring and identification of ant species

A bimonthly field survey started in January 2015 to December 2016. Each monitoring session spanned over six continuous days. To avoid a time bias for a particular monitoring site when recording ant species, each selected monitoring site was covered at different times of the day during the monitoring period.

Field monitoring of ant species across the touristic hiking trail passing through Mount Sinai area was carried out at different distances (~ 0, 10, 20 m) along both sides of the hiking trail in Farsh Elias, Farsh El Losa, Farsh Shoeby and Farsh El Hemar (Fig. 2). As a control, monitoring was conducted at a distance of 150 m along both sides of the hiking trail. Ant species were

sampled using pitfall traps. For identification of insect species, the collected samples were placed in a petri dish filled with an adequate amount of the fixative (10 parts of Formalin and 90 parts of Ethyl alcohol 60 %) to prevent sample dryness under examination. The manipulation of the samples was done under stereomicroscope (model МБС-9, USSR), using a fine forceps and a dissecting needle to prevent sample distortions. Ant species were identified using the key of Bolton (1994).

Data analysis:

Spatial variation of ant species in the study area was measured using species richness (S) and species evenness (E). Alpha diversity (α-diversity) within study localities was measured using Simpson`s diversity index, while beta diversity (β-diversity) among study localities was measured using the Jaccard similarity index. Chi-square test of goodness-of-fit was used to determine whether the different ant species were equally distributed in the population within the study localities in Mount Sinai and to determine whether there was a significant difference, in ant species richness among the study localities in Mount Sinai. Spearman correlation test was used to measure the relation between species richness and abundance of ants and distance from the hiking trail for assessing the impact of hiking trail on ants` species distribution within the study localities in Mount Sinai. Statistical analysis was carried out using SPSS computer package (ver.18, 2009).

RESULTS

1. Ants abundance and diversity in Mount Sinai:

A total of 583 individuals belonging to nine ant species, three subfamilies, from (Family: Formicidae; Order: Hymenoptera) were recorded from January 2015 through December 2016.

Spatial variation in ants` diversity among the study localities was given in Table 2. Most species belonged to subfamily formicinae. However, highest number of individuals collected belonged to subfamily Myrmicinae. Total ant diversity in Mount Sinai was 0.754 ± 0.007. A high variation in Simpson diversity index (1-λ) was reported among the study localities in Mount Sinai. The highest diversity was recorded in Farsh Shoeab (1-λ = 0.645 ± 0.015) and Farsh El Losa (1-λ = 0.579 ± 0.025). The species richness recorded for these localities was seven and five, respectively. Lowest diversity was recorded in Farsh Elias (1-λ= 0.409 ± 0.066) and Farsh El Hemar (1-λ = 0.312 ± 0.052). The species richness recorded for these localities was four and five, respectively.

Spatial distribution of ant species among the four study localities was given in Table 3; Fig. 3 & 4. Chi-square test of goodness-of-fit revealed that ant species were not equally distributed among the four study localities where an overall significant difference in ant species distribution among the study localities was recorded (χ^2 = 712.40, df =8, $P < 0.05$). The most dominant ant species in the study area was *Monomorium venustum.* Ant species distribution within each locality varied significantly. There was a significant difference in the ant species distribution in the population within Farsh El Hemar, (χ^2 = 306.320, df =4, $P < 0.05$), Farsh Shoeab (χ^2 = 416.399, df =6, $P < 0.05$),

Farsh El Losa (χ^2 = 102.333, df =4, $P < 0.05$) and Farsh Elias (χ^2 = 75.333, df =3, $P < 0.05$). The most dominant ant species was *Crematogaster aegyptiaca* in Farsh El Hemar, *Crematogaster antaris* and *Monomorium venustum* in Farsh Shoeab, *Monomorium venustum* and *Crematogaster aegyptiaca* in Farsh El Losa, and *Lepisiota hirsute* in Farsh Elias.

There was also no significant difference, in ant species richness among the four localities (Farsh El Hemar, Farsh Shoeab, Farsh El Losa, and Farsh Elias) in Mount Sinai (χ^2 = 0.90, df =3, P = 0.843).

Table 2. Spatial variations in the ants' diversity (measured by Simpson`s diversity index, species richness, and species evenness), within the study localities.

localities	Species Richness (S)	Simpson diversity index (1-λ)	Species Evenness(E)
Farsh El Hemar	5	0.312 ± 0.052	0.415
Farsh Shoeab	7	0.645 ± 0.015	0.633
Farsh El Losa	5	0.579 ± 0.025	0.619
Farsh Elias	4	0.409 ± 0.066	0.508
Study area (overall)	9	0.754 ± 0.007	0.705

Table 3. Spatial distribution of the ant species within the study localities in Mount Sinai.

The ant species	Subfamily	Number of individuals			
		Farsh El Hemar	Farsh Shoeab	Farsh El Losa	Farsh Elias
Camponotus fellah	Formicinae	0	2	0	0
Cataglyphis franchettii	Formicinae	6	2	0	0
Crematogaster aegyptiaca	Myrmicinae	103	6	41	0
Crematogaster antaris	Myrmicinae	4	131	0	1
Lepisiota gracilicornis	Formicinae	1	20	2	1
Lepisiota hirsuta	Formicinae	0	22	0	40
Lepisiota obtusa	Formicinae	0	0	2	0
***Monomorium venustum*.**	Myrmicinae	11	131	42	12
Tapinoma simrothi	Dolichoderinae	0	0	3	0

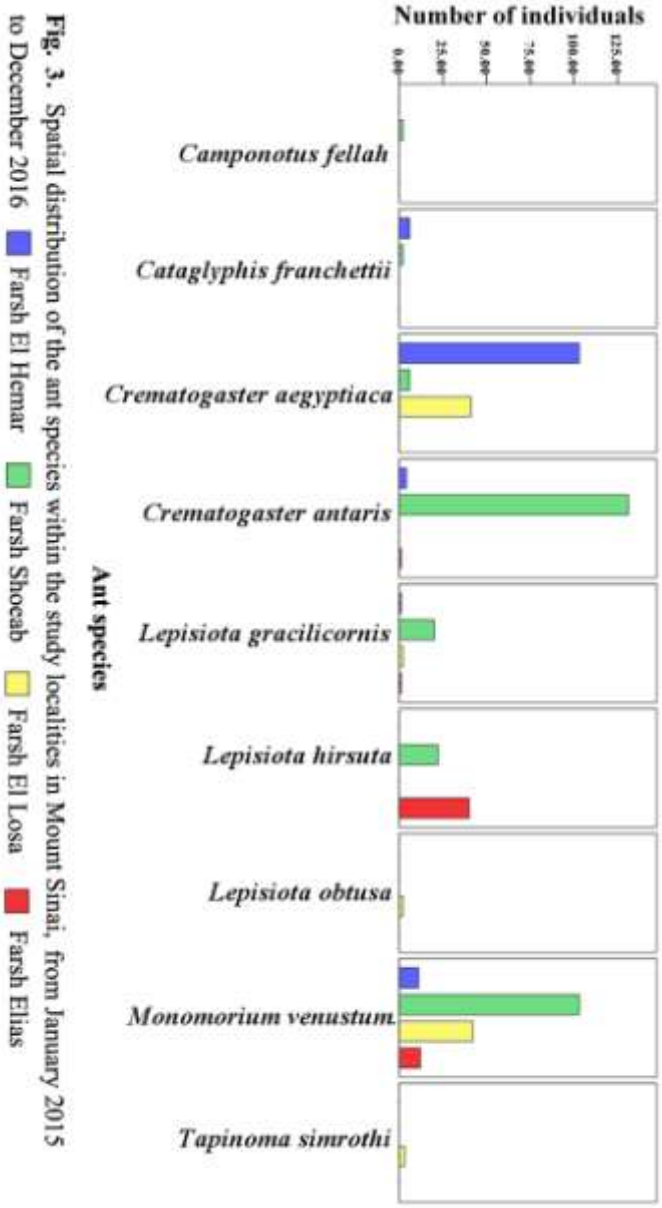

Fig. 3. Spatial distribution of the ant species within the study localities in Mount Sinai, from January 2015 to December 2016

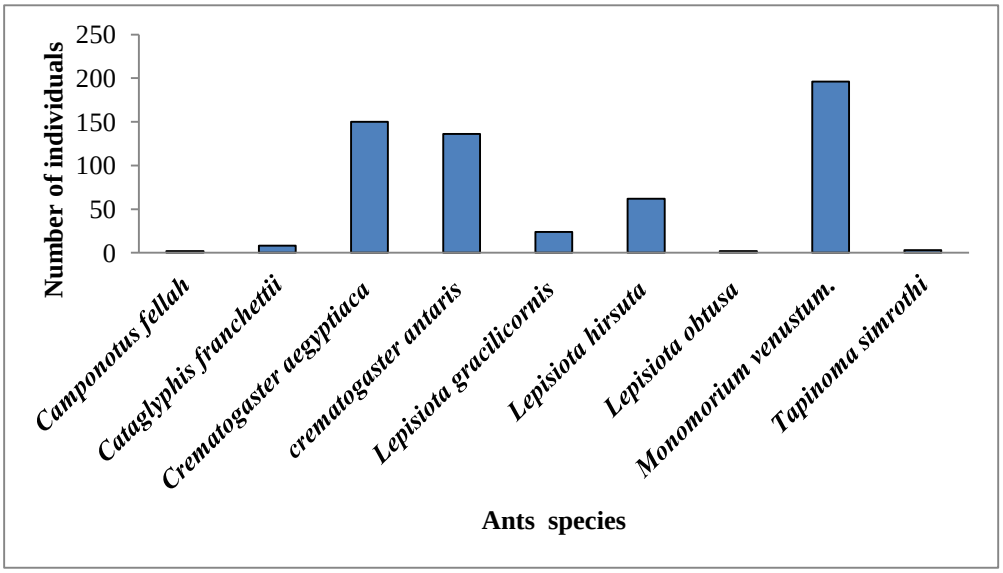

Fig. 4. Overall abundance of the ant species collected from the study localities in Mount Sinai.

2. Impact of hiking trail disturbance on the ant species richness and abundance distribution within the study localities in Mount Sinai

Ant species richness along the hiking trail was significantly positively correlated to the distance from the hiking trail (r_s = 0.475, $P < 0.01$). Highest ants' species richness was recorded at 150 m from the hiking trail (S= 5), and the ants' species richness recorded at 0 m, 10 m and 20 m was two, three, and four species, respectively (Fig. 5). Abundance of ant species along the hiking trail was significantly positively correlated to the distance from the hiking trail (r_s = 0. 087, $P < 0.05$). The highest ants' abundance was recorded at 150 m from the hiking trail (170 individuals), and the ants' abundance recorded at 0 m, 10 m and 20 m were 106, 150, and 129 individuals, respectively (Fig. 6).

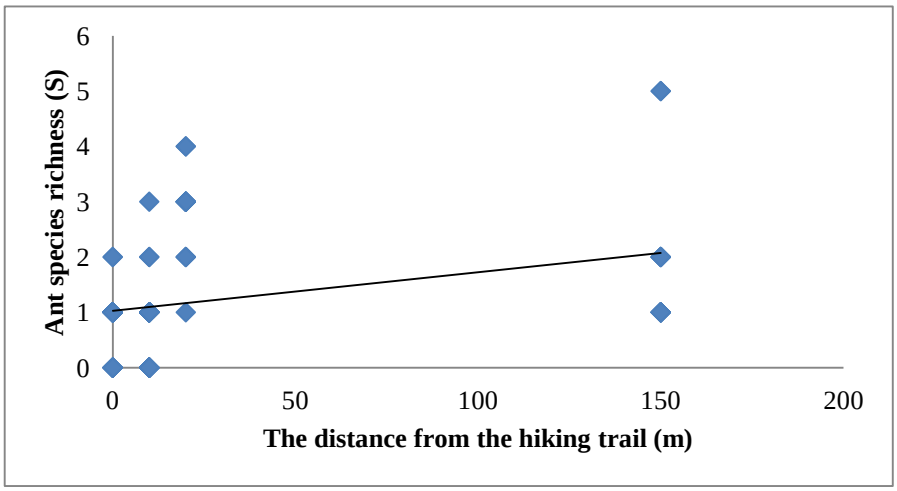

Fig. 5. The relationship between the distance from the hiking trail and the number of the ants' species richness within the study localities in Mount Sinai.

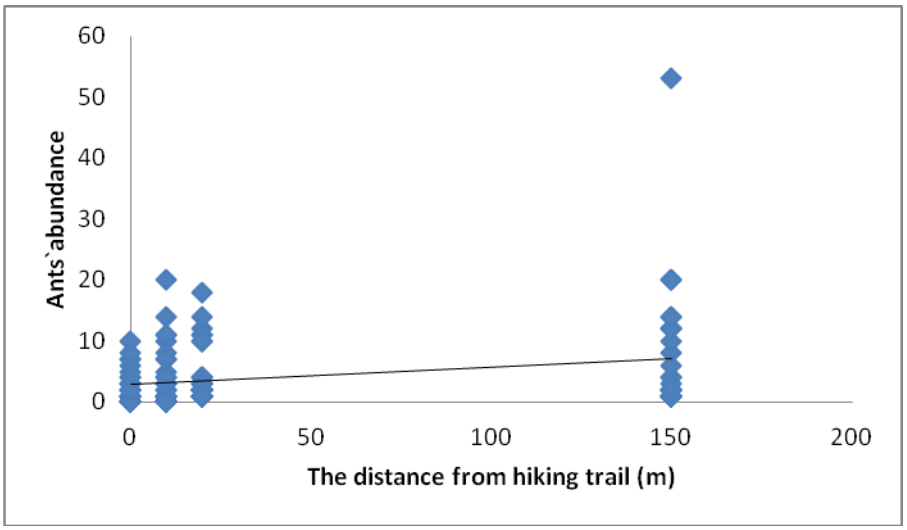

Fig. 6. The relationship between the distance from the hiking trail and the ants' abundance within the study localities in Mount Sinai.

3. Similarity indices of ant species composition between study localities.

Similarity index of ant species composition sites was calculated using Jaccard similarity index and given in Fig.7. Highest Jaccard similarity coefficients were observed between Farsh El Hemar and Farsh Shoeab (0.714), followed by Farsh El Hemar and Farsh Elias (0.536), followed by Farsh El Hemar and Farsh El Losa (0.349). The overall similarity ratio among communities was 71.8 %.

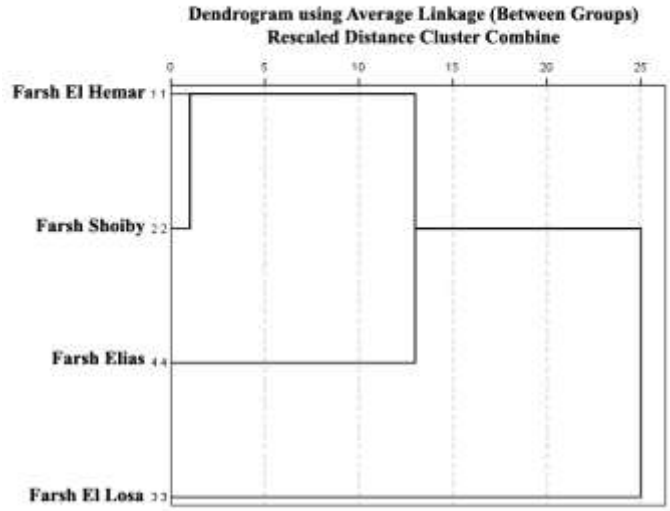

Fig. 7. Hierarchical cluster analysis of the study localities in Mount Sinai according to the type of the ants' species in each locality.

DISCUSSION

One of the most important challenges facing conservation biology was the increased human impacts on biodiversity hotspots (Zafra-Calvo *et al.*, 2010). Land use modifications are responsible for loss of biodiversity (Michelsen *et al.*, 2014). Species richness is used to assess the impact of habitat changing on biodiversity (Barragan *et al.*, 2011; Michelsen *et al.*,

2014) and human impacts may cause a strong effect on species richness and diversity patterns (Petraitis *et al.,* 1989). Generally, species richness is declining when human impacts increase at a local scale (Pautasso, 2007).

In this study, hiking trail passing through the four study localities (Farsh El Hemar, Farsh Shoeab, Farsh El Losa and Frash Elias) negatively impacted the species richness and abundance of ants in Mount Sinai as revealed by the positive correlation between the species richness and abundance of ants and the distance from the hiking trail within the study localities in Mount Sinai. This might be attributed to the increased mortality of ants by hikers on hiking trails. Similar results were obtained by Gray and Jongepier (2012) who reported a decrease in arthropod species diversity with an increase in human disturbance at Kirindy Forest, Western Madagascar. Hiking trails usage had negative impacts on insect populations, where hiking trail acts as a barrier to dispersal of non-flying species (Mader, 1984; Ciach *et al.,* 2017). Contrary to that, Kwon (2015) found that high ant abundance were observed towards the trail and less population tended to be located further from the trails. He related his finding to the effect of the high humidity level found further away from the trail and the low competition among ant species near trails on ant abundance.

Total ants' diversity among the study localities was 0.754 ± 0.007 reflecting the high diversity of the ant species in Mount Sinai. The highest ants' diversity and species richness were recorded in Farsh Shoeab. The highest Jaccard similarity coefficients were observed between Farsh El Hemar and Farsh Shoeab. This might be due to the common occurrence of five ant species in both localities. In addition, the high similarity in vegetation

structure and other physical environmental features might have influenced such high similarity. This agrees with the view of Aslan (2010) who reported that vegetation composition, topography, and human activities are the main influential factors on insect diversity.

CONCLUSION

It is advisable to move the hiking trails to slopes of Mount Sinai away from the basins (farshs) habitats. More studies are needed to assess the impact of hiking trails and associated human activities on other biodiversity elements in SKP.

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أثر الاضطراب الناتج عن مسار التنزه على التنوع الحيوي للنمل بمنطقة جبل سيناء، محمية سانت كاترين، جنوب سيناء، مصر

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المستخلص

تعتبر محمية سانت كاترين إحدى أهم مناطق التنوع الحيوي بمصر. وتعد السياحة والأنشطة المتعلقة بها من أهم الموارد الاقتصادية داخل محمية سانت كاترين والتي قد يكون لها أثر سلبي على التنوع الحيوي داخل المحمية. يعتبر النمل من الكواشف الحيوية المؤثرة حيث أن التنوع الحيوي للنمل يعكس مدى التنوع في باقي مجموعة اللافقاريات المتواجدة في نفس البيئة. لذا تهدف الدراسة الحالية إلى تقدير وتقييم تأثير بعض الأنشطة البشرية على طول مسار التنزه السياحي الذي يمر عبر منطقة جبل سيناء (فرش إلياس، فرش اللوزة، فرش شعيب وفرش الحمار) على التنوع الحيوي للنمل في تلك المناطق. وتم تسجيل خمسمائة وثلاثة وثمانين فرد من النمل تنتمي إلى تسعة أنواع حشرية وثلاثة عائلات ثانوية من (فصيلة فورماسيدي – رتبة غشائيات الأجنحة) داخل مناطق الدراسة في جبل سيناء. كما أظهرت الدراسة الحالية أن الاضطراب الناتج عن استخدام مسار التنزه السياحي له أثر سلبي على عدد الأفراد وثراء الأنواع المختلفة من النمل داخل مناطق الدراسة في جبل سيناء. واعتمادًا على نتائج الدراسة فإنه ينصح بنقل مسار التنزه السياحي الى منحدرات جبل سيناء بعيدًا عن المواقع الحالية داخل الفروش. يجب إجراء المزيد من الدراسات لتقييم تأثير مسارات التنزه والأنشطة البشرية المتعلقة بها على عناصر أخرى من عناصر التنوع الحيوي داخل محمية سانت كاترين.