Ectoparasite Fauna of Commensal Rodents Collected from the North Sinai Governorate - Egypt and its Public Health Significance

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Abstract | Rodents have a huge impact on the natural environment. Rat and mice are considered a natural host for a large number of ectoparasites. The present study aimed to determine the geographical distribution and ectoparasites infestation rates of commensal rats and mice collected from the North Sinai governorate - Egypt. The survey was conducted during the period from December 2016 to November 2017 in three different locations namely Bir el‘ Abd city, Rabaa, and Qattia villages located in the North Sinai governorate. The ectoparasites were isolated from four species of rodents including Rattus norvegicus (Brown rats), Rattus rattus frugivorus (Black rats), Rattus rattus alexandrinus, and Mus musculus (House mouse). The survey recovered and identified three species of fleas including Echidnophaga gallinacea, Xenopsylla cheopis, and Leptopsylla segnis, four species of lice including Holopropylea bursuta, Hophpleura ocanthopus, Hophpleura senomydis, Polyplax spinulosai, and five species of mites including Laelaps nuttalli, Dermanyssus gallinae, Ornithonyssus bacoti, Myobia musculi, Alldermanyssus sanguine. The distribution of the ectoparasites was identified according to several factors including rodent species, sex, location, and seasonal effects and the zoonotic role of some of the identified rodent ectoparasites was discussed.

Keywords | Rodents, Ectoparasite, North Sinai, Fleas, Egypt

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INTRODUCTION

Rodents have an important role in the maintenance and transmission of vector-borne zoonoses (Tomassone et al., 2018), they are considered the largest mammals order with wide species diversity; they can be found in all terrestrial environments which support life (Vaughan, et al., 2000). Rodents presented one of the health problems worldwide (Pakdad et al., 2012). They have huge negative impacts on the natural environment causing great economic losses to the livestock and human in direct and indirect ways (Harpera and Bunbury, 2015). Rodents can induce damage to properties like homes, apartments, hotels, office complexes, retail, and warehouse facilities, as well as, public utility operations (Abdel- Azeem, 2008). In urban environments, rodent species such as Norway rats (Rattus norvegicus) are prevalent and pose a threat to public health by serving as a vector and/or reservoir host with their ectoparasites for various pathogens that can be transmitted to humans and livestock (Chagas et al., 2017).

Ectoparasites that infest rodents include various species of fleas, lice (Insecta), ticks, and mites (Acari); they can serve as vectors of several diseases including bubonic plague, murine typhus, and tularemia (Mohd Zain et al., 2015).

From the public health perspective, rodents considered a key role in the transmission of many zoonotic disease-
es such as plague, leishmaniasis, typhus, and salmonellosis (Hamidi et al., 2015). Besides, they can host some of the ectoparasites that act as vectors of pathogens as bacteria, viruses, helminths, and protozoa with their health problems in human (Kia et al., 2009). Rodents can harbor four groups of ectoparasites fleas (Siphonaptera), ticks (Acari), mites (Mesostigmata), and lice (Siphonaptera) (Asiry and Fetoh 2014). Flea species are considered to be one of the most important vectors of human infectious diseases in the world, for instance, they are capable of transmitting plague through their bites, particularly Xenopsylla cheopis, additionally, they are playing a role in the transmission of Bartonella spp. and tularemia (Bendek et al., 2011). Concerning the rodent lice, they are important vectors for Haemobartonella muris and Rickettsia typhi (Farahat et al., 2014). Mites are temporarily ectoparasites that can infest humans and animals, causing severe irritation by their bites, which may lead to allergic dermatitis or respiratory allergy especially in children (Farahat et al., 2014).

In Egypt, rats and mice are considered the most damaging wild vertebrates based on economic losses and health-related issues. They are very common in many Egyptian Governorates (Yassin, 2009). Consequently, the data on rodents and their relationships with ectoparasites in Egypt is limited, therefore, the main objective of this study was to determine the distribution and infestation rates of ectoparasites that parasitizing rats and mice in this area and discuss our results in the context of possible zoonotic disease risk based on the hosts and vectors present.

MATERIALS AND METHODS

Rodent’s collection
The study was designed as cross-sectional study considering the detection of the period prevalence of the rate of infestation amonge rats in the North Sinai governorate-Egypt. The survey was conducted during the period from December 2016 to November 2017 in three geographical locations namely Bir el-`Abd city, Rabaa, and Qatia villages located at the North Sinai governorate, Egypt. Rodent species were collected by applying the common wire traps. The traps were placed close to the walls inside and outside houses and near the household poultry and livestock animals (sheep and goat). Before applying, the traps were thoroughly cleaned with hot water and quaternary ammonium compound based detergent and baited with fresh food (tomato slices, carrot, fish, cucumber, cheese, and canned salmon). The traps were distributed in the evening and checked in the early morning before sunrise. The baits were changed from time to time to ensure maximum catch probability.

The captured rodents were transported to the laboratory,
Table 1: Taxonomic taxa of ectoparasites species grouped by families collected from commensal rodents from three location of the North Sinai, Egypt.

| Ectoparasite | No. Examined rodents examined | No of rodent with ectoparasites | Prevalence (%) | No of Ecto-parasite Individual | Constituent ratio (C) | Index Mean Abundance (MA) |
|--------------|-------------------------------|---------------------------------|----------------|-------------------------------|----------------------|-------------------------|
| Fleas        | 119                           | 67                              | 56.3           | 230                           | 1.93                 | 230/67 (3.43)           |
|              |                               |                                 |                | 28.50                         |                      |                         |
| Lice         | 119                           | 40                              | 33.61          | 87                            | 0.73                 | (2.18)                  |
| Mites        | 119                           | 87                              | 73.11          | 490                           | 4.11                 | 5.63                    |
| Total        | 807                           | 100                             |                | 4.16                          |                      |                         |

Table 2: Prevalence of ectoparasite infestation in rodents species captured from the three localities in North Sinai Governorate, Egypt during the period from December 2016 till November 2017

| Ecto-parasite | No. Examined rodents examined | Total Prevalence No. (%) | Flea                      | Lice                      | Mites                     |
|---------------|-------------------------------|--------------------------|---------------------------|---------------------------|---------------------------|
| Rat Species   |                               |                          |                           |                           |                           |
| R. norvegicus | 82                            | 69 (84.15)               | 45 (54.88)                | 31 (37.80)                | 58 (70.73)                |
| R. r. frugivorus | 28                        | 27 (96.43)               | 17 (60.71)                | 9 (32.14)                 | 25 (89.29)                |
| R. r.alexandrinus | 6                        | 5 (83.33)                | 5 (83.33)                 | 0                         | 4 (66.67)                 |
| M. musculus   | 3                             | 0                        | 0                         | 0                         | 0                         |
| Total         | 119                           | 101 (84.87)              | 67 (56.30)                | 40 (33.61)                | 87 (73.11)                |

Rodent sex

| No. Of Examined rodents | Total Prevalence No. (%) | Flea                      | Lice                      | Mites                     |
|-------------------------|--------------------------|---------------------------|---------------------------|---------------------------|
| Male                    | 54                       | 45 (83.33)                | 33 (61.11)                | 12 (22.22)                | 36 (66.67)                |
| Female                  | 65                       | 56 (86.15)                | 34 (52.31)                | 28 (43.08)                | 51 (78.46)                |

Table 3: Prevalence of ectoparasite infestations according to the collected rodent species, the host sex, area of collection and seasons.

| Item       | No. Of Examined rodents | Total Prevalence No. (%) | Flea                      | Lice                      | Mites                     |
|------------|-------------------------|--------------------------|---------------------------|---------------------------|---------------------------|
| Rat Species|                         |                          |                           |                           |                           |
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| M. musculus | 3                      | 0                        | 0                         | 0                         | 0                         |
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Locations

| No. Of Examined rodents | Total Prevalence No. (%) | Flea                      | Lice                      | Mites                     |
|-------------------------|--------------------------|---------------------------|---------------------------|---------------------------|
| Bir el-`Abd             | 76                       | 70 (92.11)                | 39 (51.32)                | 25 (32.89)                | 55 (72.37)                |
| Rabaa                   | 23                       | 23 (100)                  | 16 (69.57)                | 8 (34.78)                 | 16 (69.57)                |
| Qatia                   | 20                       | 18 (90)                   | 12 (60)                   | 7 (35)                    | 16 (80)                   |

Seasons

| No. Of Examined rodents | Total Prevalence No. (%) | Flea                      | Lice                      | Mites                     |
|-------------------------|--------------------------|---------------------------|---------------------------|---------------------------|
| Winter                  | 24                       | 18 (75)                   | 1.33±0.08                 | 3.33±0.03                 | 3.66±0.18                 |
| Spring                  | 27                       | 24 (88.89)                | 7.0±0.64                  | 2.66±0.03                 | 8.0±0.08                  |
| Summer                  | 26                       | 24 (92.31)                | 4.66±0.06                 | 3.00±0.05                 | 8.00±0.15                 |
| Autumn                  | 42                       | 35 (83.33)                | 9.33±0.23                 | 4.33±0.66                 | 9.33±0.62                 |
Means carrying different superscripts in the same column are significantly different at \( P \leq 0.05 \) or highly significantly different at \( P < 0.01 \). Means carrying the same superscripts in the same column are non-significantly different at \( P < 0.05 \).

\( SE = \)standard error.

**Prevalence of ectoparasite infestations according to the rodent species**

*R. norvegicus, R.r.frugivorus* were the most infested individuals, they were parasitized with three groups of ectoparasites; fleas, lice, and mites. On the other hand, and *R.r. alexandrinus* was parasitized with only two groups of ectoparasites; fleas and mites. *M. musculus* didn't show any infestation with the ectoparasites species (Table 2).

**Prevalence of ectoparasite infestations according to the location.**

In the present study, there is a change in the prevalence rate with different geographical locations. The highest infestation rate was localized in Rabaa although the number of rodents collected from this area was the lowest. Concerning the mites and, lice, the highest infestation rate was detected in the Qatia by 80% and 35%, respectively, while the flea highest infestation rate was detected in Rabaa by 69.57% (Table 3).

**Prevalence of ectoparasite infestations according to the host sex.**

The ectoparasites’ infestation rate was higher in females than males, the infestation rate of male individuals was 83.33%, while in females was 86.15% (Table 3).

**Prevalence of ectoparasite infestations according to the seasons.**

The highest prevalence rates were recorded in the autumn season for both Flea and Mites, meanwhile, there were no significant differences detected in lice infestations with the seasonal fluctuations (Table 3).

**Morphological description of the collected ectoparasites**

**Morphological description of the collected fleas (Insecta: Siphonaptera)**

*Family: Pulicidae*

*Xenopsylla cheopis* (Rothschild,1903)

Angulated head, wingless insects compressed laterally, dark brown, the thorax is not reduced, the thoracic segments together are wider than the first abdominal segment, absence of ctenidia, more than one post occipital bristles, and the presence of mesopleural rod Figures 1 D and E.

*Echidnophaga gallinacea* (Westwood, 1875)

Angulated fronts, well-developed occipital lobe, genal lobe directed backward, the thorax narrower dorsally than the tergum of the first abdominal segment, absence of ctenidia, and the presence of two posts occipital bristle Figures 1 A and B.

*Leptopsylla segnis* (Schönherr, 1811)

The presence of genal and pronotal ctenidia, vertical genal ctenidia composed of four elements, and pronotal ctenidia present as presented in Figure 1C.

**Figure 1:** Light microscopy (LM) of permanent preparation of Flea spp. (X10)

A&B: *Echidnophaga gallinacea*; C: *Leptopsylla segnis*; D & E: *Xenopsylla cheopis*

**Family: Leptopsyllinae**

*Leptopsylla segnis* (Schönherr, 1811)

The presence of genal and pronotal ctenidia, vertical genal ctenidia composed of four elements, and pronotal ctenidia present as presented in Figure 1C.

**Morphological description of the collected sucking lice**

(Insecta: Anoplura)

**Family: Hoplopleuridae (Ferris, 1951)**

The Antennae were five-segmented, similar in males and females. The first pair of legs were small with slender claws, the second pair was larger with broader claws, and the paratergal plates project apically from the body with distinct tergal and sternal plates.

*Hoplopleura hirsuta*

Characterized by the presence of six pairs of distal abdominal setae, females presented paratergal plates by 4–6 only slightly elongated, and males with only seven tergal plates bearing a row of setae (Figures 2 A, B, C).

*H. ocanthopus*

Slender, 1–2 mm, characterized by large paratergal plates which are four and five with two large setae on posterior margin (Figures 2 D, E, F).
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Figure 2: Light microscopy (LM) of permanent preparation of lice spp. (X40)
A, B, C: *Hoplopleura hirsuta*; D, E, F: *Hoplopleura ocanthopus*

*H. oenomydis*
Abdomen with setae in the membrane between sternal and paratergal plates (Figures 3A and B). Family: Polyplacidae

*Polyplax spinulosa*
Paratergal plates 3-5 with only dorsal apical angle produced into a point as in Figures 3C and D.

Figure 3: Light microscopy (LM) of permanent preparation of lice spp. (X40)
A&B: *Hoplopleura oenomydis*; C&D: *Polyplax spinulosa*

Morphological description of the collected mites
Family: Dermanyssidae (Kolenta, 1859)
*Ornithonyssus bacoti* (Hirst, 1931)
The dorsal plate is narrower than in the other species and tapers gradually to a blunt point. Setae of the same size. There are no teeth on the chelicera (Figures 4A and B).

*Dermanyssus gallinae* (DeGeer, 1778)
The dorsal shield does not reach the post end and the post-ed margin. The setae are smaller on it than around the dorsal plate (Figures 5A and B).

*Allodermanyssus sanguine* (Hirst, 1914)
Has 2 dorsal plates, the sternal plate bears all three pair of setae (Figure 4D).
Family: Laelaptidae

*Laelaps nuttalli* (Hirst, 1915)
Hypostome has a dorsal labrum of two lobes covered with minute papillae, segmented chelicerae, and ventral labium carrying two median lobes with laciniæ and two lateral club-like lobes. Palpal and foreleg tarsal organs comprised ten and fifteen sensilla, respectively. Each pulvillus terminated with two medioventral claws and integumental folds beside longitudinal folds (Figures 5C and D). Family: Myobiidae

*Myobia musculi* (Schranck, 1781)
has four pairs of legs, but the first pair is very short as an adaptation for grasping the hair shaft and giving the second pair of legs end in empodia (claw-like structures) (Figure 4C).

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Rodents play an important role in the transmission of several pathogens, also, they affect the arthropod vectors abundance; consequently, the increase in zoonotic risk (Tomassone et al., 2018). One of these important rodents is rats that act as hosts for vector-borne diseases; they act as a source of infection for vectors besides they serve as hosts for the vectors themselves, supporting their populations (Easterbrook et al., 2007). They provide a stable habitat for a wide variety of ectoparasites that are considered as vectors of many zoonotic diseases (Krasnov et al., 2004) such as plague, leishmaniasis, and typhus. The risk of human exposure to these numerous pathogens is a public health concern, some of these pathogens can cause less or even non-symptomatic diseases in humans, besides, there are difficulties in the diagnosis of these infections in humans (Easterbrook et al., 2007). Several epidemiological studies described the relationship between the rodents and their vectors in a high prevalence and great diversity. For instance, the relationship in rodents and their flea parasites with *Bartonella* species are complicated, evolving scenarios and reflect the high degree of adaptation of these organisms (Gutiérrez et al., 2015).

The rodent species captured in this survey were *R. norvegicus*, *R. r. frugivorus*, *R. r. alexandrinus*, and *M. musculus*. They are the most common rat species of ecological and public health significance (Bonnefoy et al., 2008). These species were also recorded in Egypt by El Kady et al. (2009) in Behera governorate, Yassin, (2009) in Qaliubiya, and Soliman and Mikhail, (2011), Desoky et al. (2015). The current study revealed that four species of lice were recovered; *Hoplopleura bursuta*, *Hoplopleura ocanthopus*, *Hoplopleura oenomysida*, and *Polyplax spinulosa*. The present findings went parallel with those reported by Abdel-Azeem, (2008), Pakdad et al. (2012) and Chakma et al. (2017) who recorded the same species infesting rodents. Lice are species-specific (Madinah, et al., 2013) and they harbor zoonotic pathogens such as plague bacilli and can transmit *tularemia* and bartonellosis to humans, besides, their bites can cause severe pain, irritation, and anemia in severe infestation (Bowman et al., 2003).

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The current findings revealed that the overall prevalence of infested rodents with ectoparasites was 84.87%, the highest ectoparasite infestation rates were recorded in Rabaa. Some studies also recorded the relationship between the density, prevalence of ectoparasite groups, and the localities of the hosts such as Farahat et al. (2014).

Mites are temporally blood-sucking ectoparasites of mammals. Rodent mites frequently attack humans living in rodent-infested buildings and their bites may produce irritation and sometimes painful allergic dermatitis or mite respiratory allergy particularly in children (Bakr et al., 1995). Mite species could play a role in the epidemiological triad of murine typhus and the Seoul virus (Himsworth et al., 2015). The current study recovered five species of mites that were identified as *Laelaps nuttalli*, *Dermanyssus gallinae*, *Ornithonyssus bacoti*, *Myobia musculi*, and *Alldermanyssus sanguine*. Many studies reported these mite species on different hosts including Bahgart (2013), Soliman et al. (2001) and Telmadarraiy et al. (2007). Mites and fleas were the most predominant ectoparasites of the all-identified rodents species, with exception of *Mus musculus* that didn't show any infestation with the ectoparasites species. The high infestation rate of ectoparasite species in *Rattus norvegicus* and *Rattus rattus* were attributed to the ecological and behavioral characters related to each species, as well as, these species' preferences for more crowded localities where houses and cultivated areas were located (Heaney et al., 2005). In addition to the morphological features such as the size and differences in the skin and the fur covering it (Hamidi et al., 2015), *Rattus* species are characterized by dense fur comparing with *M. musculus* which are small in size with thin fur (Solanki et al., 2013).

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Fleas species can transmit many zoonotic pathogens from rodents to humans through their bites. Such as *Yersinia pestis* which is the causative agent of Plague. In the current study, three species of flea were identified *E. gallinacea*, *X. Cheopis*, and *L. segnis*. These species were also recorded in Egypt by Soliman and Mikhail, (2011), Desoky et al. (2014) and Loftis et al. (2006), who also recovered these species from mammals in 17 cities of Egypt.

The current study revealed that four species of lice were recovered; *Hoplopleura bursuta*, *Hoplopleura ocanthopus*, *Hoplopleura oenomysida*, and *Polyplax spinulosa*. The present findings were parallel with those reported by Abdel-Azeem, (2008), Pakdad et al. (2012) and Chakma et al. (2017) who recorded the same species infesting rodents. Lice are species-specific (Madinah, et al., 2013) and they harbor zoonotic pathogens such as plague bacilli and can transmit *tularemia* and bartonellosis to humans, besides, their bites can cause severe pain, irritation, and anemia in severe infestation (Bowman et al., 2003).

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nancy and lactating, similar findings were recorded by Kia et al. (2009) and Asiry and Fetoh (2014).

**CONCLUSION**

The study was carried out to establish baseline data for ectoparasite-infested rodents in the North Sinai region - Egypt and may help for appropriate planning to control and eradicate zoonotic diseases in this area. Further studies are required to determine new methods of control for these rodents and ectoparasites.

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**ETHICS**

This study was approved by the Ethics Committee of the Suez Canal University. All animal experiments were conducted following the guidelines of the Guide for the Care and Use of Laboratory Animals, Faculty of Veterinary Medicine Science, Suez Canal University, Egypt (approval number 2020004).

**CONFLICT OF INTEREST**

The authors have no conflicts of interest relevant to this article.

**AUTHORS CONTRIBUTION**

All the authors contributed equally during the study.

**REFERENCES**

• Abdel-Azeem (2008). M IEcological studies on some commensal rodent species and their ectoparasites in different habitats at Sharkia governorate. M. Sc. Thesis, Fac. Agric. Suez Canal University, Egypt. 2008. 193.

• Asiry KA, Fetoh Bel-S (2014). Occurrence of ectoparasitic arthropods associated with rodents in Hail region northern Saudi Arabia. Environ. Sci. Pollut. Res. Int. 21: 10120-10128. https://doi.org/10.1007/s11356-014-3016-3

• Bahgat IM (2013). Monthly abundance of rodent and their ectoparasites in newly settled areas, east of lakes, Ismailia Governorate, Egypt. J. Egyptian Soc. Parasitol. 43: 387-98. https://doi.org/10.12816/0006394

• Bakr M, Morsy T, Nasref N, El Meligi M (1995). Flea ectoparasites of commensal rodents in Shebin El Kom, Menoufa Governorate, Egypt. J. Egyptian Soc. Parasitol. 26:39-52.

• Bendek AM, Sirbu I, Lazar AM, Cheoca D (2011). Ecological aspects of ectoparasites’ infestation in the yellow-necked mouse (Apodemus flavicollis: Rodentia, Muridae) from Transylvania (Romania). Proceedings of the 11th International Conference on Environment: Adv. Environ. Ecosyst. Sustain. Tourism. Pp. 197-202.

• Bonnefoy X, Kampen H, Sweeney K (2008). Public Health Significance of Urban Pests, World Health Organization, Copenhagen. Retrieved from, http://www.euro.who.int/__data/assets/pdf_file/0011/98426/E91435.pdf

• Bowman DD, Lynn RC, Eberhard ML (2003). Georgi’s Parasitology for veterinarians. St Louis: WB Saunders Co.

• Chagas CF, Gonzalez IL, Favoretto SM, Ramos PL (2017). Parasitological surveillance in a rat (Rattus norvegicus) colony in São Paulo Zoo animal house. Ann. Parasitol. 63: 291-297.

• Chakma S, Picard J, Duffy R, Constantinou C, Gummbow B (2017). A Survey of Zoonotic Pathogens Carried by Non-Indigenous Rodents at the Interface of the Wet Tropics of North Queensland, Australia. Transbound. Emerg. Dis. 64: 185-193. https://doi.org/10.1111/tbed.12360

• Desoky A, Baghdadi SA, Ahmed HS (2014). Population density and seasonal distribution of rodent species at sheep farming in El-Kawther City, Sohag region, Egypt. J. Plant Prot. Path. 5: 903-907. https://doi.org/10.21608/jppp.2014.88005

• Easterbrook JD, Kaplan JB, Vanasco NB, Reeves WK, Purcell RH, Kosoy MY, Glass, GE, Watson J, Klein SL. (2007). A Survey of zoonotic pathogens carried by Norway rat in Baltimore, Maryland, USA. Epidemiol. Infect. 135: 1192-1199. https://doi.org/10.1017/S0950268806000774

• El Kady G, Gheneam Y, Bahgat I (2008). Zoonotic helminthes of commensal rodents in Talkha Center, Dakahlia Governorate, J. Egyptian Soci. Parasitol. 38: 863-872.

• Farahat AF, Hassan MF, Abdelwahab MA (2014). Arthropod ectoparasites of Rattus norvegicus in four Governorates in Egypt and the effect of host location, sex and age on their prevalence. ACARINES. 9 (2): 11-18.

• Green SB, Salking NJ (2016). Using SPSS for Windows and Macintosh, Books a la Carte (8th Edition). Pearson ©ISBN: 0134319885 9780134319889.

• Gutiérrez R, Krasnov B, Morick D, Gottlieb Y, Khokhlova IS, Harres S (2015). Bartonella infection in rodents and their flea ectoparasites: an overview. Vector Borne Zoonot. Dis. 15(1):27-39. https://doi.org/10.1089/vbz.2014.1606

• Hamidi K, Nourani L, Moravej G (2015). The relationship of ectoparasite prevalence to the capturing season, locality and species of the murine rodent hosts in Iran. Persian J. Acarol. 4(4):409-23.

• Harpera GA, Bunbury N (2015). Invasive rats on tropical islands: Their population biology and impacts on native species. Global Ecol. Conservat. 3: 607-627. https://doi.org/10.1016/j.gecco.2015.02.010

• Heaney LR, Joseph S, Walsh JA, Peterson T (2005). The roles of geological history and colonization abilities in genetic differentiation between mammalian populations in the Philippine archipelago. J. Biogeogr. 32(2):229 – 247. https://doi.org/10.1111/j.1365-2699.2004.01120.x

• Hendrix CM (2011). Diagnostic Veterinary Parasitology, 4th Edition. Mosby; St. Louis, MO, pp., 74–76, 153–156, 178, 213–219.

• Himsworth CG, Bai Y, Michael YK, Wood H, DiBernardo A, Lindsay R, Bidulka J, Tang P, Jardine C, Patrick D (2015). An Investigation of Bartonella spp., Rickettsia typhi, and Seoul Hantavirus in Rats (Rattus spp.) from an Inner-City Neighborhood of Vancouver, Canada: Is Pathogen Presence...
a Reflection of Global and Local Rat Population Structure? Vector-Borne Zoonot. Dis. 15: 1. https://doi.org/10.1089/vbz.2014.1657

• Honey SF, Sarwar ZM, Bashir MH, Ali S, Kamran M, Afzal M (2014). Two New Species of AcotyledonOudemans, 1903(Acari: Acaridae)Infesting Stored Chickpea,Cicer arietinum, from Pakistan. Pakistan J. Zool. 46: 479-484.

• Kia E, Moghddas-Sani H, Hassanpoor H, Vatandoost H, Zahabiun F, Akhavan A, Hanafi-Bojd A, Telmadarraiy Z (2009). Ectoparasites of rodents captured in Bandar Abbas, southern Iran. Iranian J. Arthropod-borne Dis. 3(2): 44-49.

• Krasnov BR, Shenbrot GI, Khokhlova IS, Degen AA (2004). Flea species richness and parameters of host body, host geography and host 'milieu'. J. Anim. Ecol. 73(6): 1121-1128 https://doi.org/10.1111/j.0021-8790.2004.00883.x

• Loftis AD, Reeves WK, Szumlas DE, Abbassy MM, Helmy I M, Mioriarity JR, Dasch GA (2006). Surveillance of Egyptian fleas for agents of public health significance: Anaplasma, Bartonella, Coxiella, Ehrlichia, Rickettsia, and Yersinia pestis. American J. Trop. Med. Hyg. 75: 41-48. https://doi.org/10.4269/ajtmh.2006.75.41

• Mmetwaly A, Montasser S, Al-Gendy (2009). A Survey of rodent species and damage assessment caused by Meriones shawi isis (Thomas) in some field crops at Bustan area. J. Appl. Sci. Res. 5(1): 40-45.

• Mohd Zain SN, Amdan SK, Braima KA, AbdulAziz NM, Wilson JJ, Sithambaran P, Jeffery J (2015). Ectoparasites of murids in peninsular Malaysia and their associated diseases. Parasit. Vectors. 8: 254. https://doi.org/10.1186/s13071-015-0850-1

• Osborn DJ, Helmy I (1980). The Contemporary Land Mammals of Egypt (including Sinai).Fieldiana Zoology,5. Field Museum of Natural History, USA. https://doi.org/10.5962/bhl.title.2801

• Pakdad K, Ahmadi NA, Aminalroaya R, Piazzak N, Shahnehri M (2012). A Study on Rodent Ectoparasites in the North district of Tehran, Iran During 2007-2009. J. Paramed. Sci. (JPS). 3 (1): 2008-4978.

• Madinah A, Mariana A, Fatimah A, Abdullah MT (2013). A preliminary field survey of ectoparasites of rodents inurban park, Sarawak, Malaysian Borneo.Trop. Biomed. 30(3): 547–551.

• Solanki S K, Chauhan R, Rahman A, Solanki K (2013). Prevalence of Ectoparasites in commensal rats in Dehradun, India. Int. J. Curr. Microbiol. App. Sci. 2: 38–41.

• Soliman M I, Abd El-Halim AS, and Mikhail MW (2010). Rodent borne diseases and their fleas in Menoufia Governorate, Egypt. J. Egypt Soc. Parasitol. 40: 107-17.

• Soliman MI, Mikhail MW (2011). Field studies on dominant rodents and the efficacy of certain insecticides to their fleas in Dakahlia Governorate, Egypt. J. Egypt Soc. Parasitol. 41(2):315-26.

• Soliman S, Main AJ, Marzouk AS, Montasser AA (2001). Seasonal studies of commensal rats and their ectoparasites in a rural area of Egypt: the relationship of ectoparasites to the species, locality, and relative abundance of the host. J. Parasitol. 87:545-553. https://doi.org/10.1645/0022-3395(2001)087[0545:SSOCRA]2.0.CO;2

• Soulsby E (1986). Helminths, arthropods and protozoa of domestic animals, 7 edn. Bailliere M. Tindall, London.

• Telmadarraiy Z, Vatandoost H, Mohammadi S, Akhavan AA, Abai MR, Rafinejad J, Kia EB, Naini FF, Jedari M, Aboulhasani M (2007). Determination of rodent ectoparasite fauna in Sarpole-Zahab district, Kermanshah Province, Iran, 2004-2005. J. Arthropod-Borne Dis. 1(1): 58-62.

• Tomassone L, Berriatua E, De Sousa R (2018). Neglected vector-borne zoonoses in Europe: Into the wild. Vet. Parasitol. 251:1. https://doi.org/10.1016/j.vetpar.2017.12.018

• Vaughan JA, Ryan JM, Czaplewski NJ (2000). Mammalogy. 4th ed., Harcourt Inc., London, UK. 45:3. 371-396

• Yassin MK (2009). Ectoparasites infesting rats at mostorand bahteem Districts in Qualubiya Governorate, Egypt. Egyptian Acad. J. Biolog. Sci. 1: 95-101. https://doi.org/10.21608/ajbzs.2009.16025