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Biodiversity of minute pirate bugs (Hemiptera: Anthocoridae) in agricultural and natural habitats of Lorestan province, west Iran

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The minute pirate bugs (Hemiptera: Anthocoridae) are an important group of natural enemies for biological control of many pests such as aphids, whiteflies, thrips, and spider mites. In this study, biodiversity of anthocorid bugs was studied in three geographical localities of Lorestan province (Khoramabad, Veisian, and Borujerd) during March 2014 to June 2016. A total of seven species, including *Anthocoris pilosus* (Jakolev, 1877), *Orius albidipennis* (Reuter, 1884), *Orius laevigatus* (Fieber, 1860), *Orius minutus* (Linnaeus, 1758), *Orius niger* (Wolff, 1811), *Orius pallidicornis* (Reuter, 1884) and *Orius vicinus* (Ribaut, 1923) were identified. We calculated the Shannon-Wiener index as 1.197, 0.939, and 0.898, the Simpson's index as 2.96, 1.75, and 1.75, and the Margalef's index as 0.66, 0.85, and 0.88 for anthocorid communities in Khoramabad, Veisian, and Borujerd, respectively. The biodiversity indices varied significantly in different seasons. The highest and the lowest diversity and abundance were recorded in summer and winter, respectively. The diversity indices were not statistically different between intensified (crop fields and orchards) and natural (rangelands and forests) habitats, though bugs in intensified habitats tended to have higher frequency and diversity than natural habitats. This study may provide useful information about species frequency and biodiversity of anthocorid bugs in Lorestan province.
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Key words: *Anthocoridae, biodiversity, Lorestan, agricultural intensification, predatory bugs.*

INTRODUCTION

Agricultural systems around the world have faced intensification to produce more crops per unit area for the demands of growing human population (Crowder & Jabbour, 2014). The increased use of pesticides and fertilizers as well as decrease in crop diversity, as parts of agricultural intensification practices, have substantial impacts on biodiversity of natural enemies, thus are expected to negatively affect sustainability, pest population dynamics, and eventually crop yield (Cardinale *et al.*, 2003; Crowder *et al.*, 2010). Besides direct effects of individual natural enemies, the non-additive interactions between diverse arrays of natural enemies, including predators, parasitoids, and pathogens, may also contribute significantly to suppression of pest populations (Cardinale *et al.*, 2003). For example, Cardinale *et al.* (2010) reported that population suppressions of the pea aphid, *Acyrthosiphon pisum* (Hemiptera: Aphididae), on alfalfa (*Medicago sativa*) by a complex of ladybird beetles (Coleoptera: Coccinellidae), damsel bugs (Hemiptera: Nabidae) and parasitic wasps

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(Hymenoptera: Braconidae) were more than could be expected from the summed impact of each natural enemy alone.

Minute pirate bugs (Hemiptera: Anthocoridae) are generalist predators of a wide diversity of pests including aphids, whiteflies, psyllids, spider mites, scale insects, thrips, insect eggs and small caterpillars (Sampaio *et al*., 2009). Several species, particularly within the genera *Orius* Wolff, 1811 and *Anthocoris* Fallen, 1814, are currently reared commercially for biological control of hemipterous pests and thrips around the world. Understanding the relationships between biodiversity of anthocorid bugs and agricultural intensification, as well as the impacts of climate and geographic conditions and seasonal fluctuations on this biodiversity is essential for improving and conserving biological control by these natural enemies in modern agricultural systems. In this study, the species richness, diversity, and seasonal fluctuation of anthocorid bugs were studied in either intensified or natural habitats of Lorestan province.

MATERIAL AND METHODS

Study area and sampling

This study was performed in Lorestan province, located at west of Iran with an area of 23,392 km^2 (Fig. 1). Although, the climate of Lorestan province is largely influenced by occurring on the western foothills of Zagros Mountains, this province can be divided into three distinct climatic zones: a mountainous cold zone on eastern regions (including the counties Borujerd, Doroud, Azna, and Alishtar) experiencing cold winters and moderate summers, a temperate zone in central regions (including Khorrmabad county) with moderate winter and summer, and a tropical to semi-tropical zone (including Pol-e-Dokhtar and southern parts of Khoramabad) which is under the influence of the warm air currents of Khuzestan province, and have hot summers and relatively moderate winters. We set our samplings in three geographical localities, including Borujerd County (33° 53' 39" N, 48° 46' 01" E, 1564 m asl), Khoramabad County (33° 27' 52" N, 48° 20' 20" E, 1167 m asl) and Veisian Section (33° 49' 56" N, 48° 02' 71" E, 1012 m asl) (Fig. 1). Sampling was performed bi-weekly from the three locations during March 2014 to June 2016. In each location, four vegetation types, including orchards and agricultural fields (as intensified habitats), and rangelands and forests (as natural habitats) were selected and in each habitat, three plots (about 2000 m^2) were considered as replicates. In each plot, we walked across the diameter and selected one plant/tree for sampling every three meters. For all locations and habitats, sampling was performed during 10:00 to 16:00 by shaking selected plants on a white tray and collecting the bugs immediately using an aspirator. Specimens were preserved in ethanol (75%) plus 5% glycerol (Tommasini, 2004).

Species identification was performed based on characteristics of male genitalia. Male and female bugs were identified by observing the ventral part of the last abdominal segment, which is asymmetrical and curved in males, but symmetrical with a median cleft in females. Anthocorid males have only the left paramere; the right one has been lost (Yasunaga *et al*., 1997c; Tommasini, 2004) (Fig. 2).

For preparation of microscopic slides from male genitalia, the last abdominal segment of male bugs was removed, placed in 10% KOH, and boiled in a water bath for 10-15 min. The samples were then washed with distilled water for 10 min and dehydrated by gradually passing through ascending series (50%, 70%, and 96%) of ethanol so as to gradually replace water with the alcohol. After incubating the samples in xylene solution for 10 min, the genitalia were removed using fine needle and placed on slides with Hoyers solution. Specimens and mounted genitalia were examined under a stereo-microscope (Olympus SZ40, Japan) and microscope (Olympus BX51, Japan), respectively, both equipped with digital cameras. Specimens were identified at species level using keys provided by Pericart (1972) Elove (1996), Yasunaga *et al*. (1997a, 1997b, 1997c) Erfan & Ostovan (2005), and Hasanzadeh Awal & Modares Awal (2010). The specimens have been deposited in the entomological collection of Shahid Chamran University (Ahwaz, Iran).

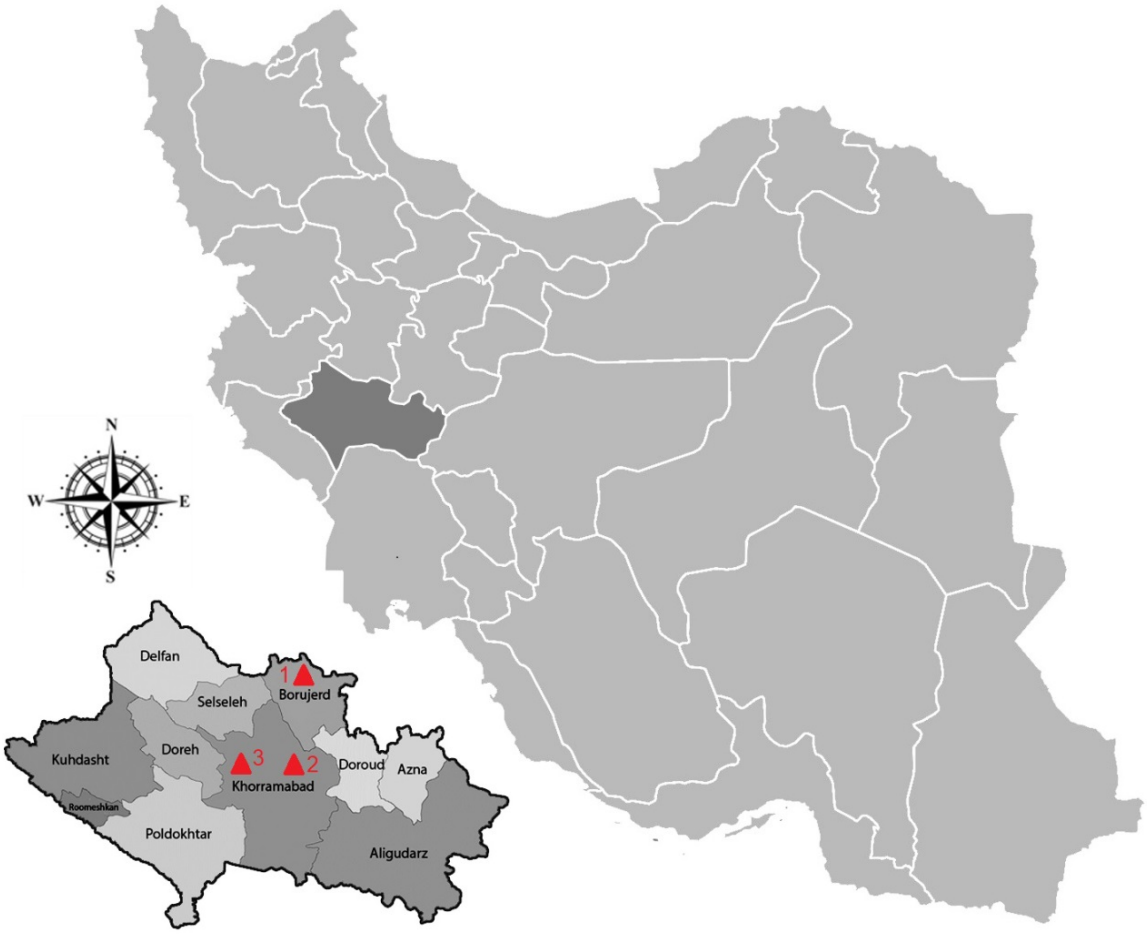

FIGURE 1. Geographical map of the study area (Lorestan Province) and three selected locations, 1) Borujerd, 2) Khoramabad, 3) Veisian.

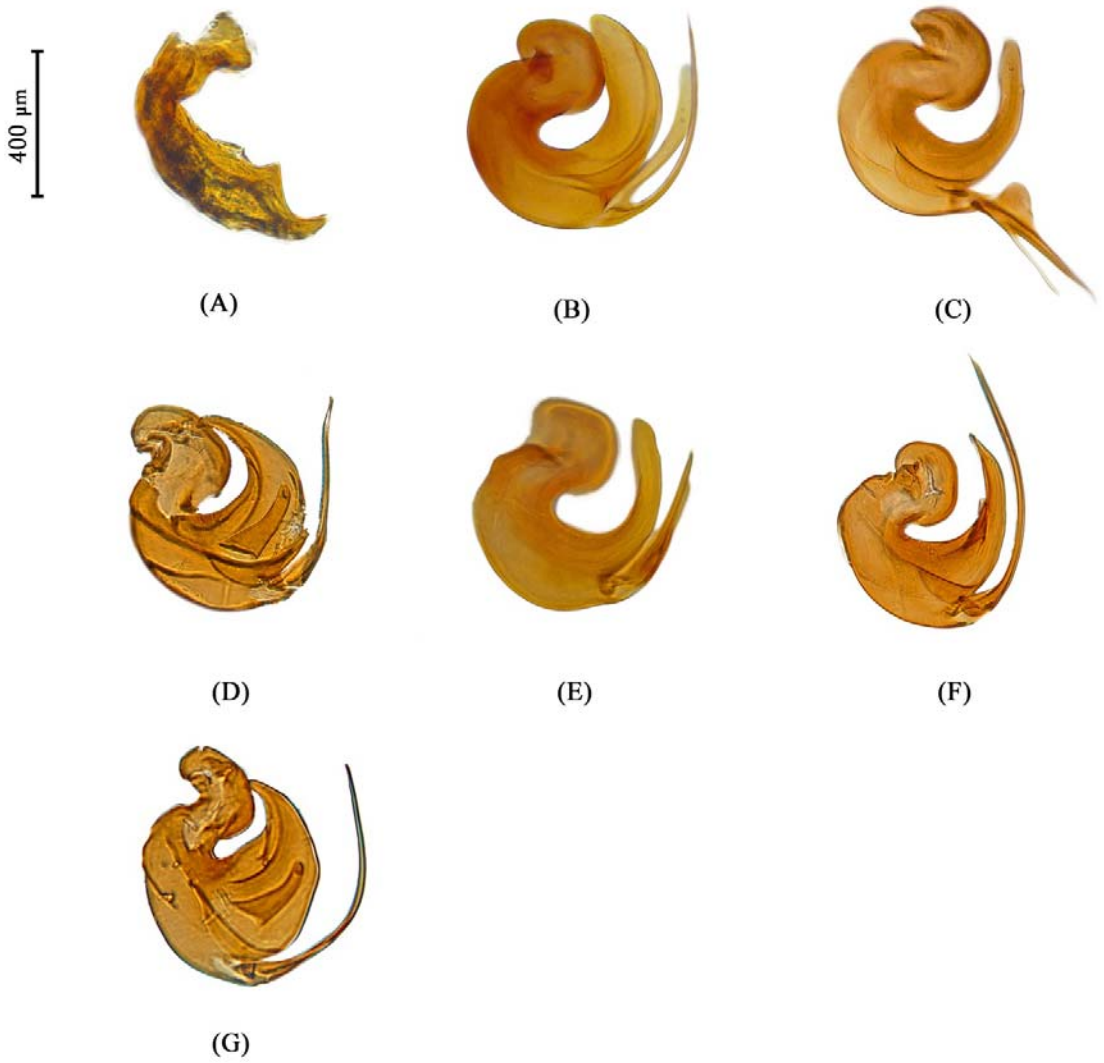

FIGURE 2. Lateral view of male genitalia, A) *Anthocoris pilosus*, B) *Orius albidipennis*, C) *O. laevigatus*, D) *O. minutus*, E) *O. niger*, F) *O. pallidicornis*, G) *O. vicinus*.

Data analysis

Data were analyzed using Species Diversity and Richness (SDR) software (version 2.1.4) developed by Henderson & Seaby (2006). After species identification, the relative frequency of each species in each location was estimated by dividing the individual number of the species (*S*) by the total number of collected individuals (*N*). By having the number of species and their relative frequencies, the diversity indices were calculated as follow:

The Shannon-Wiener diversity index (H') was calculated using the following formula:

$$H' = -\sum p_i \operatorname{Ln} p_i$$

Where p_i is the relative frequency of ith species (p_i=S/N) (Krebs, 1985).

For calculating the evenness of species, the Simpson's index was used. The Simpson's index is based on the probability of any two individuals drawn at random from the community belonging to different species and is calculated as follow:

$$\text{Simpson's index} = 1 - D = 1\text{-} [\Sigma\, n_i\,(n_i - 1) \,/\, N\,(N - 1)]$$

Where n_i is the individual number of ith species and N is the total number of individuals (Schowalter, 2012).

Margalef's index (R) was used as a simple measure of species richness as follow (Margalef, 1958).

$$R = (S - 1) \,/\, \text{Ln}\,(N)$$

Where S is the total number of species and N is the total number of individuals in the sample.

RESULTS AND DISCUSSION

Insect identification

Faunestic study

A total of seven species, belonging to two genera (*Orius* and *Anthocoris*) were collected and identified during March 2014 to June 2016. Adult Anthocoridae can be identified by a combination of characteristics including a body length of 1.5-5 mm, elongated oval body, usually patterned in black and white, a three-segmented beak, three or four-segmented antennae, metathoracic scent glands grooves present on metapleuron, forewing with a distinct costal fracture, membrane usually with four free veins, and male genitalia asymmetrical, right paramere greatly reduced or absent, left paramere usually sickle-shaped (Schuh & Slater, 1995). The family consists of three subfamilies, Lyctocorinae, Lasiochilinae, and Anthocorinae, all of our specimens belonged to the latter one.

Subfamily Anthocorinae Fieber, 1837

Tribe Anthocorini Fieber, 1837

The tribe Anthocorini is composed of more than 10 genera, with strong representation in the Palearctic region (Carpintero, 2002). Members of this tribe can be identified by a distinct callus on pronotum, larger size (3-5 mm) and a sickle-shaped paramere in males. The largest genus within this tribe is *Anthocoris* Fallen, 1814, with more than 50 described species worldwide (Carpintero, 2002). In this study, a single species of the genus *Anthocoris* was identified.

***Anthocoris pilosus* (Jakolev, 1877) (Fig. 2A)**

Materials examined: Lorestan province: Borujerd County (33° 53' 39" N, 48° 46' 01" E, 1564 m asl), 19.03.2015, 2♂, on *Jasminum* sp.; 17.04.2015, 2♂, on *Jasminum* sp.; 17.07.2015, 2♂, on *Dahlia* sp.

General distribution: Palaearctic region.

Distribution in Iran: Ardabil, Fars, East Azarbaijan, Guilan, Ilam, Isfahan, Kerman, Khuzestan, Mazandaran, Northern Khorasan, Razavi Khorasan, Semnan, Tehran (Ostovan *et al*., 2017), Lorestan (Current study).

Tribe Oriini Carayon, 1955

The tribe Oriini consists of about 17 genera worldwide. Members of this tribe are characterized by smaller size (2-3 mm), less distinct callus on pronotum, and a spiral paramere in males. The largest genus within this tribe is *Orius* Wolff, 1811, with more than 50 described species worldwide, about

20 of which occur in Palearctic region (Postle *et al*., 2001). In this study, six species of the genus *Orius* were identified.

***Orius* (*Dimorphella*) *albidipennis* (Reuter, 1884) (Fig. 2B)**

Materials examined: Lorestan province: Borujerd County (33° 53' 39" N, 48° 46' 01" E, 1564 m asl), 30.04.2015, 3♂, on *Zinnia* sp.; 10.07.2015, 2♂, on *Helianthus* sp.; 17.07.2015, 1♂, on *Dahlia* sp.; 31.06.2015, 3♂, on *Medicago* sp. and *Trifolium* sp.; 14.08.2015, 5♂, on *Medicago* sp. and *Trifolium* sp.; 28.08.2015, 3♂, on *Medicago* sp.; 18.09.2015, 2♂, on *Medicago* sp.; Khoramabad County (33° 27' 52" N, 48° 20' 20" E, 1167 m asl), 06.03.2015, 3♂, on *Dianthus* sp.; 20.03.2015, 4♂, on *Amaranthus* sp.; 06.04.2015, 10♂, on *Calendula* sp.; 01.05.2015, 5♂, on *Fraxinus* sp.; 14.05.2015, 11♂, on *Amaranthus* sp.; 18.06.2015, 3♂, on *Calendula* sp.; 01.07.2015, 12♂, on *Helianthus* sp.; 11.07.2015, 10♂, on *Calendula* sp.; 28.07.2015, 10♂, on *Mentha* sp.; 16.08.2015, 14♂, on *Matricaria* sp.; 23.08.2015, 30♂, on *Amaranthus* sp.; 09.09.2015, 28♂, on *Medicago* sp.; 29.09.2015, 5♂, on *Calendula* sp.; 30.10.2015, 2♂, on *Calendula* sp.; 13.11.2015, 5♂, on *Nerium* sp.; 04.12.2015, 2♂, on unknown weed; 11.12.2015, 3♂, on *Calendula* sp.; Veisian section (33° 29' 14" N, 48° 01' 48" E, 1012 m asl), 16.03.2015, 9♂, on *Brassica napus*; 01.05.2015, 13♂, on *Jasminum* sp.; 16.05.2015, 13♂, on *Jasminum* sp.; 18.06.2015, 12♂, on *Calendula* sp.; 13.07.2015, 15♂, on *Antirrhinum* sp.; 18.07.2015, 12♂, on *Helianthus* sp.; 28.07.2015, 12♂, on *Mentha* sp.; 16.08.2015, 10♂, on *Sinapis arvensis*; 24.08.2015, 40♂, on *Zea mays* sp.; 08.09.2015, 32♂, on *Medicago* sp.; 26.09.2015, 15♂, on *Cucumis sativus*; 04.10.2015, 18♂, on *Calendula* sp.; 19.10.2015, 24♂, on *Zea mays*; 30.10.2015, 5♂, on *Lycopersicum esculentum*; 12.11.2015, 1♂, on *Solanum melongena*; 03.12.2015, 1♂, on unknown weed; 11.12.2015, 5♂, on unknown weed.

General distribution: Palearctic region.

Distribution in Iran: Alborz, Ardabil, Chaharmahal & Bakhtiari, East Azarbaijan, Fars, Golestan, Guilan, Hamadan, Hormozgan, Isfahan, Kerman, Khuzestan, Kordestan, Kuhgiloyeh & Boyerahmad, Mazandaran, Razavi Khorasan, Semnan, Sistan & Baluchestan, Tehran, West Azarbaijan, Yazd (Ostovan *et al*., 2017), Lorestan (Current study).

***Orius* (*Orius*) *laevigatus* (Fieber, 1860) (Fig. 2C)**

Material examined: Lorestan province: Borujerd County (33° 53' 39" N, 48° 46' 01" E, 1564 m asl), 15.05.2015, 5♂, on *Dahlia* sp.; 10.07.2015, 8♂, on *Helianthus* sp.; 17.07.2015, 1♂, on *Calendula* sp.; 31.07. 2015, 4♂, *Medicago* sp.; 14.08.2015, 11♂, *Medicago* sp.; 28.08.2015, 5♂, *Medicago* sp.; 18.09.2015, 1♂, *Medicago* sp.; 09.10.2015, 1♂, on *Zinnia* sp.; Khoramabad County (33° 27' 52" N, 48° 20' 20" E, 1167 m asl), 01.05.2015, 5♂, on *Fraxinus* sp.; 15.05.2015, 4♂, on *Amaranthus* sp.; 01.07.2015, 2♂, on *Helianthus* sp.; 16.08.2015, 11♂, on *Matricaria* sp.; 29.09.2015, 1♂, on *Calendula* sp.; 29.09.2015, 1♂, on *Calendula* sp.; Veisian section (33° 29' 14" N, 48° 01' 48" E, 1012 m asl), 15.03.2015, 3♂, on *Brassica napus*; 01.04.2015, 1♂, on *Sinapis arvensis*; 01.05.2015, 4♂, on *Jasminum* sp.; 24.08.2015, 10♂, on *Zea mays*; 04.10.2015, 5♂, on *Calendula* sp.; 19.10.2015, 4♂, on *Zea mays*.

General distribution: Palearctic region.

Distribution in Iran: Ardabil, Guilan, Hormozgan, Mazanadaran, Fars, Golestan, Ilam, Khuzestan, Kuhgiloyeh & Boyerahmad, Northern Khorasan, Yazd (Ostovan *et al*., 2017), Lorestan (Current study).

***Orius* (*Heterorius*) *minutus* (Linnaeus, 1758) (Fig. 2D)**

Material examined: Lorestan province: Veisian section (33° 29' 14" N, 48° 01' 48" E, 1012 m asl), 28.07.2015, 1♂, on *Calendula* sp.; 08.09.2015, 1♂, on *Zea mays*.

Distribution in Iran: Alborz, East Azarbaijan, Tehran, Fars, Guilan, Hamadan, Isfahan, Kermanshah, Kordestan, Markazi, Tehran, Mazandaran, Northern Khorasan, Razavi Khorasan, Semnan, West Azarbaijan (Ostovan *et al*., 2017), Lorestan (Current study).

General distribution: Palearctic region.

***Orius* (*Orius*) *niger* (Wolff, 1811) (Fig. 2E)**

Material examined: Lorestan province: Borujerd County (33° 53' 39" N, 48° 46' 01" E, 1564 m asl), 17.04.2015, 1♂, on *Calendula* sp.; 30.04.2015, 2♂, on *Zinnia* sp.; 19.06.2015, 7♂, on *Nerium* sp.; 10.07.2015, 4♂, on *Helianthus* sp.; 17.07.2015, 5♂, on *Calendula* sp.; 31.07.2015, 18♂, on unknown weed.; 14.04.2015, 14♂, on *Medicago* sp.; 28.08.2015, 15♂, on *Medicago* sp.; 18.09.2015, 30♂, on *Medicago* sp.; 09.10.2015, 50♂, on *Dahlia* sp.; 23.10.2015, 60♂, on *Medicago* sp.; 19.10.2015, 5♂, on *Nerium* sp.; Khoramabad County (33° 27' 52" N, 48° 20' 20" E, 1167 m asl), 01.05.2015, 10♂, on *Fraxinus* sp.; 18.06.2015, 14♂, on *Calendula* sp.; 01.07.2015, 14♂, on *Helianthus* sp.; 11.07.2015, 7♂, on *Calendula* sp.; 28.07.2015, 11♂, on *Mentha* sp.; 23.08.2015, 25♂, on *Amaranthus* sp.; 09.09.2015, 30♂, on *Medicago* sp.; 29.09.2015, 14♂, on *Zinnia* sp.; 16.10.2015, 24♂, on *Zinnia* sp.; 30.10.2015, 1♂, on *Zinnia* sp.; 04.12.2015, 7♂, on *Calendula* sp.; 11.12.2015, 5♂, on *Calendula* sp.; Veisian section (33° 29' 14" N, 48° 01' 48" E, 1012 m asl), 01.05.2015, 2♂, on *Jasminum* sp.; 26.07.2015, 4♂, on *Cucumis sativus*; 14.10.2015, 1♂, on *Calendula* sp.; 19.10.2015, 3♂, on *Zea mays*; 12.11.2015, 1♂, on *Solanum melongena*; 03.12.2015, 5♂, on unknown weed; 11.12.2015, 3♂, on unknown weed.

Distribution in Iran: Alborz, Ardabil, Bushehr, Hormozgan, Qazvin, East Azarbaijan, Fars, Golestan, Guilan, Hamadan, Ilam, Isfahan, Kerman, Khuzestan, Kordestan, Kuhgiloyeh & Boyerahmad, Mazandaran, Northern Khorasan, Razavi Khorasan, Semnan, Tehran, West Azarbaijan, Yazd (Ostovan *et al*., 2017), Lorestan (Current study).

General distribution: Palearctic region.

***Orius* (*Orius*) *pallidicornis* (Reuter, 1884) (Fig. 2F)**

Material examined: Lorestan province: Borujerd County (33° 53' 39" N, 48° 46' 01" E, 1564 m asl), 19.06.2015, 5♂, on *Nerium* sp.; 18.07.2015, 4♂, on *Medicago* sp.; 18.07.2015, 1♂, on *Dahlia* sp.; Khoramabad County (33° 27' 52" N, 48° 20' 20" E, 1167 m asl), 01.05.2015, 1♂, on *Fraxinus* sp.; 18.06.2015, 12♂, on *Calendula* sp.; 01.07.2015, 18♂, on *Helianthus* sp.; 11.07.2015, 4♂, on *Calendula* sp.; 23.08.2015, 17♂, on *Calendula* sp.; 16.10.2015, 1♂, on *Dahlia* sp.; Veisian section (33° 29' 14" N, 48° 01' 48" E, 1012 m asl), 16.03.2015, 1♂, on *Brassica napus*; 01.05.2015, 11♂, on *Jasminum* sp.; 13.07.2015, 2♂, on *Antirrhinum* sp.; 08.09.2015, 5♂, on *Zea mays*; 19.10.2015, 2♂, on *Zea mays*.

Distribution in Iran: Alborz, Fars, Golestan, Isfahan, Khuzestan, Kuhgiloyeh & Boyerahmad, Mazandaran, Razavi Khorasan, Semnan, Yazd (Ostovan *et al*., 2017), Lorestan (Current study),

General distribution: Palearctic region.

***Orius* (*Heterorius*) *vicinus* (Ribaut, 1923) (Fig. 2G)**

Material examined: Lorestan province: Borujerd County (33° 53' 39" N, 48° 46' 01" E, 1564 m asl), 15.05.2015, 1♂, on *Jasminum* sp.; Khoramabad County (33° 27' 52" N, 48° 20' 20" E, 1167 m asl), 29.09.2015, 1♂, on *Zinnia* sp.; Veisian section (33° 29' 14" N, 48° 01' 48" E, 1012 m asl), 18.06.2015, 2♂, on *Calendula* sp.; 02.07.2015, 4♂, on *Helianthus* sp.; 28.07.2015, 4♂, *Mentha* sp.; 08.09.2015, 5♂, *Zea mays*; 26.09.2015, 2♂, *Cucumis sativus*.

Distribution in Iran: Fars, Golestan, Guilan, Isfahan, Khuzestan, Kuhgiloyeh & Boyerahmad, Mazandaran, Northern Khorasan, Razavi Khorasan, Tehran, West Azarbaijan, Yazd (Ostovan *et al*., 2017), Lorestan (Current study),

General distribution: Palearctic region.

Diversity indices

Diversity indices provide useful information about rarity, commonness, and species distribution across habitats. In particular to natural enemies, they enable us to determine the abundant

(dominant) or endangered species and explore the effect of agricultural intensifications on population structure of natural enemies and process of biological control. In this study, the population diversity of Anthocoridae was compared among intensified or natural habitats, among different seasons, and among three geographic locations by calculating the three common diversity indices, Shannon-Wiener index, Simpson's index, and Margalef's index. A total of 404, 285, and 336 adult bugs were collected from Khoramabad, Borujerd and Veisian, respectively (Table 1). The Shannon-Wiener diversity index accounts for both abundance and evenness of species in the community. The values of Shannon-Wiener index ranges between 0 and 5, with common ranges usually between 1.5 and 3.5 (Altieri, 1999). In this study, the Shannon-Wiener index was estimated as 1.197, 0.939, and 0.898 for Khoramabad, Veisian, and Borujerd communities, respectively (Table 1). Besides low diversity for all studied locations (indices < 1.5), these results indicate higher diversity of anthocorid bugs in Khoramabad community when compared with Borujerd and Veisian. In similar studies, the Shannon-Wiener index of Anthocorid communities has been estimated as 0.48 in Mashhad County (north eastern Iran) (Hasanzadeh Awal & Modares Awal, 2010) and between 0.96 and 1.24 in Kohgiloyeh and Boyerahmad Province (central Iran) (Davari *et al*., 2015).

The Simpson's diversity index takes into account the number of species present in a community as well as the relative abundance of each species. The Simpson's index was calculated as 2.96, 1.75, and 1.75 for Khoramabad, Borujerd, and Veisian communities, respectively, indicating significantly higher rate of species evenness in Khoramabad community than either Borujerd or Veisian (Table 1). The Margalef's index is a simple measure of species richness within a community. As seen in the Table 1, this index was calculated as 0.66, 0.88, and 0.85 for anthocorid communities in Khoramabad, Borujerd, and Veisian, respectively. These results simply indicate higher species richness of Anthocoridae in Borujerd and Veisian communities, but significantly higher species evenness in Khoramabad one (Table 1).

TABLE 1. Calculation of diversity indices for anthocorid bugs collected from three locations in Lorestan province.

Location	*N*	*H′*	*S*	R
Khoramabad	404	1.197^{a}	2.96^{a}	0.66^{b}
Borujerd	285	0.898^{b}	1.75^{b}	0.88^{a}
Veisian	336	0.939^{b}	1.75^{b}	0.85^{a}
Jacknife SE		0.061	0.214	0.114

N, total number of collected individuals, H', Shannon-Wiener index, S, Simpson's index, R, Margalef's index, different superscript letters in each column show significant difference at P<0.05 level

The dominant species were determined based on relative frequency either for Lorestan province or each of studied location (Table 2). Although, the most abundant species in all specimens collected form Lorestan province were *O. albidipennis* (41.65%) and *O. niger* (38.34%), this pattern of abundance was not observed in any separated location. The most abundant species were *O. niger* (40.34%) and *O. albidipennis* (39.1%) in Khoramabad community, *O. niger* (74.03%) and *O. laevigatus* (12.63%) in Borujerd community, and *O. albidipennis* (74.4%) in Veisian community (Table 2).

TABLE 2. species abundance (relative frequency) of anthocorid bugs in Lorestan province and three separated locations within this province.

Species	Lorestan pro.	Khoramabad	Borujerd	Veisian
Anthocoris pilosus	6 (0.58%)	0 (0%)	6 (2.1%)	0 (0%)
Orius albidipennis	427 (41.65%)	158 (39.1%)	19 (6.66%)	250 (74.4%)
Orius laevigatus	88 (8.58%)	25 (6.18%)	36 (12.63%)	27 (8.03%)
Orius minutus	2 (0.19%)	0 (0%)	0 (0%)	2 (0.59%)
Orius niger	393 (38.34%)	163 (40.34%)	211 (74.03%)	19 (5.65%)
Orius pallidicornis	90 (8.78%)	57 (14.1%)	12 (4.21%)	21 (6.25%)
Orius vicinus	19 (1.85%)	1 (0.24%)	1 (0.35%)	17 (5.05%)

The data were used to study the seasonal fluctuations of diversity indices for anthocorid bugs in Lorestan province. According to the results, the Shannon-Wiener index varied from 0.884 at autumn to 1.357 at spring months (Table 3). In a similar pattern, the highest and the lowest values of Simpson's index were recorded during spring (3.271) and autumn (2.021), respectively, indicating higher frequency of dominant species during spring and higher species diversity and evenness during autumn months (Table 3). By contrast, the Margalef's index was maximized during winter months (1.243) and showed a continuous descending pattern towards spring (0.968), summer (0.954), and autumn (0.706) (Table 3). The seasonal changes in the relative frequency of species in Lorestan province were determined based on sampling data (Table 4). According to the results, *O. albidipennis* was the dominant species during spring, summer, and winter months, while the dominant species during autumn was *O. niger* (Table 4). Specifically for each location, the dominant species for Veisian was *O. albidipennis* for all seasons. In Khoramabad, the dominant species was *O. albidipennis* during spring, summer, and winter, but *O. niger* during autumn. By contrast, the dominant species in Borujerd was *O. niger* during all seasons, except for winter, which shifted towards *O. albidipennis* (data not shown). In line with this study, Davari *et al.* (2015) showed that *O. albidipennis* and *O. niger* are the most abundant species of anthocorid bugs in all seasons and different regions of Kohgiloyeh and Boyerahmad Province, a province that is geographically close to Lorestan region. By contrast, the dominant species in Mashhad County, a region far from Lorestan, has been identified as *O. vicinus* (Hasanzadeh Awal & Modares Awal, 2010).

TABLE 3. Calculation of diversity indices for anthocorid bugs collected during different seasons from Lorestan province.

Season	*N*	*H′*	*S*	R
Spring	175	1.357	3.271	0.968
Summer	537	1.310	3.073	0.954
Autumn	288	0.884	2.021	0.706
Winter	25	1.067	2.29	1.243
Jacknife SE		0.086	0.230	0.065

N, total number of collected individuals, H', Shannon-Wiener index, S, Simpson's index, R, Margalef's index.

The highest population density of anthocorid bugs was recorded for summer, which may be related to suitable temperature and availability of food resources in this season. By contrast and as expected, the lowest population density was recorded for winter months (Table 4). The high population density of *O. albidipennis* and *O. niger* during autumn may arise from the fact that these species do not enter diapause in response to low photoperiod and low temperatures (van den Meiraker, 1994). By contrast, some species such as *O. insidiosus* and *O. laevigarus* have been reported to enter diapause in encountering with low temperature and short photoperiod of autumn (Ruberson *et al.*, 1991; Chambers *et al.*, 1993), a phenomenon that was observed in this study.

TABLE 4. seasonal variations in frequency (relative frequency) of seven species of anthocorid bugs in Lorestan province.

Species	Spring	Summer	Autumn	Winter
N	175	544	298	25
Anthocoris pilosus	2 (1.14%)	2 (0.37%)	0 (0%)	2 (8%)
Orius albidipennis	82 (46.85%)	242 (45.06%)	87 (30.20%)	16 (64%)
Orius laevigatus	19 (10.85%)	54 (10.05%)	10 (3.47%)	5 (20%)
Orius minutus	0 (0%)	2 (0.37%)	0 (0%)	0 (0%)
Orius niger	36 (20.57%)	173 (32.21%)	183 (63.45%)	1 (4%)
Orius pallidicornis	33 (18.85%)	51 (9.49%)	5 (1.70%)	1 (4%)
Orius vicinus	3 (1.71%)	13 (2.42%)	3 (1.04%)	0 (0%)

We compared the diversity indices of anthocorid bugs between intensified and natural habitats. According to the results, although bugs in intensified habitats tended to have higher values of Shannon-Wiener, Simpson, and Margalef's indices (Table 5), these values were not statistically different among habitats. A total of 7 species was collected from intensified habitats, which was higher than 4 species in natural habitats. In addition, the total number of specimens collected from intensified habitats (936 adult bugs) was much higher than those collected from natural habitats (78 bugs). The higher frequency, higher species diversity and slightly higher values of biodiversity indices in intensified habitats may be related to more sustainable availability of food resources (both prey and flowering plants). In agreement with this study, Davari *et al.* (2015) showed that anthocorid bugs have a higher value of Shannon-Wiener index in intensified habitats. These results may imply that in contrast to many previous studies (Mone *et al.*, 2014; Fritch *et al.*, 2017), anthocorid bugs are able to establish and survive in intensified habitats, an ability that is favorable from biological control point of view.

TABLE 5. Calculation of diversity indices for anthocorid bugs collected from intensified (crop fields and orchards) and natural (rangelands and forests) habitats in Lorestan province.

Habitat type	*N*	*H'*	*S*	R
Intensified	936	1.25^{ns}	2.92^{ns}	0.87^{ns}
Natural	78	1.41	2.66	0.74

N, total number of collected individuals, H', Shannon-Wiener index, S, Simpson's index, R, Margalef's index, ns superscript shows non-significant differences within the same column.

Altogether, results of the current study indicate that the abundance and biodiversity of anthocorid bugs in Lorestan province is significantly influenced by locality, but not with intensification of habitats. According to Erfanfar *et al.* (2014), the abundance of anthocorid bugs in Iran is a function of prey availability and temperature. The diversity indices were relatively low for Lorestan communities of anthocorid bugs, which is probably due to uneven distribution of species frequency within the population. Human activities are expected to decrease the biodiversity of flowering plants as an important food resource for predatory bugs. However, on the other hand, agricultural intensification may underlie increased predator populations by providing a wide variety of prey, *i. e.* agricultural pests such as aphids, thrips, spider mites, etc. This study may provide useful information about dominant species of anthocorid bugs in Lorestan province and can be used by local producers of biological control agents to obtain more adapted species of predatory bugs for biocontrol targets.

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