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Ticks (Metastigmata: Ixodidae) parasitizing songbirds in Iran with new host records

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Abstract
The present study investigates the occurrence and the identification of tick species infesting wild songbirds in northern Iran. Totally, 342 songbirds belonging to 15 families and 37 species were captured and examined for tick infestation during 2015-2016. Of which, 70 specimens were infested by ticks (infestation rate = 20.46%). Three tick species detached from examined birds and identified as follow: *Ixodes ricinus* (Linnaeus, 1758), *Hyalomma* sp., and *Rhipicephalus* sp. The most common one was *I. ricinus*. In all infected birds, collected ticks were in immature stages and the number of specimens of the larval stage was more than in the nymphal stage, and no adult tick was found. Following songbirds were introduced as new hosts: *Petronia petronia* (Linnaeus, 1766), *Gymnoris xanthocollis* (Burton, E, 1838), *Hippolais pallida* (Hemprich & Ehrenberg, 1833), *Emberiza calandra* Linnaeus, 1758, *Acridotheres tristis* (Linnaeus, 1766), *Oenanthe picata* (Blyth, 1847), *O. pleschanka* (Lepechin, 1770), *Rhodospiza obsoleta* (Lichtenstein, MHC, 1823), *Serinus pusillus* (Pallas, 1811), and *Ficedula parva* (Bechstein, 1792) for *I. ricinus*. The overall mean intensity and mean abundance were 4.6 and 0.95, respectively. The highest mean intensity, 12.18 ticks per bird, was recorded from Common Starling. The highest prevalence of infestation was recorded on Common Blackbird (53%). The most prevalence of tick infestation occurred in the Turdidae family (37.83%) followed by Passeridae (33.33%) and Sturnidae (28.57%).

Key words: *passerine birds, ixodid, Ixodes ricinus, tick infestation.*

INTRODUCTION

Hard ticks (Metastigmata: Ixodidae) are medically important ectoparasites and known as vectors of important diseases such as lyme borreliosis, tick-borne encephalitis (TBE) and babesiosis to animals and humans. These hematophagous ectoparasites transmit a wide variety of pathogens including: viruses (such as tick borne encephalitis and Crimean-Congo hearnorrhagic fever virus), rickettsia (such as tickborne spotted fever rickettsioses, typhus fever rickettsioses, Scrub Typhus, and Ehrlichioses), bacteria (such as relapsing fever borrelioses, tularemia and Q fever) and protozoa (such as *Babesia* species and *Hepatozoon* species) (Cupp, 1991; Parola & Raoult, 2001; Labuda & Nuttall, 2008; Nicholson et al., 2019; Ceylan et al., 2021). The family Ixodidae comprises of 14 genera and approximately 707 species known throughout the world (Guglielmone et al., 2014). Ticks require vertebrate hosts at each stage of their life to complete life cycles. Birds, mainly songbirds, are often hosts of ticks (Smith et al., 1996). The significance of birds as hosts for ticks and tick-borne diseases is more than the other vertebrate hosts because of their worldwide distribution and wide range of habitat (Smith et al., 1996). The long migration paths of birds enable these parasites to occupy new areas (Loss et al., 2016; Ogden et al., 2008; Smith et al., 1996). Additionally, many of the songbirds, especially those are ground foraging species show a

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reasonable high tick infestation rate. Ticks parasitize songbirds, especially in subadult stages (Humair et al., 1993; Smith et al., 1996). Songbirds are known as hosts of ticks belong to Ixodidae family especially in following genera: *Ixodes*, *Haemaphysalis* and *Amblyomma* (Guglielmone et al., 2014). About 154 species of ixodid ticks at different stages (larva, nymph or adult) are parasite of birds, of which 40 species are exclusively parasites of birds for all stages (Guglielmone et al., 2014; Hoogstraal & Aeschlimann, 1982).

Of the 729 currently recognized Ixodidae species more than 41 species of ticks belonging to Ixodidae has reported in Iran. Almost all these reported species include ixodid ticks on domestic animals and wild mammals (Deply, 1936; Janbakhsh, 1956; Abbassian-Lintzen, 1960; Mazlum, 1968; Mazlum, 1971; Hoogstraal & Wassef, 1979; Piazak, 1991; Tavakoli, 1997; Nekoui et al., 1999; Kamali et al., 2001; Telmadarraiy et al., 2004; Aghighi et al., 2007; Rahbari et al., 2007; Razmi et al., 2007; Guglielmone & Robbins, 2018; Hosseini-Chegeni, 2019).

The avifauna of Iran includes 548 birds, of which approximately 235 species belong to the songbirds (Dickinson and Christidis, 2014). Despite the importance of wild birds as a transmitter of tick and tick-borne diseases (Hasle, 2011), no study has been conducted on their tick fauna in Iran.

Due to the rich songbird diversity in the north of Iran and the importance of ticks as a vector of pathogens, the main objective of this study is evaluating tick infestation rate on songbirds in the north of Iran.

MATERIAL AND METHODS

Samplings were conducted at 23 different localities of Iran's northern regions (36°32'49.2" N, 61°09'07.2" E to 37°03'56.9" N, 48°29'10.6" E) during 2015-2016 (Table 1). The songbirds were captured from different ecosystems to cover all species of songbirds as many as possible using mist-nets (Fig. 1).

The trapped birds were identified by field guides (Porter & Aspinall, 2016), examined carefully for ticks by naked eyes and immediately released. Collected ticks were preserved in vials containing 75% ethanol. Ticks were examined under a stereomicroscope and identified to species level and categorized according to their developmental stages (Nosek & Sixl, 1972; Filippova, 1977a; Filippova, 1997b; Aeschlimann et al., 1979; Perry, 2001; Pérez-Eid, 2007; Kleinjan & Lane, 2008; Estrada-Peña et al., 2018). In order to reduce bias for small size samples, bird species fewer than ten individuals were excluded from the study. Parasitological indices, including prevalence, mean intensity, mean abundance of infestation, were calculated for each infested bird (Lafferty et al., 1997).

To evaluate the association between nutrition and migration with tick infestation, the hosts were classified based on their trophic guild (granivorous, omnivorous and insectivorous), their feeding habitats (non-ground feeders and ground feeders) and their migrant guild (sedentary, short-distance migration, long-distance migration) (Hoyo et al., 1992). Statistical analyses were performed only for *Ixodes ricinus* (Linnaeus, 1758) because it was the most common tick species among hosts that were examined in this study. Data were statistically analyzed by SPSS version 16 using the chi-square and Fisher exact test. For bird's taxon names and taxonomy, we follow Dickinson and Christidis (2014).

RESULTS

From 342 birds, 326 ticks were collected, 263 (80.67%) were in larval stage and, 63 (19.32%) in the nymphal stage. These immature ticks were included three genera (*Ixodes* Latreille, 1795, *Rhipicephalus* Koch, 1844 and, *Hyalomma* Koch, 1844) and three species. The most frequent tick species detected was *I. ricinus* (323 individuals, 99%, 260 larvae, 63 nymphs) followed by *Hyalomma* sp. (1 individual, 0.30%, 1 Larva) and *Rhipicephalus* sp. (2 individuals, 0.61%, 2 Larva) (Fig. 2).

In this study, *I. ricinus* were collected from 24 bird species belonging to 32 genere and 13 families, consisting: House Sparrow (*Passer domesticus* (Linnaeus, 1758)), Tree Sparrow (*P. montanus* (Linnaeus, 1758)), Rock Sparrow (*Petronia petronia* (Linnaeus, 1766)), Chestnut-shouldered Petronia (*Gymnoris xanthocollis* (Burton, E, 1838)) from the family Passeridae; Eastern Olivaceous Warbler (*Hippolais pallida* (Hemprich & Ehrenberg, 1833)) from the family Sylviidae; Common Chiffchaff

TABLE 1. Sampling localities, birds and the number of ticks per bird. Examined birds/ Infested birds/ Number of separated ticks.

Localities Host / Species	Mashhad	Kardeh	Ortokand	Dam Zavin	Qarah su	Kalat	Lof abad	Dargaz	Tandoreh	Kashmar	Sarakhs	Shirvan	Bojnord	Azad shahr	Alangdareh	Gorgan	Bandar Gaz	Vaz-e-olys	Chamestan	Nur	Eshkavarat	Masal	Asalem	Total
Passer domesticus	7/1/2	3/0/0	4/0/0	2/0/0	3/0/0	1/0/0	2/0/0	1/0/0	1/0/0	1/0/0	1/0/0	3/0/0	1/0/0	1/0/0	-	6/2/6	3/1/5	2/2/4	4/2/3	3/2/7	4/2/4	3/2/3	3/2/5	59/16/39
Passer montanus	2/0/0	1/0/0	-	-	-	1/0/0	3/2/3	1/0/0	3/1/1	-	-	3/1/2	6/2/3	-	-	1/1/1	-	2/1/1	-	1/1/2	1/0/0	1/1/1	2/1/1	33/10/15
Petronia petronia	-	-	-	-	-	2/0/0	-	-	2/1/1	-	-	2/1/2	-	-	-	-	-	-	-	-	-	-	-	6/2/3
Gymnoris xanthocollis	-	-	-	-	-	-	-	-	1/0/0	-	-	2/1/2	-	-	-	-	-	-	-	-	-	-	-	3/1/2
Carpospiza brachydactyla	-	-	-	-	-	-	-	-	-	1/0/0	-	-	-	-	-	-	-	-	-	-	-	-	-	1/0/0
Hippolais pallida	3/0/0	1/0/0	-	-	-	-	-	-	1/0/0	2/0/0	1/0/0	1/1/2	-	-	-	-	-	-	-	-	-	-	-	9/1/2
Iduna caligata	1/0/0	2/0/0	1/0/0	-	-	2/0/0	1/0/0	-	2/0/0	-	1/0/0	-	1/0/0	-	-	-	-	-	-	-	-	-	-	11/0/0
Acrocephalus stentoreus	1/0/0	2/0/0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3/0/0
Sylvia communis	2/0/0	-	-	-	-	2/0/0	2/0/0	-	1/0/0	2/0/0	-	1/0/0	-	-	-	1/0/0	-	-	-	-	-	-	-	11/0/0
Phylloscopus collybita	2/0/0	-	-	-	-	1/0/0	2/0/0	-	3/2/2	-	2/0/0	3/0/0	-	-	-	-	-	-	-	-	-	-	-	13/2/2
Scotocerca inquieta	-	-	-	-	-	-	-	-	1/0/0	-	-	1/0/0	-	-	-	-	-	-	-	-	-	-	-	2/0/0
Emberiza calandra	-	-	-	2/0/0	-	-	2/0/0	2/2/4	1/1/2	4/0/0	-	2/1/1	-	-	-	-	-	-	-	-	-	-	-	13/4/7
Emberiza bruniceps	-	-	-	-	-	-	-	-	4/0/0	-	-	3/0/0	-	-	-	-	-	-	-	-	-	-	-	7/0/0
Sitta europaea	-	-	-	-	-	-	-	2/0/0	2/0/0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4/0/0
Sturnus vulgaris	1/0/0	-	-	-	-	3/1/19	-	-	2/0/0	1/0/0	-	1/0/0	-	2/1/9	-	1/1/106	-	-	-	-	-	-	-	11/3/134
Acridotheres tristis	-	-	-	-	-	-	1/0/0	-	1/0/0	-	-	1/1/2	-	-	-	-	-	-	-	-	-	-	-	3/1/2
Turdus merula	7/4/14	2/1/1	-	-	-	-	-	2/2/3	-	-	-	2/0/0	-	-	-	-	-	-	-	-	-	-	-	13/7/18
Erithacus rubecula	-	-	-	-	-	-	-	-	-	-	1/0/0	2/1/5	-	-	-	-	-	-	-	-	-	-	-	3/1/5

Oenanthe lugens	-	-	-	-	-	-	-	-	-	-	1/0/0	2/0/0	-	-	-	-	-	-	-	-	-	-	-	3/0/0
Oenanthe picata	-	-	-	-	-	-	-	1/0/0	-	1/0/0	1/0/0	1/0/0	1/1/5	-	-	-	-	-	-	-	-	-	-	5/1/5
Oenanthe albonigra	-	-	-	-	-	-	-	-	1/0/0	-	1/0/0	-	-	-	-	-	-	-	-	-	-	-	-	2/0/0
Oenanthe pleschanka	-	-	-	-	-	1/0/0	1/0/0	-	1/0/0	-	1/0/0	2/1/5	-	-	-	-	-	-	-	-	-	-	-	6/1/5
Phoenicurus ochruros	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2/1/4	2/0/0	4/1/4
Rhodospiza obsoleta	-	-	-	-	-	1/0/0	-	2/2/2	1/0/0	1/0/0	-	1/0/0	-	-	-	-	-	-	-	-	-	-	-	6/2/2
Serinus pusillus	2/1/3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2/1/3
Fringilla coelebs	-	-	-	-	-	-	-	1/0/0	-	-	-	-	-	-	-	3/0/0	-	2/0/0	-	-	3/0/0	3/1/15	2/1/9	14/2/24
Carduelis chloris	-	-	-	-	-	-	-	-	-	-	-	2/0/0	3/0/0	-	-	1/0/0	-	2/0/0	-	2/0/0	-	2/0/0	-	12/0/0
Parus major	10/0/0	4/0/0	-	-	-	-	3/0/0	10/0/0	3/0/0	-	1/0/0	2/0/0	-	-	-	7/0/0	-	5/2/4	-	2/1/5	1/1/5	1/1/3	2/1/3	51/6/20
Cyanistes caeruleus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3/0/0	-	2/2/6	-	1/0/0	1/0/0	-	-	7/2/6
Galerida cristata	-	-	-	-	-	-	-	-	-	-	3/1/5	-	-	-	-	-	-	-	-	-	-	-	-	3/1/5
Calandrella rufescens	-	-	-	-	-	-	-	-	2/0/0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2/0/0
Hirundo rustica	-	-	-	-	-	-	-	-	-	-	1/0/0	-	-	-	-	-	-	-	-	-	-	-	-	1/0/0
Ficedula parva	2/0/0	-	-	-	-	-	1/0/0	-	2/0/0	-	1/0/0	-	-	-	-	3/1/1	1/1/2	-	-	-	-	-	-	10/2/3
Pica pica	-	-	-	-	-	-	-	-	-	-	1/0/0	-	-	-	-	-	-	1/1/4	-	-	-	-	-	2/1/4
Corvus corone	1/0/0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1/0/0
Motacilla alba	3/1/9	-	-	-	-	1/0/0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4/1/9
Oriolus oriolus	-	-	-	-	-	-	2/1/4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2/1/4
																								342/70/32

TABLE 2. *Ixodes ricinus* collected from passerine birds in the north of Iran. Exa. b, Examined birds; Inf. b, Infested birds; P., Prevalence; M.I., Mean intensity; M.A., Mean abundance, G., Granivorous; O., Omnivorous and I., insectivorous. * Record on new host.

Host family	Common name	Host species	No. of Exa. b	No. of Inf. b	P	No of ticks found			Mean I.	Mean A.	Trophic guild	Migrating behavior	Feeding behavior
						Larvae	Nymphs	Total					
Passeridae	House Sparrow	*Passer domesticus*	59	16	27.11	35	4	39	2.43	0.66	O	Sedentary bird	Ground feeder
	Tree Sparrow	*Passer montanus*	33	10	0.30	14	1	15	1.5	0.45	O	Sedentary bird	Ground feeder
	Rock Sparrow	*Petronia petronia**	6	2	0.33	3	0	3	1.5	0.5	Gr	Sedentary bird	Ground feeder
	Chestnut-shouldered Petronia	*Gymnoris xanthocollis* *	3	1	0.33	2	0	2	2	0.66	Gr	Short-distance migratory bird	Ground feeder
	Pale Rock Sparrow	*Carpospiza brachydactyla*	1	0	0	0	0	0	0	0	Gr	Short-distance migratory bird	Ground feeder
Sylviidae	Eastern Olivaceous Warbler	*Hippolais pallida**	9	1	0.11	2	0	2	0	0.22	I	Short-distance migratory bird	Non-ground feeder
Acrocephalidae	Booted Warbler	*Iduna caligata*	11	0	0	0	0	0	0	0	I	Long-distance migratory bird	ground feeder
	Clamorous Reed Warbler	*Acrocephalus stentoreus*	3	0	0	0	0	0	0	0	I	Short-distance migration	Non-ground feeder
	Greater Whitethroat	*Sylvia communis*	11	0	0	0	0	0	0	0	I	Long-distance migratory bird	Non-ground feeder
Phylloscopidae	Common chiffchaff	*Phylloscopus collybita*	13	2	0.15	2	0	2	1	0.15	I	Long-distance migratory bird	Ground feeder
Scotocercidae	Streaked scrub warbler	*Scotocerca inquieta*	2	0	0	0	0	0	0	0	I	Sedentary bird	Ground feeder
Emberizidae	Corn Bunting	*Emberiza calandra**	13	4	0.30	7	0	7	1.75	0.53	Gr	Sedentary bird	Ground feeder
	Red-headed Bunting	*Emberiza bruniceps*	7	0	0	0	0	0	0	0	Gr	Long-distance migratory bird	Ground feeder
Sittidae	Eurasian Nuthatch	*Sitta europaea*	4	0	0	0	0	0	0	0	I	Sedentary bird	Ground feeder
Sturnidae	Common Starling	*Sturnus vulgaris*	11	3	0.27	95	39	13 4	44.6 6	12.1 8	O	Short-distance migratory bird	Ground feeder
	Common mynah	*Acridotheres tristis**	3	1	0.33	2	0	2	2	0.66	O	Sedentary bird	Ground feeder
Turdidae	Common Blackbird	*Turdus merula*	13	7	0.53	16	2	18	2.57	1.38	I	Short-distance migratory bird	Ground feeder
Muscicapidae	European Robin	*Erithacus rubecula*	3	1	0.33	5	0	5	5	1.66	I	Short-distance migratory bird	Ground feeder
	Mourning Wheatear	*Oenanthe lugens*	3	0	0	0	0	0	0	0	I	Short-distance migratory bird	Ground feeder
	Eastern Pied Wheatear	*Oenanthe picata*	5	1	0.2	2	3	5	5	1	I	Short-distance migratory bird	Ground feeder

	Hume's Wheatear	*Oenanthe albonigra*	2	0	0	0	0	0	0	0	I	Sedentary bird	Ground feeder
	Pied Wheatear	*Oenanthe pleschanka*	6	1	0.16	4	1	5	5	0.83	I	Long-distance migratory bird	Non- Ground feeder
	Black Redstart	*Phoenicurus ochruros*	4	1	0.25	4	0	4	4	1	I	Long-distance migratory bird	Ground feeder
	Red-breasted Flycatcher	*Ficedula parva**	10	2	0.2	3	0	3	1.5	0.3	I	Long-distance migratory bird	Ground feeder
Fringillidae	Desert Finch	*Rhodospiza obsoleta**	6	2	0.33	2	0	2	0	0.33	Gr	Sedentary bird	Ground feeder
	Fire-fronted Serin	*Serinus pusillus*	2	1	0.5	3	0	3	3	1.5	Gr	Sedentary bird	Ground feeder
	Common chaffinch	*Fringilla coelebs*	14	2	0.14	20	4	24	12	1.71	O	Short-distance migratory bird	Ground feeder
	European Greenfinch	*Carduelis chloris*	12	0	0	0	0	0	0	0	Gr	Short-distance migratory bird	Ground feeder
Paridae	Great Tit	*Parus major*	51	6	0.11	19	1	20	3.33	0.39	O	Sedentary bird	Non-ground feeder
	Blue Tit	*Cyanistes caeruleus*	7	2	0.28	4	2	6	3	0.85	O	Sedentary bird	Ground feeder
Alaudidae	Crested Lark	*Galerida cristata*	3	1	0.33	4	1	5	5	1.66	Gr	Sedentary bird	Ground feeder
	Lesser Short-toed Lark	*Calandrella rufescens*	2	0	0	0	0	0	0	0	O	Sedentary bird	Ground feeder
Hirundinidae	Barn Swallow	*Hirundo rustica*	1	0	0	0	0	0	0	0	I	Long distance migration	Non-ground feeder
Corvidae	Common Magpie	*Pica pica*	2	1	0.5	3	1	4	4	2	O	Sedentary bird	Ground feeder
	Carrion Crow	*Corvus corone*	1	0	0	0	0	0	0	0	O	Sedentary bird	Ground feeder
Motacillidae	White Wagtail	*Motacilla alba*	4	1	0.25	6	3	9	9	2.25	I	Short-distance migration	Ground feeder
Oriolidae	Golden Oriol	*Oriolus oriolus*	2	1	0.5	3	1	4	4	2	O	Long-distance migratory bird	Ground feeder
Total			342	70		260	63	323					

TABLE 3. Other tick species collected on songbirds in the north of Iran. *Record on new host.

Host family	**Common name**	**Host species**	**Number examined birds**	**No of infested birds**	**Prevalence**	***Rhipicephalus* sp. *L/N/A***	***Hyalomma* sp. *L/N/A***
Paridae	Great Tit	*Parus major*	51	1	1.96	0/2/0	-
Emberizidae	Corn Bunting	*Emberiza calandra*	13	1	7.6	-	0/1/0
Total						0/2/0	0/1/0

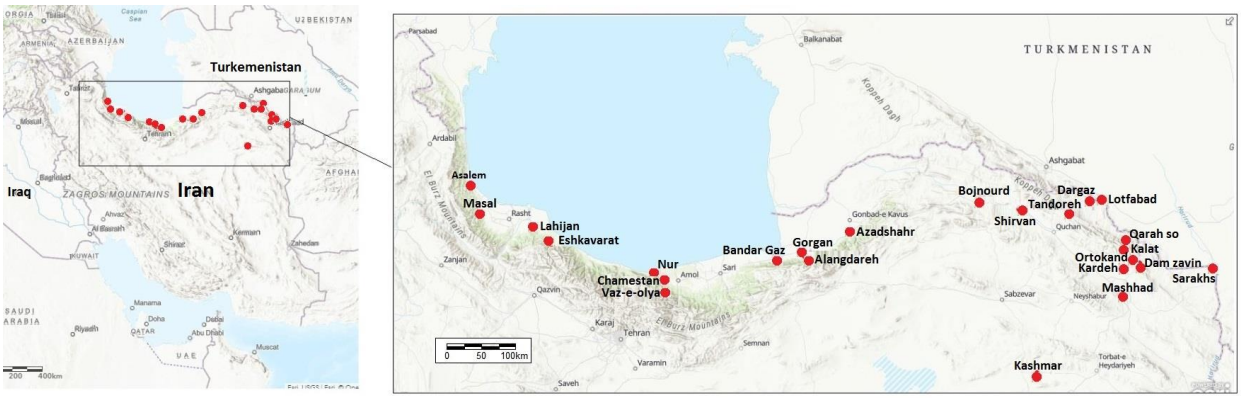

FIGURE 1. Bird sampling localities in the north of Iran. The 23 sampling stations are showed by red dots.

(*Phylloscopus collybita* (Vieillot, 1817)) from the family Phylloscopidae; Corn Bunting (*Emberiza calandra* Linnaeus, 1758)) from the family Emberizidae; Common Starling (*Sturnus vulgaris* Linnaeus, 1758), Common Mynah (*Acridotheres tristis* (Linnaeus, 1766)) from the family Sturnidae, (Common Blackbird *Turdus merula* Linnaeus, 1758) from the family Turdidae; Desert Finch (*Rhodospiza obsoleta* (Lichtenstein, MHC, 1823)), Fire-fronted Serin (*Serinus pusillus* (Pallas, 1811)), Common chaffinch (*Fringilla coelebs* Linnaeus, 1758) from the family Fringillidae; Great Tit (*Parus major* Linnaeus, 1758), Blue Tit (*Cyanistes caeruleus* Linnaeus, 1758) from the family Paridae; Crested Lark (*Galerida cristata* (Linnaeus, 1758)) from the family Alaudidae; (Red-breasted Flycatcher *Ficedula parva* (Bechstein, 1792), European Robin *Erithacus rubecula* (Linnaeus, 1758), Eastern Pied Wheatear *Oenanthe picata* (Blyth, 1847), Pied Wheatear *Oenanthe pleschanka* (Lepechin, 1770), Black Redstart *Phoenicurus ochruros* (Gmelin, SG, 1774) from the family Muscicapidae; Common Magpie (*Pica pica* (Linnaeus, 1758)) from the family Corvidae; White Wagtail (*Motacilla alba* Linnaeus, 1758) from the family Motacillidae, Golden Oriol (*Oriolus oriolus* (Linnaeus, 1758)) from the family Oriolidae (Table 2).

Rhipicephalus sp. specimens were separated from the Paridae (Great Tit) (Table 3). *Rhipicephalus* specimens were damaged and the specimen belonging to the genus *Hyalomma* was in premarginal stage, therefore they only identified at the genus level. Ticks were located on the anterior part of the body, around the eyes, crown, and forehead.

The overall mean intensity and mean abundance were 4.6 and 0.95, respectively. The highest mean intensity, 12.18 ticks per bird, was recorded from Common Starling, followed by Common Chaffinch and European Robin with 1.71 and 1.66 per bird, respectively. The highest prevalence of infestation was recorded on Common Blackbird (53%). The most prevalence of tick infestation occurred in the Turdidae family (37.83%) followed by Passeridae (33.33%) and Sturnidae (28.57%).

In order to evaluate the association between trophic guild, feeding habitats and their migrant guild with tick infestation, Fisher's exact and Chi-square tests were performed. Feeding habitats and their migrant guild represented significant association with tick infestation (P= 0.02 and P= 0.03 respectively, P< 0.05) but no association was observed between trophic guild and tick infestation (P= 0.217, P> 0.05).

DISSCUSSION

In the past few decades, there has been a surge of interest in research on ticks. This increasing interest is because of their economic and medically importance as vectors of dangerous diseases to animals and humans (Aeschlimann et al., 1979; Estrada-Peña et al., 2018). In these studies, birds with their flying capability and their essential roles in transportation and spreading ticks and tick-borne diseases to new areas have drawn more attention compared to other vertebrate hosts (Loss et al., 2016; Ogden et al., 2008; Smith et al., 1996). However, the study of ticks associated with wild birds has been neglected in Iran.

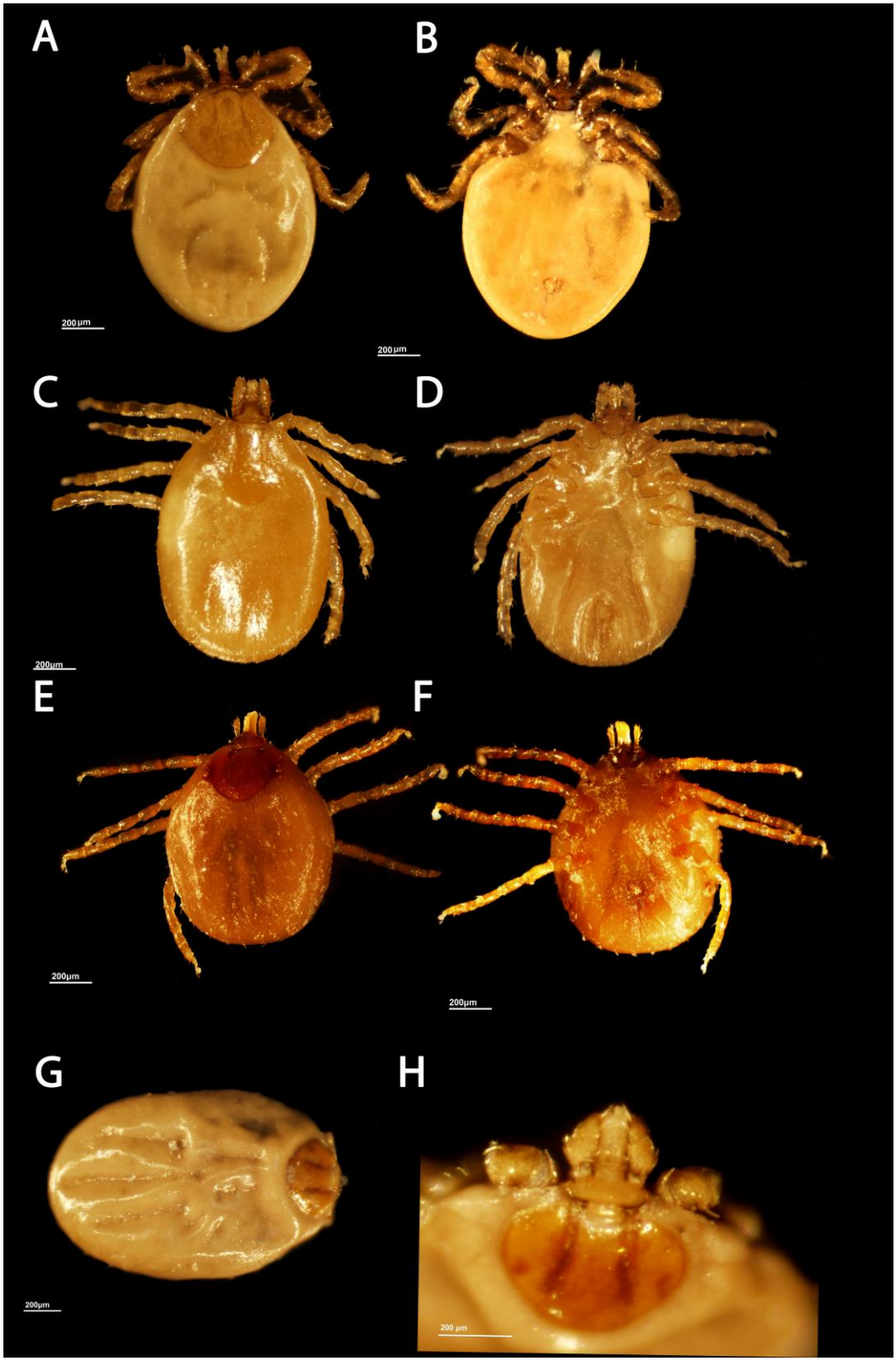

FIGURE 2. *Ixodes ricinus* larva: A. dorsal view, B. ventral view; *Ixodes ricinus* nymph: C. dorsal view, D. ventral view; *Hyalomma* sp. nymph: E. dorsal view, F. ventral view; *Rhipicephalus* sp. larva: G. dorsal view, H. Basis capituli and scutum (200 µm).

In the current study, ticks infesting songbirds were investigated in the north of Iran, which is a contact zone hotspot of songbirds (Aliabadian et al., 2005). This study reports three ixodid ticks, including *I. ricinus*, *Hyalomma* sp. and *Rhipicephalus* sp. from 70 out of 342 examined songbirds. Birds, especially songbirds are known as the host of ticks in subadult stages (Humair et al., 1993; Fourie et al., 2006; Ogrzewalska et al., 2010; da Cunha Amaral et al., 2013; Maturano et al., 2015).

In this study, only larval and nymphal stages were found on examined birds, and no adult ticks were found. The genus *Ixodes* are known as commonly or even exclusively parasitizing birds especially immature stages, which this study corroborates (Klaus et al., 2016; Papadopoulos et al., 2001). The most common tick species collected in this study was *I. ricinus*, constituted 94% (323 of 342) of all collected ticks. The previous studies have been reported it on domestic ruminant in northern mountain slopes and humid and lower hills of Caspian Sea from spring to autumn (Abbassian-Lintzen, 1960; Hoogstraal & Valdez, 1980; Hosseini-Vasoukolaei et al., 2014; Hosseini-Chegeni et al., 2019; Nabian et al., 2007; Razmi et al., 2007; Vahedi-Noori et al.,2012). *I. ricinus* has also been collected from foxes in the north and northwest of Iran (Meshgi et al. 2009). This species is known as one of the most critical vectors of many of Europe's tick-borne diseases and as telotropic parasite, in immature stages feed on small mammals, birds and, lizards and in adult stage prefer large mammals (Estrada-Peña et al., 2018). Our study showed that *I. ricinus* infestation rate was 20.46% (parasitize 70 examined birds), which is considerable in comparison with other tick infestation rates (*Hyalomma* sp. *and Rhipicephalus* sp. 1.71%). Birds, especially songbirds, have been frequently introduced in various studies as an obvious host for immature *I. ricinus* (Ciebiera et al., 2019; Humair et al., 1993). In this study, both nymphal and larval stages of *I. ricinus* have been reported, but the larval stage was more frequent on songbirds (nymphal/larval ratios 0.24, 63 nymphs and 260 larvae).

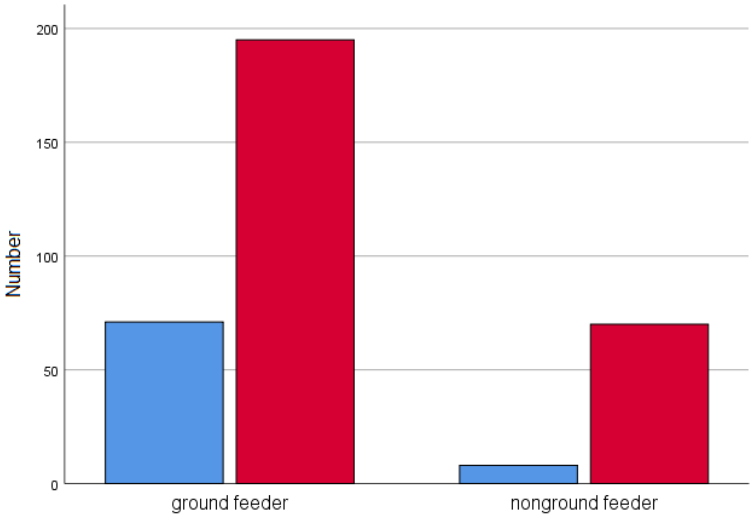

FIGURE 3. Number of infested and non-infested birds in relation to their feeding behaviour, Red: Positive tick infestation, Blue: Negative tick infestation (P = +0.002, P < 0.05).

Common Blackbird (*Turdus merula*) has shown the highest prevalence of tick infestation (53%), followed by House Sparrow (*Passer domesticus*) (35.5%), which is consistent with the results of James et al. (2011). The highest prevalence of tick infiestaion in these hosts depends mainly on their high degree of feeding on the ground (Klaus et al., 2016). In Europe, Japan, Russia, Common Blackbird also have been reported as the most important hosts for harbouring ticks (Hasle, 2013). The highest mean intensity of infestation for *I. ricinus* was recorded on Common Starling (*Sturnus vulgaris*) (12.18 ticks per bird). The cause of the high amount of mean intensity in Common Starling was infestation of one individual by 106 tick specimens.

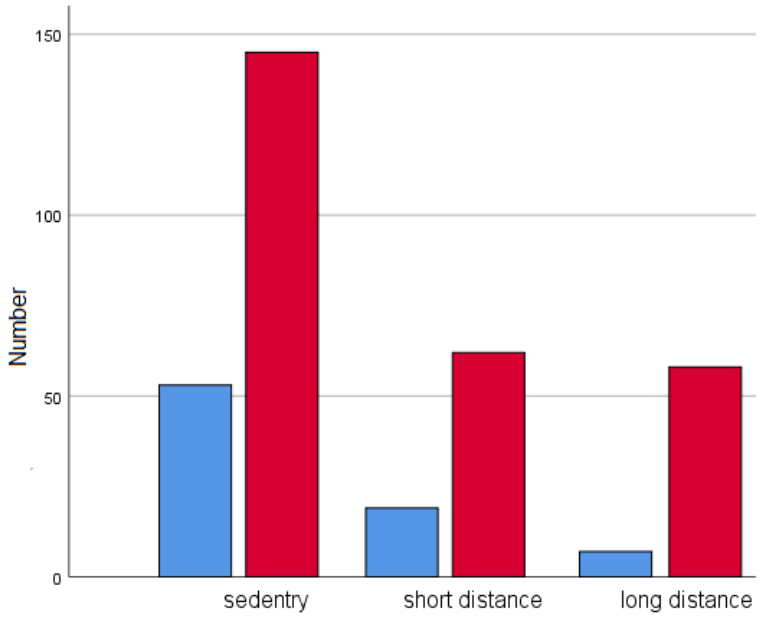

FIGURE 4. Number of infested and non-infested birds to *Ixodes ricinus* in relation to their migrating behaviour, Red: Positive tick infestation, Blue: Negative tick infestation (P = +0.029, P < 0.05).

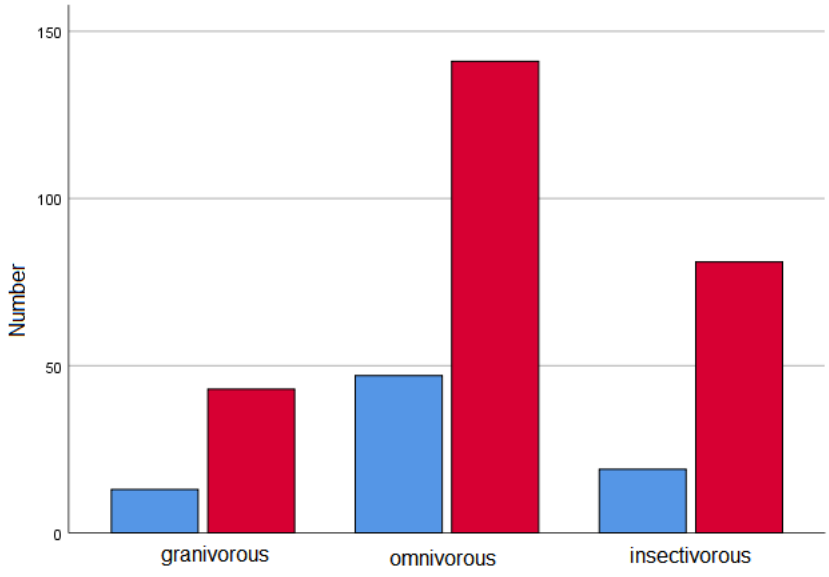

FIGURE 5. Number of infested and non-infested birds in relation to their trophic guild, Red: Positive tick infestation, Blue: Negative tick infestation (P = +0.514, P > 0.05)

The most prevalent tick infesting songbirds was reported in the Turdidae family that is in line with previous studies (Aeschlimann et al.,1974; Humair et al.,1993). In this study, the occurrence of *I. ricinus* on Rock Sparrow, Chestnut-shouldered Petronia, Eastern Olivaceous Warbler, Corn Bunting, Common Mynah, Desert Finch, Red-breasted Flycatcher is documented for the first time.

According to previous studies, ground feeder birds and the birds which nest on the ground are more exposed to tick infestations than nonground feeder birds or the bird's nest on the top of the trees [7, 9, 56] (Brinck et al., 1965; Cohen et al., 2015; Wang & Moore, 2005). Our study confirmed that differences between tick infestation rates for ground feeder birds (25.75%) and non-ground feeder (10.25%) were more than twice as much. Differences between these two groups of birds were statistically significant ($P< 0.05$) (Fig. 3).

The data presented here showed that the total *I. ricinus* infestation rate for sedentary birds (26.39%) was more than migratory birds (16.55%) (Fig. 4). It was predictable because sedentary birds are more likely to be exposed to ticks. It is in agreement with the results of Klaus et al. (Klaus et al., 2016) in Germany.

The statistical analysis showed that no association was observed between the probability of infestation by ticks and trophic guild, (Fig. 5). In previous studies, diet alone was presented as a weak component for the probability of tick infestation rate (Kolonin, 2008; Marini et al., 1996).

The species of the genus *Hyalomma* are predominantly infesting mammals. Only some species of this genus in immature stages parasitize ground feeding birds (Apanaskevich, 2004). A larva identified as *Hyalomma* sp. was recorded on Corn Bunting in the current study.

Of 37 studied species here, 11 species carried no ticks, including: Pale Rock Sparrow, Booted Warbler *Iduna caligata* (Lichtenstein, MHC, 1823), Clamorous Reed Warbler *Acrocephalus stentoreus* (Hemprich & Ehrenberg, 1833), Greater Whitethroat *Sylvia communis* Latham, 1787, Red-headed Bunting *Emberiza bruniceps* von Brandt, 1841, Eurasian Nuthatch *Sitta europaea* Linnaeus, 1758, Mourning Wheatear *Oenanthe lugens* , Hume's Wheatear, European Greenfinch *Carduelis chloris* (Linnaeus, 1758), Lesser Short-toed Lark *Calandrella rufescens* (Vieillot, 1819), Barn Swallow *Hirundo rustica* Linnaeus, 1758, Carrion Crow *Corvus corone* Linnaeus, 1758 carried no ticks maybe because of being in environment that they were not exposed to ticks.

Our study improved our knowledge about songbirds as transmitter of ticks and effects of their migrating and feeding behaviours on tick infestation rates. According to data presented here, some songbird species introduced as new hosts of some tick species in the world. It seems that Iran, with a relatively high amount of diversity in different wild bird species, especially songbirds might provide good cases for reporting new records of tick fauna for Iran and the Middle East.

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