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Braconid wasps (Hymenoptera) in two Iranian hotspots: Conservation implications

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Abstract

Biodiversity hotspots are key for identifying priority areas for species conservation. The Alborz Mountains, with two hotspots (the Caucasus on the northern slope and the Irano-Anatolian on the southern slope), provide an ideal landscape for assessing the impacts of vegetation, slope and elevation on species diversity. We examined the alpha and beta diversity of Braconidae across different slopes (northern/southern), elevations (upper/lower positions) and provinces (Guilan, Mazandaran, Qazvin, Tehran, Alborz) in northern Iran. Using 31 Malaise traps, we collected 276 species and 5950 individuals from 20 subfamilies. Shannon-Wiener and Brillouin's indices showed higher diversity on the northern slope. Species diversity peaked at mid-elevation (800–1200 m). Alpha diversity was highest in Guilan and Alborz-Tehran. Beta diversity analysis indicated that slope, elevation and province influenced species composition. Similar compositions were found in Mazandaran-Guilan (northern slope), and Alborz-Tehran and Qazvin (southern slope) in vegetation zones with similar environmental conditions. Additionally, the highest species composition similarity was observed between the southern and northern slope positions and upper positions of both slopes. These findings have important implications towards the maintenance of the diversity of braconids, a major beneficial species group, by prioritizing their hotspots.

Keywords: Alpha diversity, Beta diversity, species richness, evenness, dominant species, conservation.

Introduction

The geographical and evolutionary histories of mountainous regions have led to the emergence of biodiversity hotspots (Perrigo *et al*., 2020). The biodiversity of northern Iran lies within two main hotspots: The Irano-Anatolian (southern slope of the Alborz Mountains) and the Caucasus

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(northern slope of the Alborz Mountains) hotspots (Noroozi *et al.*, 2019). Iran encompasses 54% of the Irano-Anatolian hotspot and nearly 10% of the Caucasus hotspot (Noroozi *et al.*, 2019). The Alborz Mountains in northern Iran form a natural barrier to the flow of humid air masses from higher latitudes and prevent the flow of dry central Iranian air masses to the northern slope. As a result, the northern and southern slopes experience distinct climate conditions (Kiani *et al*., 2017; Noroozi and Körner, 2018). The northern slope is characterized by a semi-humid to humid climate, with an average annual precipitation ranging from 500 and 1800 mm, low solar radiation and predominantly forest vegetation that covers the southeastern part of the Caucasus biodiversity hotspot (Williams *et al*., 2006). It contains one of the greatest biological diversity of temperate forest regions across the world, including more than 6,500 species of vascular plants. Interestingly 25% of the plant species are endemic. This area has more than twice the plant and animal diversity if compared with the adjacent regions of Europe and Asia (Zazanashvili and Mallon, 2009). The southern slope (Irano-Anatolian hotspot) has an arid/semi-arid climate with average annual rainfall, i.e., less than 200 mm to over 500 mm, and sparse herbaceous vegetation (Heidari *et al*., 2020). Climates, elevation, and vegetation could be among the most important key factors that lead to species diversity in different geographical slopes (Ghaladze, 2012; Song *et al*., 2023).

Species diversity is an important feature of the biological community, describing the ecosystems' health (Dudgeon *et al*., 2006). An accurate understanding of species diversity patterns is a prerequisite step to provide an extensive reference for protecting zonal diversity (Socolar *et al*., 2016) and determining the strategies for species conservation in the target areas (Whittaker, 1972). Species diversity has two basic components including species richness and evenness. Species richness refers to the number of species observed in a certain ecosystem and evenness measures the relative importance of each species. Indeed, when there are large disparities in the number of individuals within each species, the ecosystem has low species evenness. In contrast, high species evenness occurs when the number of individuals within a species is constant (Nwoko *et al*., 2022). It is important to consider species richness and diversity since increasing species diversity can influence the stability of ecosystems. A range of factors have been hypothesized to influence spatial patterns of species richness such as climate, topography, landscape composition and configuration, or natural and human disturbances (Karp *et al*., 2018; Li *et al*., 2021). The display of the spectrum of different vegetation zones, slopes and elevation gradients, makes the Alborz Mountains an ideal landscape for studying the spatial patterns of species diversity and assessing the effects of factors linked with the spatial changes in the richness of wildlife species. Although many studies have investigated the effects of environmental or anthropogenic factors on the alpha diversity of Braconidae (Gadelha *et al*., 2012; Falcó-Garí *et al*., 2014), no comprehensive survey has been conducted on the mechanisms that drive alpha and beta diversity in Braconidae.

Braconids are the most important group of parasitoids attacking all developmental stages of their hosts, especially the larval stage (Chen and van Achterberg, 2019). The host range of Braconidae fall within Lepidoptera, Coleoptera and Diptera. Family Braconidae includes 43 subfamilies and comprises over 21,000 described species (Chen and van Achterberg 2019; Yu *et al*., 2016; Gadallah *et al*., 2022). Braconids are found in all geographic regions of the world (Yu *et al*., 2016). The braconid wasps extensively been reported from Iran (e.g., Rakhshani *et al*., 2007, 2008; Ameri *et al*., 2015; Farahani *et al*., 2012, 2014a, b, c, 2015, 2016; Ghotbi Ravandi et al., 2017; Talebi *et al*., 2018; Zargar *et al*., 2019a, b; Dolati *et al*., 2021; Gadallah *et al*., 2022; Pourhaji et al., 2022; Abdoli *et al*., 2019 a, b, c, 2021, 2022, 2023, 2024). These faunistic researches have led to an increase in the number of Iranian braconid species to 1,363 species in 203 genera and 30 subfamilies (Gadallah *et al*., 2022).

It is hypothesized that the distribution of Braconidae shows strong variation patterns among slopes and elevation gradients. Previous studies on the diversity of other parasitoid wasps in Iran (Lotfalizadeh *et al*., 2014, 2015; Safahani *et al*., 2018; Piruznia *et al*., 2022) have highlighted their ecological importance and distribution patterns. However, there remains a lack of comprehensive research on braconid wasps, which this study aims to address.

Displaying a spectrum of different vegetation zones, slopes and elevation gradients makes the Alborz Mountains an ideal landscape to study the spatial patterns of species diversity of Braconidae. We, therefore, set out to examine the roles of slope aspects, elevations and provinces on species diversity, including species richness, evenness, community compositions, and alpha and beta diversity indices in two neighboring biodiversity hotspots of the Alborz Mountains.

Materials and methods

Study area

Alborz is a mountain range in northern Iran, located south of the Caspian Sea, representing the highest mountain system of the region, rising sharply from the Caspian Sea level at -26 m to the highest summit of 5671 m a.s.l. at Damavand peak (Akhani, 1998). North-central Iran includes the northern and southern slopes of the Alborz Mountains. The northern slope (Caucasus biodiversity hotspot) comprises the provinces Mazandaran and Guilan while the southern slope (Irano-Anatolian biodiversity hotspot) comprises the provinces Alborz-Tehran and Qazvin (Myers *et al*., 2000).

Sampling

The Malaise trap is a well-known device to collect flying insects (Ssymank *et al*., 2018; Skvarla *et al*., 2021) and has been extensively used in several insect diversity projects worldwide (Karlsson *et al*., 2020; Hausmann *et al*., 2020). Thirty-one Malaise traps were placed in a range of different habitats including forests, rangelands and orchards in northern Iran (i.e., Alborz, Guilan, Mazandaran, Qazvin and Tehran provinces) (Supplementary data 1). The trapped specimens were collected and identified during 2010 and 2011 (Fig. 1). The traps operated continuously over the season, with a two-week collection interval. The slopes of the Alborz Mountains separated into the upper and lower positions to survey how species richness varies along the elevation gradient (Fig. 1). We tried to keep the sampling regions with mid-elevation peak (800–1200 m) on a position of each slope to examine the effect of these range on species diversity. Therefore, the mid-elevation peak included the upper position of the northern slope and the lower position of the southern slope. The collected braconid wasps were placed in 95% alcohol. The specimens were identified by taxonomic experts (see acknowledgements) at the species level by using appropriate identification keys (Telenga, 1955; Nixon, 1965; Mason, 1981; Tobias, 1986; van Achterberg, 1993, 1997) over the past 10 years. The specimens are deposited in the TMUC (Insect Collection of the Department of Entomology, Tarbiat Modares University, Tehran, Iran).

Statistical analysis

The SDR4 software was used to measure the indices related to species diversity (Seaby and Henderson, 2006). Species richness and alpha diversity of Braconidae were assessed using rarefaction and the Shannon–Wiener/ Brillourin indices. Pielou J, and Heip indices were also used to evaluate species evenness. Finally, the beta diversity index was calculated by Whittaker's formula to estimate habitat diversity across the studied sites (Whittaker, 1972; Legendre *et al*., 2005).

Structure of species composition

The identified species were classified using the Weigmann's classification method (Weigmann, 1973) based on their abundance into four dominance classes: eudominant (> 30%), dominant (10 to 30%), subdominant (5 to 10%), rare (1 to 5%) and sub rare (< 1%).

$D=b/a\times 100$

D: dominance; *a*: The total number of collected specimens; *b*: The number of individuals of a specific species.

Species richness

Species richness, *SR*, is the simple and most frequently used measure of biological diversity, representing the number of species per unit area (Brown *et al*., 2007). Rarefaction analysis estimates species richness and provides an expected number of species (Hurlbert, 1971). The number of species, *Sn*, that can be expected from a random sample of n individuals, drawn without replacement from *N* individuals distributed among *S* species, is given by:

$$SR = \sum_{i-1}^{S}\left(1 - \left[\frac{\binom{N-N_i}{n}}{\binom{N}{n}}\right]\right)$$

S: the total number of species in the collection, *Ni*: the number of individuals of species *i*.

Alpha diversity indices

The Shannon-Wiener index is one of the most commonly used measures of species diversity: For ecological data, it typically ranges between 1.5 and 3.5, though it can occasionally reach up to 4.5. Higher values indicate greater diversity (Southwood and Henderson, 2000). The formula is:

$$H = \sum_{i-1}^{S} P_i \log_g p$$

Pi: the relative abundance of each species meaning the individuals of each species to the whole community ratio, *S*: the number of species or species richness.

Pielou (1975) recommended the Brillouin index, which is similar to the Shannon index but is particularly sensitive to the abundance of rare species in the community. For ecological data, it also ranges between 1.5 and 3.5. Higher values indicate greater diversity (4.5). The Brillouin index is calculated as:

$$HB=\frac{\ln N! - \sum_{i=1}^{S} \ln n_i^!}{N}$$

Where N is the total number of individuals in the sample, n_i is the number of individuals belonging to the i_{th} species, and S is the total number of species.

Evenness indices

Evenness indices reflect the relative abundance of species, representing the degree of uniformity in species abundance within a community. Communities with higher evenness (value closer to 1) are more balanced, while those dominated by a single species (value closer to 0) are less diverse (Clark *et al*., 1994).

The Pielou J evenness index (Pielou, 1975) is given by:

$$J = {}^{H}\!/_{\log S}$$

Where H is the Shannon-Wiener diversity, S is the total number of species.

The Heip evenness index E (Heip, 1974) is calculated as follows:

$$E = \frac{(e^{H}-1)}{(S-1)}$$

Where H is the Shannon-Wiener diversity index and S is the total number of species.

Beta diversity index

The beta diversity index, as described by Wilson and Schmida (1984), measures the variation in species composition among habitats. Whittaker's formula is used: Whittaker's $\beta w = ({}^{S}\!/_{\alpha})$-1

Where S is the total number of species and α is the average species richness across all samples. Note that all samples must have the same size or sampling effort.

Results

Structure of subfamily composition of Braconidae

The abundance and species composition of Braconidae subfamilies were studied across different altitudes, slope aspects, and provinces in the Alborz Mountains (Fig. 2). A total of 5950 specimens representing 276 species from 20 subfamilies, were collected across various sampling sites in north-central Iran. Aphidinae was the most abundant subfamily (n = 1814), while Cardiochilinae, Ichneutinae, Microtypinae, Pambolinae and Rhyssalinae were the least abundant (n < 10). Some subfamilies, such as Rhyssalinae and Miracinae, were found exclusively on the northern slope, while Cardiochilinae and Ichneutinae were restricted to the southern slope. Among the five provinces, Guilan, Alborz, Tehran, Mazandarn and Qazvin ranked from the highest to lowest in terms of Braconidae abundance. On the northern slope, Macrocentrinae and Aphidinae dominated the lower positions, while Aphidinae showed the highest abundance across both lower and upper of the southern slope.

Species composition's structure and species relative abundance in different provinces, slopes, and elevations

The structure of species composition and relative abundance of Braconidae in five provinces is presented in Supplementary data 2. In Guilan, 163 species were recorded, the highest abundance values were for *Macrocentrus cingulum* Brischke (9.43%), *Lysiphlebus fabarum* (Marshall) (5.18%), *Aphidius smithi* Sharma and Subba Rao (6.45%), *Aleiodes* (*Aleiodes*) *bicolor* (Spinola) (5.67%), and *Microplitis tuberculifer* (Wesmael) (5.47%) classified as subdominant species. In Mazandaran, 129 species were identified, the highest value was for *M. cingulum* (30.59%) as the dominant species, followed by *Orgilus meyeri* Telenga (5.28%) and *Aphidius urticae* Haliday (5.00%) as subdominant species. In Qazvin, 74 species we recorded, *L. fabarum* (28.3) was the dominant species, while *Aphidius matricariae* Haliday, *Diaeretiella rapae* (McIntosh), *Praon volucre* (Haliday) and *Homolobus (Apatia) truncator* (Say) were subdominant with abundances ranging from 6.6%to 8.6%. In Alborz-Tehran, 122 species were noted. *A. matricariae* (5.88%), *D. rapae* (6.72%), *P. volucre* (6.07%), *Chelonus elongatus* Szepligeti (7.65%) and *A. bicolor* (8.25%) were characterized subdominant and the most abundant species when compared to all other species.

The species composition and relative abundance of Braconidae alongthe slopes of the Alborz Mountains are presented in Supplementary data 2. On the northern slopes, where 214 species were identified, *M. cingulum* (16.3%) was the dominant species, followed by *Microplitis spectabilis* (Haliday) (6.86%) as the subdominant species. Conversely, on the southern slopes, which hosted 150 species, *L. fabarum* (11.17%) was the dominant species. subdominant species on the southern slopes included *A. matricariae* (6.17%), *D. rapae* (7.06%), *P. volucre* (6.24%), *C. elongatus* (5.31%), *H. truncator* (5.21%) and *A. bicolor* (6.78%).

The species composition and relative abundance of Braconidae along different positions on the northern slope are presented in Supplementary data 2. In the lower positions of the northern slopes, *M. cingulum* (20.95%) as the dominant species, while *Ascogaster varipes* Wesmael (5.29%) was classified as the subdominant species. In the upper position of the northern slopes, the dominant species were *M. cingulum* (13.32%) and *M. spectabilis* (16.01%), subdominant species included *A. smithi* (5.06%) and *A. bicolor* (7.44%).

The species composition and relative abundance of Braconidae along the different positions of southern slopes are shown in Supplementary data 2. In the lower positions of the southern slopes, *Praon abjectum* dominated with an abundance (17.2%). Subdominant species included *Aphidius persicus* (6.15%), *Homolobus (Apatia) truncator* (9.19%) and *Aleiodes bicolor* (8.63%). In the upper positions of the southern slope, *L. fabarum* had the highest abundance (15.26%) as the dominant species, followed by the subdominant species *A. smithi* (7.71%), *A. matricariae* (6.17%), *C. elongatus* (7.52%), *D. rapae* (8.28%) and *P. volucre* (8.55%).

Species richness, evenness, and diversity in different provinces, slopes, and elevations

The results of alpha diversity indices in the provinces revealed Shannon–Wiener values ranging from 2.995 to 3.847 for and Brillouin values from 2.869 to 3.722 (Table 1). Guilan showed the highest alpha diversity, followed by Alborz-Tehran, Mazandaran and Qazvin, with significant differences. Species evenness indices (Pielou J and Heip) were highest in Alborz-Tehran, followed by Guilan, Qazvin and Mazandaran(Table 1).

The beta diversity analysis using the Whittaker's dissimilarity index indicated the highest similarity between Mazandaran and Guilan ($\beta w = 0.47$), while the greatest dissimilarity was observed between Qazvin and Mazandaran ($\beta w = 0.72$) also Mazandaran and Alborz-Tehran ($\beta w = 0.68$) (Table 2). The rarefaction analysis of provinces revealed that species richness ranged from the highest in Guilan (163 species) to progressively lower values in Mazandaran (129 species), Alborz-Tehran (122 species) and Qazvin (74 species), respectively (Fig. 3).

Regarding the alpha biodiversity indices cross slopes, no significant differences were observed between Shannon-Wiener and Brillouin methods. Both indices indicated that the northern slope exhibited greater diversity compared to the southern slope. However, the species evenness indices including Pielou J and Heip methods, revealed that the southern slope displays higher evenness than the northern slope (Table 1). The rarefaction analysis of slopes confirmed higher species richness on the northern slope (214 species) compared to the southern slope (150 species) (Fig. 3). A detailed examination of alpha diversity and species evenness indices across different slop positions of the Alborz Mountains showed that the lower positions of the southern slope were more diverse than the upper positions. Conversely, on the northern slope, the upper positions were more diverse than the lower positions. Rarefaction analysis of the slope positions revealed species richness increasing in the following order: upper positions of the southern slope (111 species), lower positions of the southern slope (92 species), upper positions of the northern slope (133 species) and lower positions of the northern slope (154 species), respectively (Fig. 3). The Whittaker's beta diversity index, which measures community dissimilarity, showed the lowest values (indicating the highest similarity) for positions on the southern slope (βw = 0.47), followed by positions on the northern slope (βw = 0.49), and the upper positions of both slopes (βw = 0.50).

Discussion

The highest species richness and alpha diversity across the different slopes of the Alborz Mountains were recorded for the northern slope, revealing that it is more diverse than the southern slope. However, evenness indices presented different results. While species richness is significantly influenced by the presence of rare species, species evenness is high when all species have a relatively similar distribution. These differences may partially stem from the fact that the Alborz region lies within two global biodiversity hotspots (Irano-Anatolian and Caucasian), which have distinct climatic conditions and vegetation types that influence species abundance. Species richness typically increases with factors like climatic stability and productivity, while it decreases with low temperatures (Mittelbach and Mcgill, 2019). The Alborz Mountain exhibits climatic and vegetative gradients, shifting from humid warm climates with diverse vegetation on the northern slope to a semi-arid continental climate with sparse vegetation on the southern slope (Noroozi and Körner, 2018). The warm and vegetatively diverse conditions in the sampling localities of the northern slope (Caucasian hotspot) compared to the southern slope (Irano-Anatolian hotspot), likely contribute to the higher species richness and biodiversity in the northern slope. Conversely, the southern slope, characterized by greater temperature fluctuations and less diverse vegetation, shows higher species evenness.

The alpha diversity and species evenness indices for provinces followed a similar trend. Guilan and Alborz-Tehran were more diverse than Mazandaran and Qazvin. It is important to note that despite the almost close numbers of species in Mazandaran and Alborz-Tehran, Mazandaran exhibited lower diversity due to non-uniform species abundance and the dominance of a single species. Dominant species play an important role in shaping the distribution of other species within ecosystems. The presence of dominant species can limit species diversity by hindering the establishment of new species (Crutsinger *et al*., 2010).

All indices related to the findings of the current study indicated positions that are close to mid-elevation peak (800–1200 m) or regions with higher sampling in this elevation range, reaching maximum diversity. For instance, the upper position of the southern slope, above 1,500 m and the lower position of the northern slope, below 800 m (further from the mid-elevation), exhibited the minimum species diversity on both slopes. The decline in species diversity at the upper position of the southern slope was expected due to temperature reduction. Conversely, species diversity on the northern slope decreases at lower elevations due to higher temperatures and relative humidity. These findings suggest that braconid diversity is correlated with temperature and altitude. A similar correlation between elevation and biodiversity was also observed by Ghaladze (2012). By studying the climate-based model of spatial pattern of ant species richness in Georgia, the authors found that diversity peaks between 800–1200 m a.s.l. and declines at both lower and upper altitudes. Additionally, previous studies have shown that maximum species richness and relative abundances occur at mid-elevations while declining strongly with the increase of elevation above 1,500 m (Sabu *et al*., 2008).

Recent studies on the diversity of other hymenopterous insects in Iran have reported similar patterns. For instance, Hajian *et al*. (2024) investigated ant diversity along an elevational gradient in the arid regions of Central Iran, highlighting the impact of altitude on species richness. Similarly, Mohammadi-Khoramabadi (2023) studied the diversity of Campopleginae in the Darab damask rose rain-fed plain and reported comparable effects of vegetation and climate on species diversity. Additionally, Piruznia *et al*. (2022) analyzed chalcidoid wasp diversity in the Lake Urmia basin, demonstrating the role of environmental conditions in shaping species composition.

In the present study, the analysis of beta diversity (using the Whittaker index) across slopes, elevations and provinces revealed that similar braconid compositions were found in areas with the same vegetation and comparable environmental conditions. Previous studies have also demonstrated the type and abundance of vegetation, along with factors such as sun exposure, temperature and humidity, play crucial roles in determining species distribution patterns and diversity (Almeida *et al*., 2009; Li and Reynolds, 2009).

The structure of species compositions and relative abundance revealed that *M. cingulum* had the highest distribution and abundance as the dominant species on the northern slope, especially in the lower elevations of Mazandaran province, where rice is primarily produced. *Macrocentrus cingulum* is a parasitoid of *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) (van Achterberg, 1993; White and Andow, 2005), a major pest in rice fields in the humid areas of northern Iran (Esmaili *et al*., 1996). The presence of *O. nubilalis* may have contributed to the increase in the *M. cingulum* population. Previous studies have also shown that as host abundance increases, so does the population of its parasitoids (Heimpel, 2001).

Lysiphlebus fabarum exhibited the highest distribution and abundance as the dominant species on the southern slope, particularly at the upper position and Qazvin province. It is an oligophagous parasitoid and ubiquitous in agricultural or natural agroecosystems, issues that make it a valuable biological control agent of aphids (Baghery-Matin *et al*., 2005; Alikhani *et al*., 2010; Tomanović *et al*., 2018). Most distribution of *L. fabarum* on the southern slope is related to sampling regions with elevation above 1,500 m, where winter fruit trees serve as plant hosts, suggesting that it is adaptable to higher elevation and colder climates (Mahi *et al*., 2014).

Praon abjectum was the most widely distributed and abundant species in the lower position of the southern slope. In Europe, several *Aphis* species have been documented as hosts for this parasitoid (Kavallieratos *et al*., 2005). However, other records indicate that it is specifically a parasitoid of *Aphis* species (Starý and Kaddou, 1971).

The occurrence of the Irano-Anatolian and Caucasus hotspots is important from the conservation point of view in terms of biodiversity and endemic species. This study clearly shows that the northern slope, where is placed in the Caucasus hotspot, has a high value in terms of faunistic biodiversity and scientific importance in the Alborz Mountains. The northern slope of the Alborz Mountains is mostly covered by Hyrcanian forests, but it is endangered due to increasing anthropogenic impacts (e.g., livestock grazing, road construction, logging, and housing developments). Braconidae can be used as bioindicators of anthropogenic effects on ecosystems and can be used to estimate the species richness in the target region (Whitfield and Lewis, 1999; Gonzales and Ruiz, 2000). Furthermore, long-term monitoring surveys are necessary to accurately assess changes in natural densities, distributions and species composition of beneficial insects in response to anthropogenic impacts and climate change**.**

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Table 1. Alpha diversity and species evenness indices of Braconidae in the north-central Iran.

		Provinces				Slopes		Southern slope		Northern Slope	
		Alborz-Tehran	Qazvin	Guilan	Mazandaran	Southern	Northern	Lower Zone	Upper Zone	Lower Zone	Upper Zone
SDI[1]	Shannon Wiener	3.757	2.995	3.847	3.462	3.756	3.966	3.589	3.471	3.501	3.643
	Brillourin	3.653	2.869	3.722	3.274	3.667	3.852	3.448	3.372	3.355	3.503
SEI[2]	Pielou J	0.782	0.695	0.755	0.712	0.749	0.739	0.793	0.737	0.695	0.744
	Heip	0.345	0.260	0.283	0.241	0.280	0.243	0.386	0.283	0.210	0.281

1. SDI= species diversity index; 2. SEI= species evenness index.

Table 2. Values Braconidae Beta diversity index (Whittaker) for dissimilarity amongst different sites.

		Provinces				Southern slope		Northern slope
Collection sites		Alborz-Tehran	Qazvin	Guilan	Mazandaran	Lower position	Upper position	Lower position
Provinces	Alborz-Tehran	1	0.5306	0.5298	0.6813			
	Qazvin		1	0.6273	0.7241			
	Guilan			1	0.4726			
	Mazandaran				1			
Southern slope	Lower position					1	0.4778	
Northern slope	Upper position					0.6444	0.5050	0.4983
	Lower position					0.6992	0.6377	1

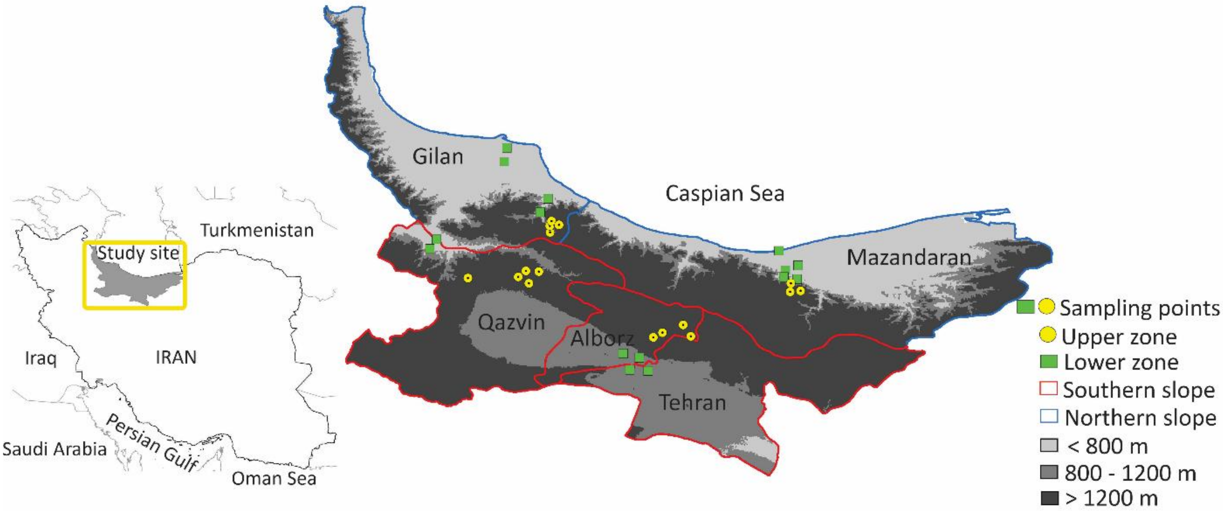

Fig. 1. Alborz, Qazvin, Tehran, Guilan and Mazandaran Provinces, where specimens have been collected.

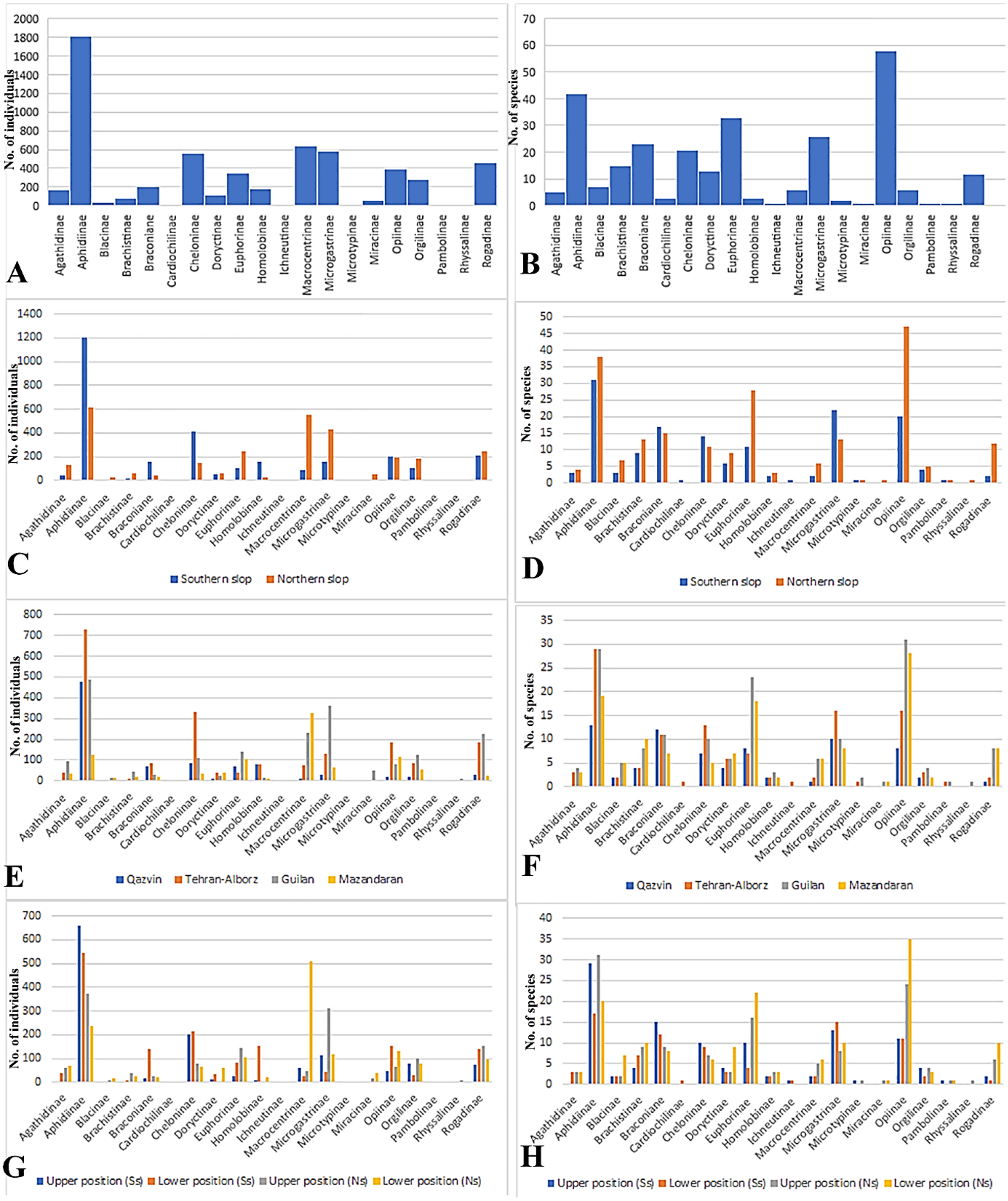

Fig. 2. Community structure of the subfamilies of Braconidae collected and identified during the years 2010–2011 in different habitats. A–B. North central Iran, C–D. Different slopes of Alborz Mountains, E–F. Five provinces of north central Iran, G–H. Elevations (upper and lower positions) of Alborz Mountains (Ss. Southern slope, Ns. Northern slope).

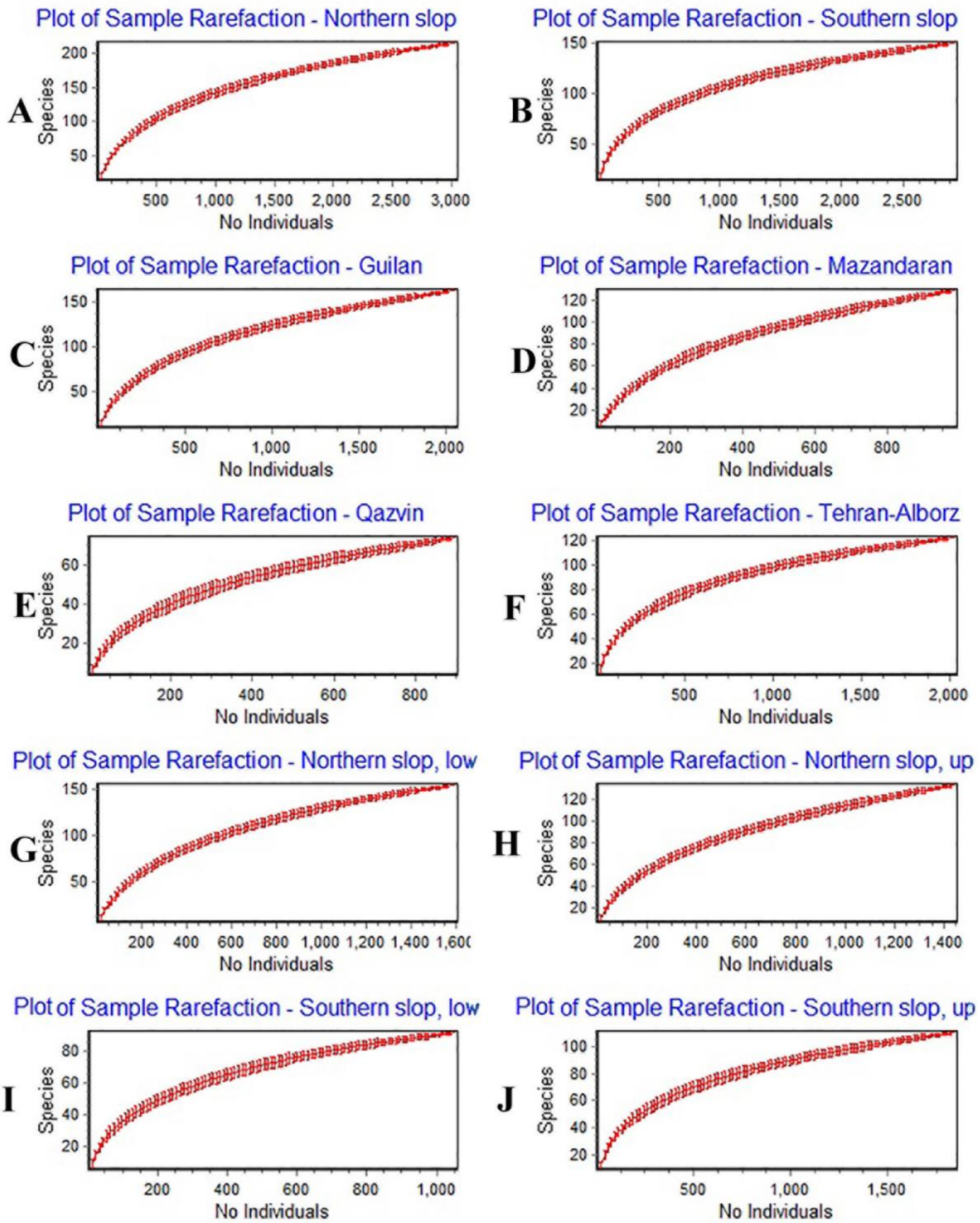

Fig. 3. Observed rarefaction curves for Braconidae (A) Northern slope (B) Southern slope (C) Guilan (D) Mazandaran (E) Qazvin (F) Tehran (G) Lower position of northern slope (H) Upper position of northern slope (I) Lower position of southern slope (J) Upper position of southern slope

زنبورهای براکونید (Hymenoptera) در دو نقطه داغ بوم‌شناختی ایران: دلالت‌ها برای حفاظت

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چکیده

نقاط داغ تنوع زیستی برای شناسایی مناطق اولویت دار برای حفاظت از گونه‌ها کلیدی هستند. رشته کوه‌های البرز با دو نقطه داغ (قفقاز در شیب شمالی و ایران-آناتولی در شیب جنوبی) چشم انداز ایده آلی را برای ارزیابی تأثیر پوشش گیاهی، شیب و ارتفاع بر تنوع گونه ها فراهم می کند. ما تنوع آلفا و بتا زنبورهای خانواده Braconidae را در شیب‌های (شمالی و جنوبی)، ارتفاعات (موقعیت‌های بالایی و پایینی) و استان‌های (گیلان، مازندران، قزوین، تهران، البرز) در شمال ایران بررسی کردیم. با استفاده از 31 تله مالیز 276 گونه و 5950 فرد از 20 زیرخانواده جمع‌آوری گردید. شاخص های شانون-وینر و بریلوین تنوع بیشتری را در شیب شمالی نسبت به شیب جنوبی نشان دادند. تنوع گونه‌ای در ارتفاع متوسط (800-1200 متر) به اوج خود رسید. بیشترین تنوع آلفا در گیلان و البرز-تهران بود. تجزیه و تحلیل تنوع بتا نشان داد که شیب، ارتفاع و استانه بر ترکیب گونه تاثیر می گذارد. وضعیت مشابه بین مازندران و گیلان (در شیب شمالی) و البرز-تهران و قزوین (در شیب جنوبی) که دارای پوشش گیاهی و شرایط محیطی مشابهی هستند، مشاهده شد. از سوی دیگر، ترکیب گونه‌ها در موقعیت‌های شیب جنوبی یا شمالی و ارتفاعات بالایی هر دو شیب بیشترین شباهت را داشتند. یافته‌های این پژوهش دلایل مهمی برای حفظ تنوع زنبورهای براکونید به عنوان یک گروه مهم از گونه‌های مفید، در مناطق داغ اکولوژیک در شمال ایران ارائه می‌دهد.