


Submitted: 14/08/2021

Accepted: 29/11/2021

Published: 05/01/2022

Flea infestation on small wild mammals in Gharyan, Northwest Libya

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Abstract

Background: Fleas play a major role as vectors for many pathogens that affect humans and livestock. Wild animals, especially wild rodents, are the most important hosts, acting as reservoir hosts for many flea species and pathogens.

Aim: This study aimed to identify seasonality and hosts of fleas that parasitize small wild mammals in Gharyan, north-western Libya.

Methods: Fleas were collected from seasonally infested hosts from summer 2017 to winter 2018.

Results: This survey identified three flea species: *Pulex irritans*, *Xenopsylla cheopis*, and *Leptopsylla segnis*. *Pulex irritans* was collected from porcupines, *X. cheopis* from hedgehogs and jerboas, whereas *L. segnis* from gundis. The highest flea prevalence was in porcupines (35.00%) and the lowest was in gundis (11.11%). The highest intensity was in porcupines (10.43 ± 4.37), and the lowest was in jerboas (1.28 ± 0.24). The highest mean flea abundance was among porcupines of 3.65, whereas in hedgehogs, jerboas and gundis were less than 0.50 flea/host. *Pulex irritans* was collected during all seasons, while *X. cheopis* was collected during all seasons except winter, whereas *L. segnis* was collected only in spring.

Conclusion: The finding in this study has increased our awareness that small wild mammals can act as hosts for medically important flea species. All collected flea species have a great specialty in choosing their hosts. Flea intensity is affected by seasonal variations.

Keywords: Fleas, Gharyan, Libya, Siphonaptera, Wild mammals.

Introduction

Mammals, especially rodents, are considered as reservoirs of several pathogens; protozoa, helminths, bacteria, and viruses (Horta *et al.*, 2007); they are infested with ectoparasites which can transmit pathogens (Azad *et al.*, 1997; Perry and Fetherston, 1997; Morick *et al.*, 2011; Iannino *et al.*, 2017). Their ability to adapt to live in urban and rural settings has increased their ability to transmit pathogens to domestic animals and humans (Oliveira *et al.*, 2010).

Fleas (Siphonaptera) are highly specialized insects. About 2,575 flea species have been described, and they belong to 16 families and 238 genera (Bitam *et al.*, 2010). Some species are restricted or specialized to certain hosts, while others have a wide host range (Maleki-Ravasan *et al.*, 2017).

Over the past decades, dramatic changes have occurred in the geographic distribution and ranges of hosts of vector-borne pathogens; this process is often driven by climate changes and deforestation (Walsh *et al.*, 1993; Gottwalt, 2013). In the last 30 years, deforestation has occurred in Libya, leading to the immigration of wild animals from their environments to areas inhabited by humans. Those animals can carry many fleas and pathogens; therefore, fleas can be transmitted to human dwellings (Hosni and Maghrbi, 2014).

Studies of flea diversity, distribution, seasonality, and associated hosts are important for preventing and controlling outbreaks of potential flea-borne pathogens (e.g., plague). Hence, having a good taxonomical knowledge of potential fleas, associated hosts, and seasonality is crucial. There are no comprehensive studies in Libya on flea diversity, seasonality, and their hosts, especially in the Jabal Nafusa region. This study aimed to identify the seasonality and hosts of fleas that parasitize small wild mammals in Gharyan in the north-western part of Libya.

Materials and Methods

Study area

This survey was carried out from summer 2017 to winter 2018 in Gharyan, which is located on Jabal Nafusa (32.1718° N, 13.0184° E), in the north-western region of Libya (Fig. 1). A great diversity characterizes this region in terms of relief (mountains, hills, and valleys).

It is also characterized by seasonal herbs, annuals, and medium-sized plants, such as olive and fig trees. The climate is between the Mediterranean climate and the desert climate. According to Gharyan meteorological station (2017), the mean monthly rainfall is 49 mm, the mean monthly relative humidity is between 15% and 83%, and the temperature ranges from 4°C to 43°C .

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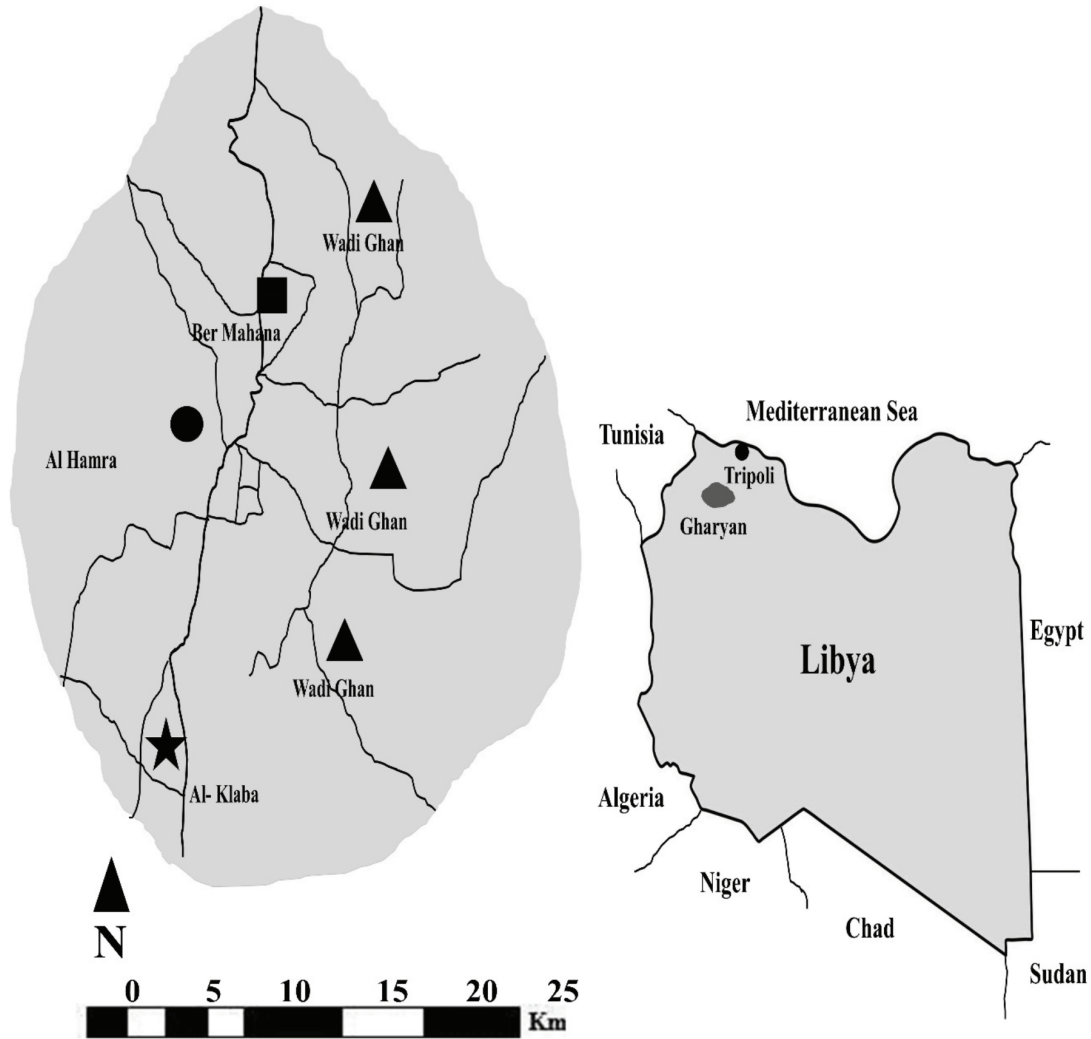


Fig. 1. Map of study area.

Table 1. FP, FI and MFA of wild mammals.

| Host | No. of examined animals | No. of infested animals | Flea species | No. of fleas collected | FP (%) | FI (fleas/ host ± SEs) | MFA (fleas/ host) |
|------------|-------------------------|-------------------------|---------------------------|------------------------|--------|------------------------|-------------------|
| Porcupines | 20 | 7 | <i>Pulex irritans</i> | 73 | 35.00 | 10.43 | 3.65 |
| Hedgehogs | 47 | 10 | <i>Xenopsylla cheopis</i> | 17 | 21.28 | 1.70 | 0.36 |
| Jerboas | 28 | 7 | <i>Leptopsylla segnis</i> | 9 | 25.00 | 1.29 | 0.32 |
| Gundis | 18 | 2 | <i>Leptopsylla segnis</i> | 7 | 11.11 | 3.50 | 0.39 |
| Over all | 113 | 26 | ----- | 106 | 23.00 | 4.08 | 0.94 |

(FP): flea prevalence; (FI): flea intensity; (MFA): mean flea abundance; (SEs): standard errors.

Animal capture and flea collection

Samples of wild mammals were collected seasonally in Gharyan during the study period. Porcupines (*Hystrix cristata*) and gundis (*Ctenodactylus gundi*) were captured using 16 live traps baited with bread and a

few vegetables. Traps were set in shadow and checked every other day in the early morning, whereas jerboas (*Allactaga elater*) were caught at night using a net. They were anesthetized with Calmivet® I.M, 3 ml for animals weighing approximately 5 to 7 kg and 1.5 ml for

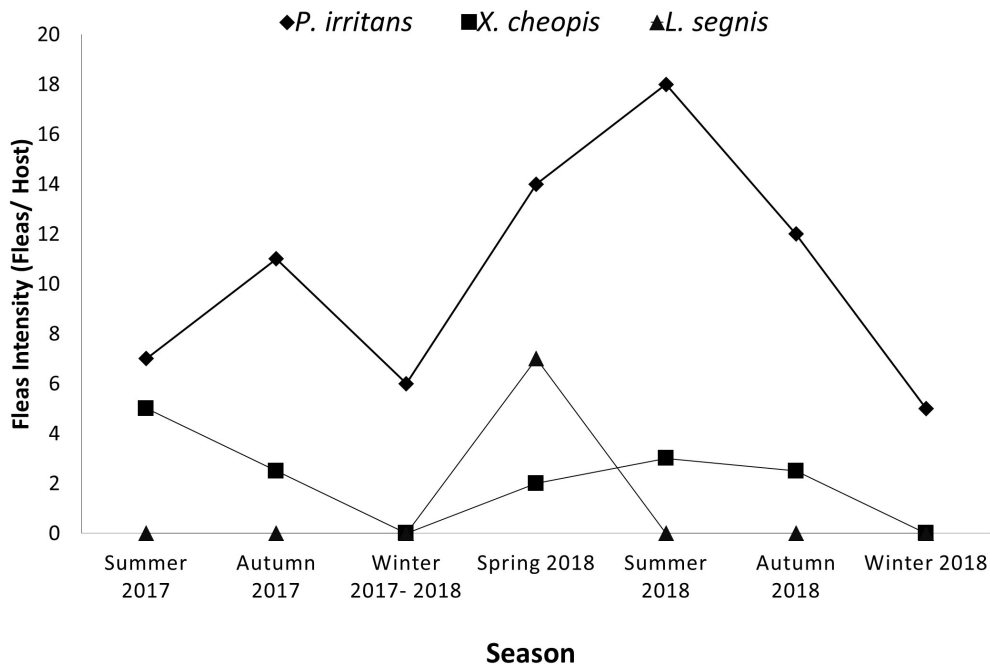


Fig. 2. Seasonal intensity of fleas that were collected in all seasons from Gharyan.

animals weighing less than 5 kg. Hedgehogs (*Atelerix algirus*) were caught by hand without anesthetization. After collecting fleas, the animals were released into their natural habitat. All fleas were collected from all infested hosts. In the case of hosts whose bodies were covered with hair and lint, fleas were collected using a metal comb (11 teeth per cm), whereas hosts whose bodies were covered with spines, fleas were collected from them by tweezers. Collected fleas were preserved in vials containing 70% ethanol. The samples were taken to the Laboratory of Entomology in Zoology Department, Faculty of Science, University of Tripoli, to mount and identify species levels by using an identification key (Smit, 1957).

Statistical analysis

The data were classified according to flea species, host species, sampling seasons, and area. Fleas per host, season, and area were calculated according to International Definitions Indicators (Yin *et al.*, 2011):

$$\text{Flea prevalence (FP)} = \frac{\text{number of hosts infested with flea}}{\text{total number of surveyed hosts}} \times 100$$

$$\text{Flea intensity (FI)} = \frac{\text{total number of fleas}}{\text{total number of hosts infested with fleas}}$$

$$\text{Mean flea abundance (MFA)} = \frac{\text{total number of fleas}}{\text{total number of surveyed hosts}}$$

The descriptive analysis of main characteristics was performed using means and standard errors (SEs) with FI as it includes the main values of fleas per infested animal. The means of collected fleas per

host and season were tested for the normality by the one-sample Kolmogorov-Smirnov test. As the means of the data were not normally distributed, the mean of FI was therefore compared by non-parametric tests (Kruskal-Wallis test and Mann-Whitney test) by SPSS (version 23.0.0, 2015), considering $p \leq 0.05$ as significant.

Ethical approval

Animal capture was carried out in compliance with the animal welfare guidelines (Ryan *et al.*, 2019).

Results

One hundred and six flea specimens were collected from 26 wild hosts; 10 hedgehogs, 7 porcupines, 7 jerboas, and 2 gundis (Table 1). About 69% of fleas were collected from porcupines, whereas hedgehogs, jerboas, and gundis were represented less than 20.00% each. Three species of fleas were identified; *Pulex irritans* which were collected only from porcupines, *Xenopsylla cheopis* collected from hedgehogs and jerboas, and *Leptopsylla segnis* was collected only from gundis. The highest FP was estimated in porcupines (35.00%), followed by jerboas (25.00%), whereas hedgehogs and gundis represented less than 25.00% each. Kruskal-Wallis H test revealed no significant difference in the prevalence of fleas among hosts ($H = 3$, $df = 3$, $p = 0.39$). The highest intensity was in porcupines (10.43 ± 4.37), and the lowest was in gundis (1.28 ± 1.22). There was no significant difference in FI among hosts (Kruskal-Wallis H test, $H = 3.00$, $df = 3$, $p = 0.29$). The highest MFA was in porcupines 3.65, whereas in hedgehogs, jerboas and gundis were less

Table 2. FP, FI and MFA of all flea species that collected from wild animals in Gharyan for the period from summer 2017 to winter 2018.

| | Species | <i>Pulex irritans</i> | | <i>Xenopsylla cheopis</i> | | <i>Leptopsylla segnis</i> | Overall |
|-------------|-------------------|-----------------------|-----------|---------------------------|--------|---------------------------|---------|
| | | Host | Porcupine | Hedgehog | Jerboe | Gundi | |
| Seasons | Summer 2017 | # caught hosts | 2 | 3 | 3 | 2 | 10 |
| | | # infested hosts | 1 | 2 | 1 | 0 | 4 |
| | | # fleas collected | 7 | 6 | 2 | 0 | 15 |
| | | FP (%) | 50 | 66.6 | 33.3 | 0 | 40 |
| | | FI | 7 | 3 | 2 | 0 | 3.75 |
| | | MFA | 3.5 | 2 | 0.7 | 0 | 1.5 |
| | Autumn 2017 | # caught hosts | 1 | 3 | 2 | 1 | 7 |
| | | # infested hosts | 1 | 1 | 1 | 0 | 3 |
| | | # fleas collected | 11 | 2 | 3 | 0 | 16 |
| | | FP (%) | 100 | 33.33 | 50 | 0 | 42.86 |
| | | FI | 11 | 2 | 3 | 0 | 5.33 |
| | | MFA | 11 | 0.7 | 1.5 | 0 | 2.29 |
| | Winter 2017-18 | # caught hosts | 3 | 6 | 3 | 3 | 15 |
| | | # infested hosts | 1 | 0 | 0 | 0 | 1 |
| | | # fleas collected | 6 | 0 | 0 | 0 | 6 |
| | | FP (%) | 33.3 | 0 | 0 | 0 | 33.3 |
| | | FI | 6 | 0 | 0 | 0 | 6 |
| | | MFA | 2 | 0 | 0 | 0 | 0.4 |
| Spring 2018 | # caught hosts | 1 | 5 | 4 | 3 | 13 | |
| | # infested hosts | 1 | 4 | 1 | 2 | 8 | |
| | # fleas collected | 14 | 4 | 1 | 7 | 26 | |
| | FP (%) | 100 | 80 | 25 | 66.6 | 61.54 | |
| | FI | 14 | 1 | 1 | 3.5 | 3.25 | |
| | MFA | 14 | 0.8 | 0.25 | 2.3 | 2 | |
| Summer 2018 | # caught hosts | 3 | 4 | 4 | 2 | 13 | |
| | # infested hosts | 1 | 1 | 2 | 0 | 4 | |
| | # fleas collected | 18 | 2 | 2 | 0 | 22 | |
| | FP (%) | 33.3 | 25 | 50 | 0 | 30.77 | |
| | FI | 18 | 2 | 1 | 0 | 5.5 | |
| | MFA | 6 | 0.5 | 0.5 | 0 | 1.69 | |
| Autumn 2018 | # caught hosts | 1 | 7 | 2 | 3 | 13 | |
| | # infested hosts | 1 | 2 | 1 | 0 | 4 | |
| | # fleas collected | 12 | 3 | 1 | 0 | 16 | |
| | FP (%) | 100 | 28.57 | 50 | 0 | 30.77 | |
| | FI | 12 | 1.5 | 1 | 0 | 4 | |
| | MFA | 6 | 0.33 | 0.33 | 0 | | |
| Winter 2018 | # caught hosts | 2 | 9 | 3 | 2 | 16 | |
| | # infested hosts | 1 | 0 | 0 | 0 | 1 | |
| | # fleas collected | 5 | 0 | 0 | 0 | 5 | |
| | FP (%) | 50 | 0 | 0 | 0 | 50 | |
| | FI | 5 | 0 | 0 | 0 | 5 | |
| | MFA | 12 | 0.43 | 0.5 | 0 | 1.23 | |

(FP): flea prevalence; (FI): flea intensity; (MFA): mean flea abundance.

than 0.40. There was no significant difference in flea abundance among hosts (Kruskal-Wallis H test, $H = 3.00$, $df = 3$, $p = 0.20$).

Seasonality

Pulex irritans was collected in all seasons, while *X. cheopis* was collected in all seasons except winter, whereas *L. segnis* was only collected in spring (Fig. 2). The highest values of fleas' indicators in all hosts were in summer and autumn, followed by spring, and the lowest in winter (Table 2).

Discussion

In recent years, most studies in Libya regarding medical and veterinary entomology have focused on ticks and mosquitoes, and they have not focused much on fleas. This is the first study investigating flea fauna, which parasitizes wild hosts in Gharyan, Libya. During the last 30 years, deforestation due to human activity has been observed in Libya, which has led to the immigration of wild animals from their natural habitat to areas inhabited by humans and domestic animals. As a result, small wild mammals have become synanthropic species in new habitats (Hosni and Maghrbi, 2014).

Only 113 wild hosts were captured; it is not easy to capture such hosts, as they inhabit rugged mountainous environments and are only present at night. In addition to the difficulty of dealing with them, there are strong and sharp thorns on their bodies. Three species of fleas were identified in this study; *P. irritans*, *X. cheopis*, and *L. segnis*. These species were among the fifteen species previously recorded in Libya (Zavattari, 1934; Misonne, 1977; Kaal et al., 2006; Mohamed and Shaurub, 2010; Elsaid et al., 2013; Hosni and Maghrbi, 2014). It is recommended to conduct more studies in Libya to have a clearer picture of fleas in different habitats.

Pulex irritans has a cosmopolitan distribution (Bitam et al., 2010). It has less host specificity, it was found in Libya infesting dogs, goats, and sheep (Kaal et al., 2006; Elsaid et al., 2013) and in other regions (Zavattari, 1934; Gracia et al., 2000; Christodouloupoulos et al., 2006). As early as the 14th century, *P. irritans* was recognized as a bubonic plague vector (Ratovonjato et al., 2014). *Pulex irritans* also has been identified as a vector for *Bartonella* and *Rickettsia* (O'Donnell and Elston, 2020).

Xenopsylla cheopis was found in north-western Libya: on rodents (Kaal et al., 2006), on common jackals (*Canis aureus*) (Hosni, 2006), and free-ranging hedgehogs (*Etelixer algirus*) (Hosni and Maghrbi, 2014); is also collected in other sites in the country (Zavattari, 1934). It is the best-known vector of the causative agents of plague (*Yersinia pestis*) and murine typhus (*Rickettsia typhi*) (Wells and Elston, 2020).

Leptopsylla segnis was collected in Libya, in Benghazi (Zavattari, 1934). It has a high host specificity; it infests only rodents (Smart, 1956; Loftis et al., 2006; Maleki-Ravasan et al., 2017). It has a wide distribution, especially in temperate regions (Gratz, 1999).

Leptopsylla segnis can transmit plague and rickettsiosis (Darvishi et al., 2014). *Rickettsia typhi* was detected in *L. segnis* in Cyprus (Christou et al., 2010).

Libya was affected by the appearance of plague foci over intermittent periods in different areas. The last foci were in Tobruk city near the Egyptian border in 2009, followed by 2011 (Tarantola et al., 2009). The collected species are vectors of plague. In the future, it will be necessary to investigate flea-transmitted pathogens both for fleas and their hosts.

Acknowledgments

We would like to express our deepest appreciation to friends and colleagues who helped us in sample collection.

Conflict of interests

The authors declare that there is no conflict of interest.

Funding

This work was funded by the University of Tripoli.

Authors' contributions

TS and SG involved in conception, design, and organization of the study; TS, SG, and WYMB contributed to the conduct of the study; WYMB was responsible for acquisition of data; TS, SG, and WYMB helped in analysis and interpretation of data, TS, SG, and WYMB contributed to drafting of the manuscript and critiquing the output for important intellectual content. All authors discussed the results and commented on the manuscript.

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