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Article

The first record of ectoparasites of raccoons (*Procyon lotor*) (Carnivora, Procyonidae) in Iran

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ABSTRACT

The raccoon, *Procyon lotor*, is native to North and Central America but has been introduced to several Old World countries including Iran. The aim of this study was to determine the prevalence of ectoparasites of raccoons in Iran. During 2015–2017, a total of 30 feral raccoons were collected from Guilan Province, northern Iran. The fur of raccoons was examined for the presence of ectoparasites. The collected ectoparasites were preserved in 70% ethanol and microscopically and morphologically identified. In total, 11 fleas and 244 ixodid ticks were collected from 18 (60%) raccoons for the first time in Iran. Two raccoons (6.7%) harbored just fleas, five raccoons (16.7%) both fleas and ticks and 11 raccoons (36.7%) just ticks. Two species of fleas: *Ctenocephalides felis* (cat flea) and *Pulex irritans* (human flea) were collected from seven raccoons (23.3%). Four species of ixodid ticks: *Haemaphysalis concinna*, *Ixodes ricinus*, *Rhipicephalus sanguineus* and *R. turanicus* were collected from 16 raccoons (53.3%). All ectoparasites, except for cat flea, were found on raccoons for the first time. The prevalence, mean abundance and mean intensity of ectoparasites and the indices of affinity, association and diversity were calculated. The pair of species *H. concinna*/*I. ricinus* showed significant association and the infestation with *I. ricinus* in cubs was significantly higher than in adults ($P < 0.05$). The medical importance of zoonotic infections transmittable by raccoons and their ectoparasites is discussed. The investigation of different possible vector-borne infections in raccoons and their ectoparasites in the study area is suggested.

KEY WORDS: Fleas; Guilan Province; host-parasite association; host-parasite relationship; Ixodidae; ticks.

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INTRODUCTION

The North American raccoon, *Procyon lotor* (Carnivora: Procyonidae) has been introduced to several Old World regions such as former Russia and Germany for fur trade in 1930's (Fischer *et al.* 2015) and to Japan as a pet in 1960's (Ikeda *et al.* 2004). After that, raccoons distributed in many parts of

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eastern and central Europe and Asia (Farashi and Naderi 2017). Raccoon is introduced as an invasive species which can live in both forests and urban habitats (Fisher *et al.* 2015). Raccoons were observed by local people in northern Iran for the first time in 1991, and their occurrence was verified in 1996 (Ziaie 2011; Farashi and Naderi 2017). Raccoons occur in two counties of Astara and Talesh in Guilan Province of northern Iran. They invaded Iran probably from the Republic of Azerbaijan (Ziaie 2011).

Raccoons harbored many different zoonotic pathogens and parasites in both New and Old Worlds including acanthocephalans (Cole and Shoop 1987), bacteria such as *Compylobacter* spp., *Francisella tularensis*, *Leptospira* spp., *Salmonella* spp. and *Yersinia pseudotuberculosis* (Berrada *et al.* 2006; Koizumi *et al.* 2009; Lee *et al.* 2011), fungi such as *Enterocytozoon bieneusi* (Leśniańska *et al.* 2016), many different helminthes of Cestoda, Nematoda and Trematoda (Cole and Shoop 1987; Telford and Forrester 1991), protozoa such as *Babesia* spp., *Cryptosporidium* spp. and *Trypanosoma* spp. (Telford and Forrester 1991; Leśniańska *et al.* 2016), rickettsiae such as spotted fever group species (Baba *et al.* 2013) and viruses such as avian and human influenza A, Borna disease, rabies, Japanese encephalitis and West Nile viruses (Curtis and Sullivan 2001; Hagiwara *et al.* 2009; Ohno *et al.* 2009; Root *et al.* 2010; Horimoto *et al.* 2011). Among aforementioned infections, rabies and baylisascariasis, caused by the nematode *Baylisascaris procyonis*, probably make the most important concerns for human health (Curtis and Sullivan 2001). Some of those infections are vector-borne such as dirofilariasis, trypanosomiasis, babesiosis (Telford and Forrester 1991), Japanese encephalitis virus (Ohno *et al.* 2009), West Nile virus (Root *et al.* 2010) and spotted fever group rickettsiae (Baba *et al.* 2013).

There are many records of ectoparasites of raccoons in North America including fleas (Siphonaptera) such as *Chaetopsylla lotoris* (Stewart, 1926) (Vermipsyllidae), *Orchopeas howardi* (Baker, 1895) (Ceratophyllidae), *Euhoplopsyllus glacialis* (Taschenberg, 1880), *Ctenocephalides felis* (Bouché, 1835) and *Pulex simulans* Baker, 1895 (Pulicidae) (Richardson *et al.* 1994; Nelder and Reeves 2005; Durden and Richardson 2013), hard ticks such as *Amblyomma americanum* (Linnaeus, 1758), *Dermacentor variabilis* (Say, 1821), *Ixodes cookei* Packard, 1869, *I. scapularis* Say, 1821, *I. texanus* Banks, 1909 (Acari: Ixodidae) (Richardson *et al.* 1994; Nelder and Reeves 2005), the louse *Stachiella octomaculatus* (Paine, 1912) (Phthiraptera: Trichodectidae) (Richardson *et al.* 1994; Nelder and Reeves 2005) and mites such as *Androlaelaps casalis* (Berlese, 1887), *A. fahrenheitii* (Berlese, 1911), *Echinonyssus isabellinus* (Oedeman, 1913), *E. staffordi* (Strandtmann & Hunt, 1951), *Hypoaspis leviculus* (Edas, 1951), *Laelaps multispinosus* (Banks, 1910) (Laelapidae), *Ornithonyssus bacoti* (Hirst, 1913), *O. wernecki* (Fonseca, 1935) (Macronyssidae), *Pygmephorus designates* Mahunka, 1973, *P. erlangensis* Krczal, 1959, *P. idea* Smiley & Whitaker, 1979, *P. spinosus* Kramer, 1877, *P. whitakeri* Mahunka, 1973 (Pygmephoridae), *Ursicoptes procyoni* Fain & Wison, 1979 (Rhyncoptidae), *Neotrombicula whartoni* (Ewing, 1929) (Trombiculidae) (Nelder and Reeves 2005; Whitaker *et al.* 2007). Some of aforementioned species are cosmopolitan and are found outside North America such as cat flea (*C. felis*) (Lewis *et al.* 1972) and the mites *A. casalis*, *O. bacoti* (Baker 1999). Some Nearctic species were introduced to the Old World with their hosts such as the flea *O. howardi* which was introduced and successfully established in the British Isles with its host the grey squirrel, *Sciurus carolinensis*, (Smith 1957) and the louse *S. octomaculatus* which was introduced to Europe with its host, raccoon, (Haitlinger and Łupicki 2009). The reports on the ectoparasites of raccoons in the Old World are not as much as those of the New World. The hard ticks of *A. testudinarium* Koch, 1844, *Haemaphysalis flava* Neumann, 1897, *H. longicornis* Neumann, 1901, *I. nipponensis* Kitaoka & Saito, 1967, *I. ovatus* Neumann, 1899, *I. pavlovskiyi* Pomerantsev, 1946, *I. persulcatus* Schulze, 1930 and *I. tanuki* Saito, 1964 are recorded from raccoons in Japan (Yamada 2000; Yamauchi *et al.* 2012). Also Sashika *et al.* (2009) reported *Sarcoptes scabiei* (Linnaeus, 1758) in Japan. Haitlinger and Łupicki (2009) reported cat flea (*C. felis*), the louse *S. octomaculatus*, the mites *H. oblonga* (Halbert, 1915), *E. isabellinus* and the tick *I. hexagonus* Leach, 1815 in Poland.

There are many studies about ectoparasites on cats (Borji *et al.* 2011), dogs (Jafari Shoorijeh *et al.* 2008; Mosallanejad *et al.* 2011), foxes and jackals (Meshgi *et al.* 2009), different rodents (Hamidi *et al.* 2016) and sheep (Farahi *et al.* 2016) in Iran. However, as far as the authors know there is no record of ectoparasites of raccoons in the country. Sharifdini *et al.* (2020) studied the helminthes of feral raccoons in northern Iran for the first time. They found five species of intestinal parasites comprising three species of nematodes (*Camerostrongylus didelphis*, *Spirocerca lupi*, *Strongyloides procyonis*), one species of trematode (*Plagiorchis* sp.) and one acanthocephalan species (*Centrorhynchus* sp.). In order to study the prevalence of ectoparasites of raccoons in Iran, an investigation was carried out within its distribution range in Guilan Province, northern Iran, considering their medical importance.

MATERIALS AND METHODS

Study area

Guilan Province is located in the Caspian Sea littoral of northern Iran, between the Caspian Sea and the Alborz Mountain range (36° 33'–38° 27' N and 48° 32'–50° 36' E). It has coastal, plain, foothill, and mountainous areas with an area of approximately 14700 square kilometers. The province is surrounded by Mazandaran Province in the east, Ardebil Province in the west and Zanzan and Qazvin Provinces in the south. It is also bordered by the Republic of Azerbaijan in the north as well as Russia across the Caspian Sea (Fig. 1). The province has a temperate climate and relatively warm-humid summer and formally includes 16 counties. Most areas of Guilan Province with about 1000–2000 mm of rainfall annually, have the greatest amount of rainfall in Iran. The present study is limited to the western regions of Guilan Province including Astara and Talesh Counties because the reports of raccoon presence in Iran are limited to these areas.

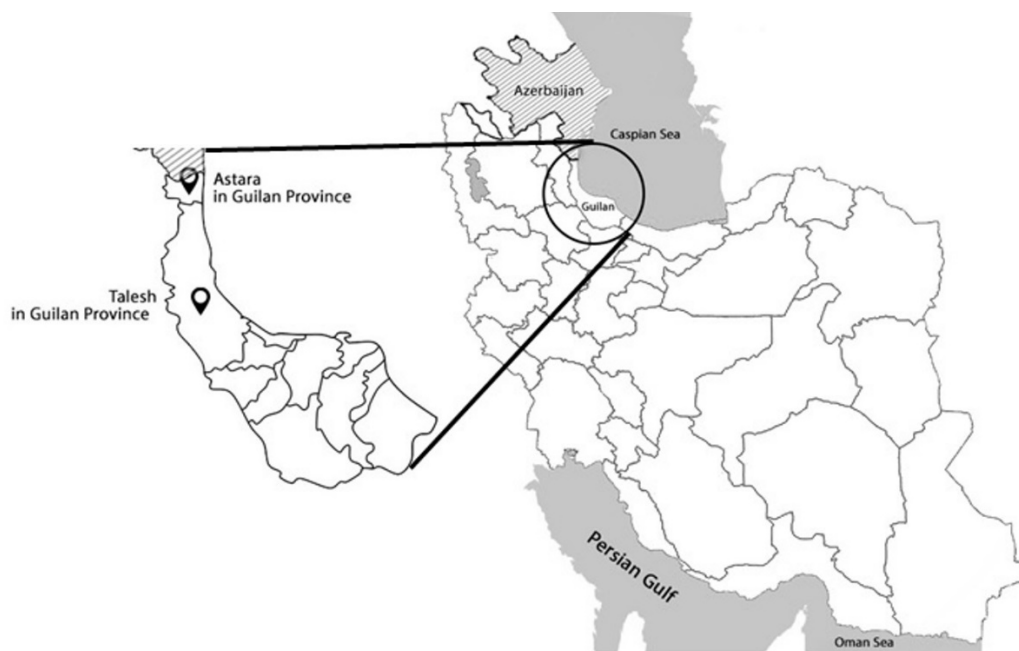


Figure 1. Map of Iran showing geographical location of Guilan Province and the study area and collecting locations, Astara and Talesh Counties.

Specimen and data collection

A total of 30 feral raccoons were collected using trapping, hunting and road kills from Astara

County (27 raccoons, 90%) and Talesh County (3 raccoons, 10%) between August 2015 and May 2017. The sex and age group of each raccoon were recorded. The raccoons were categorized as cubs or adults according to life stage using body weight (Sanderson 1961). The fur of raccoons was manually examined for the presence of ectoparasites. All samples were preserved in 70% ethanol and transferred to the laboratory for further examinations. The ticks were morphologically identified using stereomicroscope and the keys of Walker *et al.* (2003), Estrada-Peña *et al.* (2004) and Hosseini-Chegeni *et al.* (2014). The fleas were cleared using KOH and mounted in Berlese's medium and microscopically identified by means of the keys of Assmar *et al.* (1979). Ectoparasites were categorized as adults (males and females), nymphs and larvae (applicable for ticks).

Indices of affinity and association between species

The indices of affinity and association between pairs of species were calculated using two formulae: Fager and McGowan's test of affinity (Fager and McGowan 1963) and the index of association (Silver 2008). Fager and McGowan's test of affinity is defined by $[J / (NA \cdot NB)^{1/2}] - 1/2(NB)^{1/2}$ where J = number of joint occurrences, NA = total number of occurrences of species A, NB = total number of occurrences of species B, species are assigned to the letters so that $NA \leq NB$. The expressions of pairs of species which were equal to or higher than 0.5 were considered to show affinity (Fager and McGowan 1963). The index of association is defined by $I = 2[J/A+B-0.5]$ where J = the number of individuals of both species in samples where they occur together, A = the total number of individuals of species A in all samples, and B = the total number of individuals of species B in all samples. In this formula the numbers of species individuals are taken into consideration. The formula has a range of +1 to -1 (Silver 2008).

Diversity of species

The Shannon-Weaver or Shannon-Wiener function (H') was calculated for species diversity (richness) (Silver 2008). Shannon's index is defined by $H' = -\sum_{i=1}^k p_i \text{Log} p_i$ where p_i = the proportion of the number of individuals of species i in the total sample number. The maximum possible Shannon's Diversity was calculated by $H'_{\max} = \text{Log}_{10} k$ where k is the number of species collected in the sample. Evenness (J' or E or Pielou's index) was calculated by $J' = H' / H'_{\max}$.

Data analysis

Prevalence (P), mean abundance (MA) and mean intensity (MI) were calculated according to the definition of Bush *et al.* (1997). Statistical tests including Chi square (X^2) and Fisher's exact tests were used. Statistical analyses were performed using SPSS software version 18 (SPSS Inc, Chicago, IL, USA), with a probability (P) value of < 0.05 as statistically significant.

RESULTS

In total, 11 fleas (5 males, 6 females) and 244 ixodid ticks (14 males, 13 females, 136 nymphs, 81 larvae) were collected from 18 (60%) raccoons (out of 30) for the first time in Iran. Only two raccoons (6.7%) harbored just fleas, 5 raccoons (16.7%) both fleas and ticks and 11 raccoons (36.7%) only ticks. Two species of fleas: *C. felis* (cat flea) (Each raccoon with 1 to 3 fleas) and *P. irritans* Linnaeus, 1758 (human flea) (1–2) were collected from 7 raccoons (23.3%) (In total, each raccoon with 1 to 3 fleas). Four species of ixodid ticks: *H. concinna* Koch, 1844 (1–45), *I. ricinus* (Linnaeus, 1758) (1–2), *Rhipicephalus sanguineus* (Latreille, 1806) (1–35), *R. turanicus* Pomerantsev, 1936 (2–3) were collected from 16 raccoons (53.3%) (In total, each raccoon with 1 to 46 different stages of ticks) (Fig. 2). Just one raccoon collected from Talesh County (out of three) harbored ectoparasites and 17 raccoons collected from Astara County (out of 27) had ectoparasites. The number of ectoparasites of raccoons according to sex and age group is shown in Table 1. The prevalence, mean abundance and mean intensity of ectoparasites of raccoons according to sex and age group are shown in Table 2.

Two raccoons (6.7%) harbored just one flea species (*P. irritans*) (Each with 1 to 2 fleas). Four raccoons (13.3%) harbored only the tick *R. sanguineus* (Each with 1 to 29 different stages of the tick). One raccoon (3.3%) harbored only one tick *H. concinna*. The remaining eleven raccoons (36.7%) harbored at least two species of ectoparasites. The co-infestations of ectoparasites of raccoons are presented in Table 3. The affinity infestations of ectoparasites of raccoons are shown in Table 4. The pair of species *H. concinna*/*I. ricinus* showed significant association (Table 5). The indices of diversity are presented in Table 6. The infestation with *I. ricinus* in cubs was significantly higher than in adults ($P = 0.026$) but no statistically significant difference was found between *I. ricinus* infestation and sex ($P = 0.184$). There was no significant difference between sex and age group with infestation for other species ($P > 0.05$). All ectoparasites, except for *C. felis*, were found on raccoons for the first time.



Figure 2. Hard ticks collected from raccoons in Guilan Province, northern Iran, 2015–2017– **A.** *Haemaphysalis concinna*; **B.** *Ixodes ricinus*; **C.** *Rhipicephalus sanguineus*; **D.** The spiracle plate of *R. sanguineus*; **E.** The spiracle plate of *R. turanicus*.

Table 1. The number (n) of ectoparasites of raccoons in Guilan Province, northern Iran, according to age group and sex, 2015–2017 (F: adult females, M: adult males, N: nymphs, L: larvae).

Ectoparasite	Raccoon age group		Raccoon sex		Total (n = 30, 100%)
	Cub (n = 12, 40%)	Adult (n = 18, 60%)	Male (n = 12, 40%)	Female (n = 18, 60%)	
<i>Ctenocephalides felis</i>	3 (2M, 1F)	2F	3 (2M, 1F)	2F	5 (3M, 2F)
<i>Pulex irritans</i>	1F	5 (2M, 3F)	1F	5 (2M, 3F)	6 (2M, 4F)
<i>Haemaphysalis concinna</i>	57 (1M, 8N, 48L)	6 (4N, 2L)	12 (1M, 8N, 3L)	51 (4N, 47L)	63 (1M, 12N, 50L)
<i>Ixodes ricinus</i>	6 (1F, 5L)	1N	5 (1F, 4L)	2 (1N, 1L)	7 (1F, 1N, 5L)
<i>Rhipicephalus sanguineus</i>	81 (1F, 59N, 21L)	86 (7M, 10F, 64N, 5L)	80 (1F, 58N, 21L)	87 (7M, 10F, 65N, 5L)	167 (7M, 11F, 123N, 26L)
<i>R. turanicus</i>	-	7 (6M, 1F)	-	7 (6M, 1F)	7 (6M, 1F)
Total	148 (3M, 4F, 67N, 74L)	107 (15M, 16F, 69N, 7L)	101 (3M, 4F, 66N, 28L)	154 (15M, 16F, 70N, 53L)	255 (19M, 19F, 136N, 81L)

Table 2. The prevalence (%), mean abundance (MA) and mean intensity (MI) of ectoparasites of raccoons in Guilan Province, northern Iran, according to sex and age group, 2015–2017.

Ectoparasite	Raccoon age group						Raccoon sex						Total (n = 30, 100%)		
	Cub (n = 12, 40%)			Adult (n = 18, 60%)			Male (n = 12, 40%)			Female (n = 18, 60%)			% MA MI	% MA MI	% MA MI
	%	MA	MI	%	MA	MI	%	MA	MI	%	MA	MI			
<i>Ctenocephalides felis</i>	8.3	0.25	3.0	11.1	0.11	1.0	8.3	0.25	3.0	11.1	0.11	1.0	10.0	0.17	1.66
<i>Pulex irritans</i>	3.3	0.08	1.0	10.0	0.27	1.66	3.3	0.08	1.0	10.0	0.27	1.66	13.3	0.20	1.50
<i>Haemaphysalis concinna</i>	10.0	4.75	19.0	10.0	0.33	2.0	6.7	1.0	6.0	13.3	2.83	12.75	20.0	2.10	10.50
<i>Ixodes ricinus</i>	16.7	0.5	1.2	3.3	0.05	1.0	13.3	0.41	1.25	6.7	0.11	1.0	20.0	0.23	1.16
<i>Rhipicephalus sanguineus</i>	20.0	6.75	13.5	26.7	4.77	10.75	16.7	6.66	16.0	30.0	4.83	9.66	46.7	5.57	11.92
<i>R. turanicus</i>	-	-	-	100	0.38	2.33	-	-	-	100	0.38	2.33	10.0	0.23	2.33
Total	23.3	12.33	16.44	36.7	5.94	11.88	20.0	8.41	14.42	40.0	8.55	14.0	60.0	8.53	14.16

Table 3. The co-infestations of ectoparasites of raccoons in Guilan Province, northern Iran, 2015–2017.

Raccoons (n = 30)	Co-infestation of ectoparasites	n (%)
Double	<i>Ctenocephalides felis</i> + <i>Rhipicephalus sanguineus</i>	2 (6.7%)
	<i>Ixodes ricinus</i> + <i>Rhipicephalus sanguineus</i>	2 (6.7%)
	<i>Rhipicephalus sanguineus</i> + <i>Rhipicephalus turanicus</i>	1 (3.3%)
	<i>Haemaphysalis concinna</i> + <i>Ixodes ricinus</i>	1 (3.3%)
Triple	<i>Haemaphysalis concinna</i> + <i>Ixodes ricinus</i> + <i>Rhipicephalus sanguineus</i>	1 (3.3%)
	<i>Pulex irritans</i> + <i>Haemaphysalis concinna</i> + <i>Rhipicephalus sanguineus</i>	1 (3.3%)
	<i>Haemaphysalis concinna</i> + <i>Rhipicephalus sanguineus</i> + <i>Rhipicephalus turanicus</i>	1 (3.3%)
Quadruple	<i>Ctenocephalides felis</i> + <i>Haemaphysalis concinna</i> + <i>Ixodes ricinus</i> + <i>Rhipicephalus sanguineus</i>	1 (3.3%)
	<i>Pulex irritans</i> + <i>Ixodes ricinus</i> + <i>Rhipicephalus sanguineus</i> + <i>Rhipicephalus turanicus</i>	1 (3.3%)

Table 4. The affinity infestations of ectoparasites of raccoons in Guilan Province, northern Iran, 2015–2017.

Ectoparasite	Total infestations	<i>Ctenocephalides felis</i>	<i>Pulex irritans</i>	<i>Heamaphysalis concinna</i>	<i>Ixodes ricinus</i>	<i>Rhipicephalus sanguineus</i>	<i>R. turanicus</i>
<i>C. felis</i>	3		-	1	1	3	-
<i>P. irritans</i>	4	-		1	1	2	1
<i>H. concinna</i>	6	1	1		3	4	1
<i>I. ricinus</i>	6	1	1	3		5	1
<i>R. sanguineus</i>	14	3	2	4	5		3
<i>R. turanicus</i>	3	-	1	1	1	3	

Table 5. Fager and McGowan's test of affinity and the index of association of ectoparasites of raccoons in Guilan Province, northern Iran, 2015–2017. Lower part shows the index of association. Upper part shows Fager and McGowan's test of affinity (^a Dash (-) means the pair of species did not occur together, ^b Bold number shows significant association).

Fager and McGowan's Test of Affinity	<i>Ctenocephalides felis</i>	<i>Pulex irritans</i>	<i>Heamaphysalis concinna</i>	<i>Ixodes ricinus</i>	<i>Rhipicephalus sanguineus</i>	<i>R. turanicus</i>
Index of Association						
<i>C. felis</i>		- ^a	0.03	0.03	0.33	-
<i>P. irritans</i>	-		0.00	0.00	0.13	0.03
<i>H. concinna</i>	-0.86	-0.86		0.30	0.30	0.03
<i>I. ricinus</i>	-0.34	-0.54	0.70^b		0.41	0.29
<i>R. sanguineus</i>	-0.60	-0.48	-0.38	-0.26		0.33
<i>R. turanicus</i>	-	-0.24	-0.92	-0.44	-0.72	

Table 6. Shannon diversity index (H'), the maximum possible Shannon's diversity (H'_{max}) and evenness (J') of ectoparasites of raccoons in Guilan Province, northern Iran, 2015–2017.

Species	Number	p_i	$\log p_i$	$p_i \log p_i$	H'	H'_{max}	J'
<i>Ctenocephalides felis</i>	5	0.019	-0.721	-0.013	} 0.403	0.778	0.517
<i>Pulex irritans</i>	6	0.023	-1.638	-0.037			
<i>Heamaphysalis concinna</i>	63	0.247	-0.607	-0.149			
<i>Ixodes ricinus</i>	7	0.027	-1.568	-0.042			
<i>Rhipicephalus sanguineus</i>	167	0.654	-0.184	-0.120			
<i>R. turanicus</i>	7	0.027	-1.568	-0.042			

DISCUSSION

Though all collected ectoparasites of the present study have been recorded in Iran and Guilan Province before, this is the first time that they are found on raccoons. Also, as far as the authors know, all ectoparasites, except for cat flea, are found on raccoons for the first time.

The cat flea (*C. felis*) is recorded from raccoons in both New and Old Worlds (Nelder and Reeves 2005; Haitlinger and Łupicki 2009), but there is no record of the human flea (*P. irritans*) from raccoons. A very close species to the human flea, *P. simulans*, is found on raccoons in the New World (Richardson *et al.* 1994; Durden and Richardson 2013). The cat flea is found on different carnivora, rodentia and ungulates in Iran and the human flea shows a very wide range of hosts including humans, different carnivora, insectivora, rodentia, ungulates, artiodactyla and birds and both species have been recorded in Guilan Province (Maleki-Ravasan *et al.* 2017). Both cat and human fleas are assumed to play a role in the transmission of plague, murine typhus (caused by *Rickettsia typhi*) and *R. felis* (Eisen and Gage 2012). Also, it seems that the cat flea is involved in transmitting cat scratch disease (caused by *Bartonella henselae*) (Eisen and Gage 2012). There are old records of human cases of plague in

Iran (Hashemi Shahraki *et al.* 2016). Though there are some recent serological surveys which verify the presence of *Y. pestis* in rodents in Iran (Esmaeili *et al.* 2013), there is no recent human case of plague in the country (Hashemi Shahraki *et al.* 2016). The fleas *Nosopsyllus iranum* Wagner & Argyropulo, 1934, *Stenoponia tripectinata* (Tiraboschi, 1902), *Xnopsylla buxtoni* Jordan, 1949 and *X. conformis* (Wagner, 1903) are known vectors of *Y. pestis* in Iran (Karimi 1980; Eisen and Gage 2012).

There is no record of the four tick species, which were found in the present study, on raccoons before. All reported ticks have been recorded in Guilan Province since (Rahbari *et al.* 2007; Hosseini-Chegeni *et al.* 2014). *Haemaphysalis concinna* is reported on cattle and different rodents (*Gerbillus*, *Meriones*, *Mus* and *Rattus*) in Iran, *I. ricinus* on cattle, dog, gazelle, goat, sheep, rodents (*Apodemus*, *Meriones*, *Mus* and *Rattus*), *R. sanguineus* on cat, cattle, dog, fox, goat, horse, jackal, mule, porcupine, sheep, rabbit, rodents (*Gerbillus*, *Meriones* and *Nesokia*), *R. turanicus* on many carnivores, rabbit, rodents (*Apodemus*, *Meriones* and *Rhombomys*) (Kamali *et al.* 2001). *Haemaphysalis concinna* is known to transmit tick-borne encephalitis and tularemia in Europe (Salman and Teres-Call 2013), but there is no information about its vector potential in Iran. *Ixodes ricinus* is known to transmit anaplasmosis in Iran (Hosseini-Vasoukolaei *et al.* 2014). This species transmits several zoonoses in Europe such as anaplasmosis, babesiosis, bartonellosis, borreliosis (including Lyme), ehrlichiosis, louping ill, tick-bite fever and different rickettsioses, tick-borne encephalitis and tularemia (Salman and Teres-Call 2013). *Rhipicephalus sanguineus* is known the vector of Crimean-Congo hemorrhagic fever (CCHF) (Telmadarrai *et al.* 2015), anaplasmosis and ehrlichiosis (Khazeni *et al.* 2013), babesiosis (Razmi *et al.* 2002) and hepatozoonosis (Rahmani Amoli *et al.* 2012) in Iran. Also, piroplasmosis (theileriosis) is reported in Iran which *R. sanguineus* is one of its vectors (Bigdeli *et al.* 2012). This species also is known to vector bartonellosis and different rickettsioses in Europe and the Mediterranean basin (Salman and Teres-Call 2013). *Rhipicephalus turanicus* is the vector of anaplasmosis and different rickettsioses in Europe (Salman and Teres-Call 2013) but there is no data about its vector potential in Iran.

Raccoons are known reservoirs of babesiosis (Telford and Forrester 1991) and spotted fever group rickettsiae (Baba *et al.* 2013) which are transmitted by different ticks or fleas. Also, raccoons are known as a possible reservoir of Japanese encephalitis virus (Ohno *et al.* 2009). This infection is not reported in Iran, but its important vector, *Culex tritaeniorhynchus* Giles, 1901 is an abundant species in Guilan Province (Azari-Hamidian and Norouzi 2018).

In view of interspecific or intraspecific patterns of parasite-host relationship, in general, larger hosts show the higher infestation of parasites not only among but also within host species. Thus mature male hosts which tend to be larger show higher infestation. Of course, other features than size may influence the infestation for example having a wider range for finding mate (behavior), being immunologically compromised by their hormones (physiology) (Randolph 2008; Monello and Gompfer 2009). Also, flea indices naturally tend to be higher in larger rodents (Traub *et al.* 1978). Despite the general aforementioned background, the specific findings in the literature may show different results in view of samples, sampling methods or host and parasite species. In rodents, the relationship between host sex and ectoparasite presence may typically show bias depending on the host species (Lareschi 2010). Jennett *et al.* (2013) found that age, gender, breed and neutered status were not predictors in the dog infestation to *I. ricinus* around Bristol, UK. However, in a large scale surveillance in the UK, Abdullah *et al.* (2016) observed that breed, neutered status and age significantly predicted the likelihood of having ticks. Most of investigations in Iran show just abundance or prevalence of ectoparasites in their hosts without indication of sex, age or other factors related to the hosts (Meshgi *et al.* 2009; Hamidi *et al.* 2016). No significant relationship was observed between age and the prevalence of ectoparasites in dogs in Shiraz (Jafari Shoorijeh *et al.* 2008), the sex and age of cats and the prevalence of cat flea and the mite *Cheyletiella blakei* Smiley, 1970 in Mashhad (Borji *et al.* 2011), age, sex and the abundance of ectoparasites in dogs in Ahvaz (Mosallanejed *et al.* 2011), male and female hedgehogs for the prevalence of the flea *Archaeopsylla*

erinacei (Bouché, 1835) and the tick *Hyalomma anatolicum* Koch, 1844 in northwestern Iran (Hajipour *et al.* 2015), the ectoparasite infestation (including mite, tick, flea, fly and louse) and the dog sex or age in three northern provinces of Iran (Ebrahimzade *et al.* 2016). Of course, in some circumstances, other factors than sex and age group were found to have significant influence on the ectoparasite prevalence such as humidity and temperature (Jafari Shoorijeh *et al.* 2008); they were not investigated in the present study. In the present investigation, though the total numbers of ectoparasites were higher in cubs and females than adults and males, respectively, there was no significant relationship between the sex and age group of raccoons and ectoparasites, except for *I. ricinus* and the age group. This finding needs to be verified with more samples in future. Monello and Gompfer (2009) showed that age and sex are the best predictors for the prevalence and abundance of the louse *S. octomaculatus* (syn.: *Trichodectes octomaculatus*) in raccoons, but they are not predictor for the flea *O. howardi*. Also, they suggested simultaneously assessing the relative importance of multiple ecological variables during studying host-parasite associations.

There is little information about the biodiversity of ectoparasites in Iran. Farahi *et al.* (2016) reported six alpha and beta biodiversity indices of ticks on sheep in Golestan Province. They calculated Shannon index as much as 1.067, 0.847 and 0.891 and evenness as much as 0.624, 0.551 and 0.479 for plain, coastal and hillside sampling sites, respectively. The indices are higher than the present investigations' (Shannon index = 0.403, Evenness = 0.517). It seems that the prevalence and diversity of parasites in raccoons is not high in Iran as mentioned by Sharifdini *et al.* (2020).

One of limitations of the present study was sampling. Raccoon is a newly introduced species to Iran and found just in the forest areas of two counties of Guilan Province. There are many official and administrative limitations to find and sample raccoons. Another limitation was the morphological identification of larvae and nymphs of ticks. According to adults, one species from each genus *Haemaphysalis* and *Ixodes* was identified and other specimens of aforementioned genera in larval and nymphal stages were assumed to most probably belong to those species (Table 1). The ticks of *R. sanguineus* group are morphologically very similar (Estrada-Peña *et al.* 2004). *Rhipicephalus turanicus* is distinguishable from *R. sanguineus* in adult males and females based on the shapes of genital apertures and spiracle plates, but the specimens of larvae and nymphs were indeed not differentiated and mentioned under the name of *R. sanguineus* (Table 1 and Fig. 2). The taxonomy of *R. sanguineus* group in Iran needs to be extensively investigated especially using molecular data.

The study of different possible infections including vector-borne ones in feral raccoons and their ectoparasites in the study area is suggested for forthcoming investigations.

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نخستین گزارش انگل‌های خارجی راکون‌ها (*Procyon lotor*) (Carnivora, Procyonidae) در ایران

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چکیده

راکون، *Procyon lotor*، بومی آمریکای شمالی و مرکزی بوده که به چندین کشور دنیای قدیم از جمله ایران وارد شده است. هدف این بررسی تعیین وفور انگل‌های خارجی راکون‌ها در ایران است. در طول سال‌های ۲۰۱۷-۲۰۱۵ در مجموع ۳۰ عدد راکون وحشی از استان گیلان، شمال ایران، جمع‌آوری شد. خز راکون‌ها برای حضور انگل‌های خارجی بررسی شد. انگل‌های خارجی جمع‌آوری شده در اتانول ۷۰٪ ذخیره و به صورت میکروسکوپی و ریخت‌شناختی تعیین هویت شدند. در مجموع ۱۱ کک و ۲۴۴ کنه ایکسودید از ۱۸ راکون (۶۰٪) برای نخستین بار در ایران جمع‌آوری شد. دو راکون (۶۷٪) فقط کک داشتند، پنج راکون (۱۶۷٪) هم کک و هم کنه داشتند و ۱۱ راکون (۳۶۷٪) فقط کنه داشتند. دو گونه کک: *Ctenocephalides felis* (کک گربه) و *Pulex irritans* (کک انسان) از هفت راکون (۲۳/۳٪) جمع‌آوری شد. چهار گونه کنه ایکسودید: *Haemaphysalis concinna*، *Ixodes ricinus*، *Rhipicephalus sanguineus* و *R. turanicus* از ۱۶ راکون (۵۳/۳٪) جمع‌آوری شد. همه انگل‌های خارجی به جز کک گربه برای نخستین بار از راکون جمع‌آوری شدند. وفور، فراوانی میانگین و انبوهی میانگین انگل‌های خارجی و شاخص‌های همبستگی، همراهی و تنوع زیستی محاسبه شد. جفت گونه *H. concinna/I. ricinus* همبستگی معنی‌دار نشان دادند و *I. ricinus* در راکون‌های نابالغ به طور معنی‌داری بیشتر از بالغ‌ها بود ($P < 0.05$). اهمیت پزشکی بیماری‌های منتقل‌شونده توسط راکون‌ها و انگل‌های خارجی آنها مورد بحث قرار گرفت. بررسی آلودگی‌های احتمالی راکون‌ها و انگل‌های خارجی آنها در منطقه مورد مطالعه پیشنهاد می‌شود.

واژگان کلیدی: کک؛ استان گیلان؛ همبستگی میزبان-انگل؛ ارتباط میزبان-انگل؛ *Ixodidae*؛ کنه‌ها.

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