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What says the chalcidoid (Hymenoptera) diversity in the Lake Urmia basin?

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ABSTRACT. Chalcidoidea play an important role in the biological control of many agricultural pests. The present study determines and compares the diversities of this superfamily in four ecosystems in the Lake Urmia basin. It is the largest hypersaline lake in the world with a large basin of different ecological conditions in northwest Iran. These stations were: Khajeh (K) and Tasuj (T) in Lake Urmia Basin (LUB_{in}) and Khoda-Afarin (KA) and Tikme-Dash (TD) out of their (LUB_{out}). Four months of Malaise trapping in these habitats resulted in a total of 512 specimens from 11 families of Chalcidoidea, including 6, 9, 10 and 10 families in K, KA, T and TD, respectively. Maximum abundance was observed in the T station with 192 and the minimum was in the K station with 38. However, the families, Encyrtidae and Chalcididae have maximum abundance in T and KA, respectively. The maximum activity of chalcidoid wasps was observed during June-August. The majority of the species were belonging to the family Mymaridae (25%), in LUB_{out} habitats peaked at 47 specimens in TD during the sampling period, while the corresponding LUB_{in} habitats peaked at 40 specimens in T. The two LUB_{out} habitats had greater community similarity (60%) than found between in and LUB_{out} habitats (42%) and diversity of chalcidoid wasps in LUB_{out} was found much more than $LUB_{in.}$ Biodiversity studies showed that the KA station has the greatest values of diversity, evenness, and richness of Chalcidoidea. This station is located outside of Lake Urmia basin with the warmest and most humid climate and forest ecosystem on the margins of the Aras River.

Key words: Diversity, parasitoid, Chalcidoidea, Lake Urmia, halophyte, conservation

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INTRODUCTION

The presence of various insects in its diverse agricultural crops increases the frequency of their parasitoid they can be a bioindicator of ecosystems. The most diverse ecosystem, the longer the food chains and the more complex the life networks cause stability and self-regulation of ecosystems.

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Consequently, biodiversity is a key factor in the stability and protection of ecosystems (Ardakani, 2007). High diversity indicates that numerous species can be established in a station because of the favourable environmental conditions (Schowalter, 2016). The insect population of the tropical areas was reported more diverse than in temperate regions (Jones & Laughlin, 2009). But it is threatened by habitat destruction, pollution, overexploitation, or competition with introduced species (Schowalter, 2016). As the principal factor of species diversity, α-diversity reflects the number and relative abundance of species populations in a geographical region and in higher species diversity there was established a more stable and self-regulatory ecosystem (Schowalter, 2016). Among the order Hymenoptera, the superfamily Chalcidoidea is extremely important in the control of various pests (Noyes, 2020). About 22,785 chalcidoid species have been identified belonging to 2,117 genera, constituting about one-third of all known parasitoid wasps (Aguiar et al., 2013; Noyes, 2020). More than 800 species in this group have been used in biological control programs (Noyes, 2020). The evaluation of their ecological status and importance in pest control has a critical role in their application as a biocontrol agent. Therefore, their protection and increase in biological control programs may reduce chemical pesticide applications (Helyer et al., 2014).

Numerous studies were conducted on species diversity of the Chalcidoidea in the World (Lockwood et al., 1996; Sureshan, 2000; Subharani et al., 2010; Rainosek et al., 2014; Schoeninger et al., 2019) and in Iran (Nazemi et al., 2008; Abolmasoumi et al., 2009; Lotfalizadeh et al., 2014, 2015). For example, Nazemi et al. (2008) studied the species richness of oak gall wasps and their associated inquilines and parasitoids. They reported species richness and geographical distribution of oak gall wasps, their inquilines and parasitoids in some western provinces of Iran. Furthermore, Abolmasoumi et al. (2009) studied the species diversity of Aphelinidae (Hym.: Chalcidoidea) in two provinces of Iran reporting the presence of five species. Although species diversity and ecological parameters of soft and armoured scale insect parasitoids and the biodiversity of alfalfa leaf miners parasitoids were also studied in East Azarbaijan, Iran (Lotfalizadeh et al., 2014, 2015).

The biodiversity of Hymenoptera was studied in burned and unburned habitats of Yellowstone National Park and showed diversity and richness of parasitic wasps in burned sites was less than in unburned sites (Lockwood et al., 1996). Likewise, Sureshan (2000) reported 528 genera and 1,724 species of Chalcidoidea in the State of Kerala in India. Simultaneously, Subharani et al. (2010) reported 62 species in four families during the study of parasitoid wasps of various crops in India, of which, two families belonged to Chalcidoidea. The diversity of the family Eulophidae associated with *Phyllocnistis labyrinthella* (Lepidoptera: Gracillariidae) was reported by Albrectsen and Hansson (2012). They found seven eulophids during 2009–2011 in Sweden. Rainosek et al. (2014) investigated the biodiversity of Chalcidoidea in various habitats in the Dominican Republic, reporting 11 families. The diversity of parasitoid wasps was studied in conventional and organic guarana (*Paullinia cupana* var. *sorbilis*) cultivation areas in Brazil (Schoeninger et al., 2019). They found management system and habitat did not affect the richness of parasitic wasps. Most recently, Abhishek et al. (2022) compared the faunal and temporal diversities of Encyrtidae (Hym., Chalcidoidea) in three ecosystems in India and found maximum diversity in rice ecosystems.

Lake Urmia is the largest inland lake located in northwest Iran and is one of the largest hypersaline lakes in the world (Schulz et al., 2020). Its basin area of 52000 km^2 includes unique biodiversity with about 550 and 315 plant and animal species, respectively. It experienced a great decline in the level between 1995 and 2013 with a loss of the area (60%) and volume (90%). It has negative impacts on the lake's ecosystems and its basin ecosystems (Schulz et al., 2020). The present study was conducted to compare the biodiversity and ecological parameters of the superfamily Chalcidoidea in four ecosystems in and outside of Lake Urmia's basin (LUB_{in} and LUB_{out}).

MATERIAL AND METHODS

The Chalcidoidea (Hymenoptera) were chosen as the index of biodiversity because they rely on a wide spectrum of herbivorous insects and they are easy to collect by Malaise trap. Samplings were conducted from mid-June until mid-December of 2015 at the four Research Stations with more than 80Km distance: Khajeh (K) and Tasuj (T) as LUB_{in} and Khoda-Afarin (KA) and Tikme-Dash (TD) as LUB_{out} (Fig. 1 and Table 1). All of the stations are known as rangelands that LUB_{in} is covered with mainly halophyte plants and LUB_{out} is covered with non-halophyte plants. Three Malaise traps were installed ten days per month in each station and were daily visited. During each visit, the specimens were removed from the traps and placed in screw-top containers containing 70% ethanol. They were labeled with collection dates and locality data. The containers were transferred to the laboratory to separate and count Chalcidoidea specimens. Traps were damaged by weather and wildlife on three occasions resulting in missing data (two in TD and one in K). A stereomicroscope Olympus™ SZH was used to sort and identification of the Chalcidoidea families.

We calculated family richness (number of families) and parasitoid wasp abundance (number of individuals) at each sampling point, for the Malaise traps. Finally, the diversity and similarity indices were calculated using the Ecological Methodology, version 6.0 software (Krebs, 2013).

Diversity indices

Simpson's index: Simpson's diversity index was used to calculate the dominance index (Schowalter, 2016):

$$1 - \mathrm{D} = 1 - \Sigma\,(Pi)^2$$

1 – D is Simpson's diversity index and *Pi* the proportion of individuals in the *i*th species in the population. In Simpson's diversity index, the probability for two randomly selected individuals belong to two different families (P_2RSI) was estimated.

Shannon's index: The Shannon index is an information theory index and employed to calculate species diversity (Schowalter, 2016), where *S* is the number of species and *Pi* the relative frequency of the *i*th species.

$$H = -\sum_{i=1}^{s} p_i ln p_i$$

Brillouin's index: The Brillouin index uses to measure the diversity of a collection (not a sample). It was recommended in all situations where a collection is made, sampling was non-random or the full composition of the community is known (Brillouin, 1962).

Where, *N* is the total number of members and n_1, n_2, and n_3 are the numbers of individuals belonging to species 1, 2, and 3, respectively.

$$H = \frac{1}{N} log\left(\frac{N!}{n_1!\,n_1!\,n_1!\,...}\right)$$

Evenness indices

Species evenness in each station was calculated using Simpson's, Shannon's and Camargo's evenness indices (Schowalter, 2016):

Simpson's index: $E_{1/D}$ is Simpson's evenness index, $\widehat{D}$ Simpson's index, and S the number of species in the sample.

$$E_{1/D} = \frac{1/\widehat{D}}{S}$$

Shannon's index: H_{max} is the maximum value of Shannon's diversity index.

$$E = \frac{H}{H_{max}}$$

Camargo's index: E is Camargo's evenness index, P_i is the proportion of individuals in the *i*th species in the entire sample, P_j is the proportion of individuals in the *j*th species in the entire sample, and S the total number of species.

$$E' = 1 - \left(\sum_{i=1}^{S} \sum_{J=i+1}^{S} [|Pi - Pj| / S]\right)$$

Similarity index

Similaity index was calculated using the following equation (Magurran, 2004).

$$S = 2a / (2a + b + c)$$

Where, a is the number of species common to both stations, b the number of species present in station B but not in station A, and c the number of species present in station A but not in station B. We used analysis of variance (ANOVA) to compare family abundance in the studied stations. Differences between means were tested with Tukey's test (a=5%).

Table 1. Climatological information on the four studied research stations in this research.

LUB	Stations	GPS Coordinates	Altitude (m. a.s.l.)	Mean precipitation (mm)	Mean temperature (°C)	Weather type (De Martonne method)
LUB_{in}	**Khajeh (K)**	38°10'N 46° 38'E	1450	270	10	Semi-arid
	Tasuj (T)	38°19'N 45°21'E	1500	267.25	13.4	Semi-arid
LUB_{out}	**Khoda-Afarin (KA)**	39°01'N 46°50'E	400	384	16.09	Semi-arid
	Tikme-Dash (TD)	37°45'N 46°56'E	1900	386	12	Semi-arid (Cold*)

* Cold semi-arid according to Emberger classification.

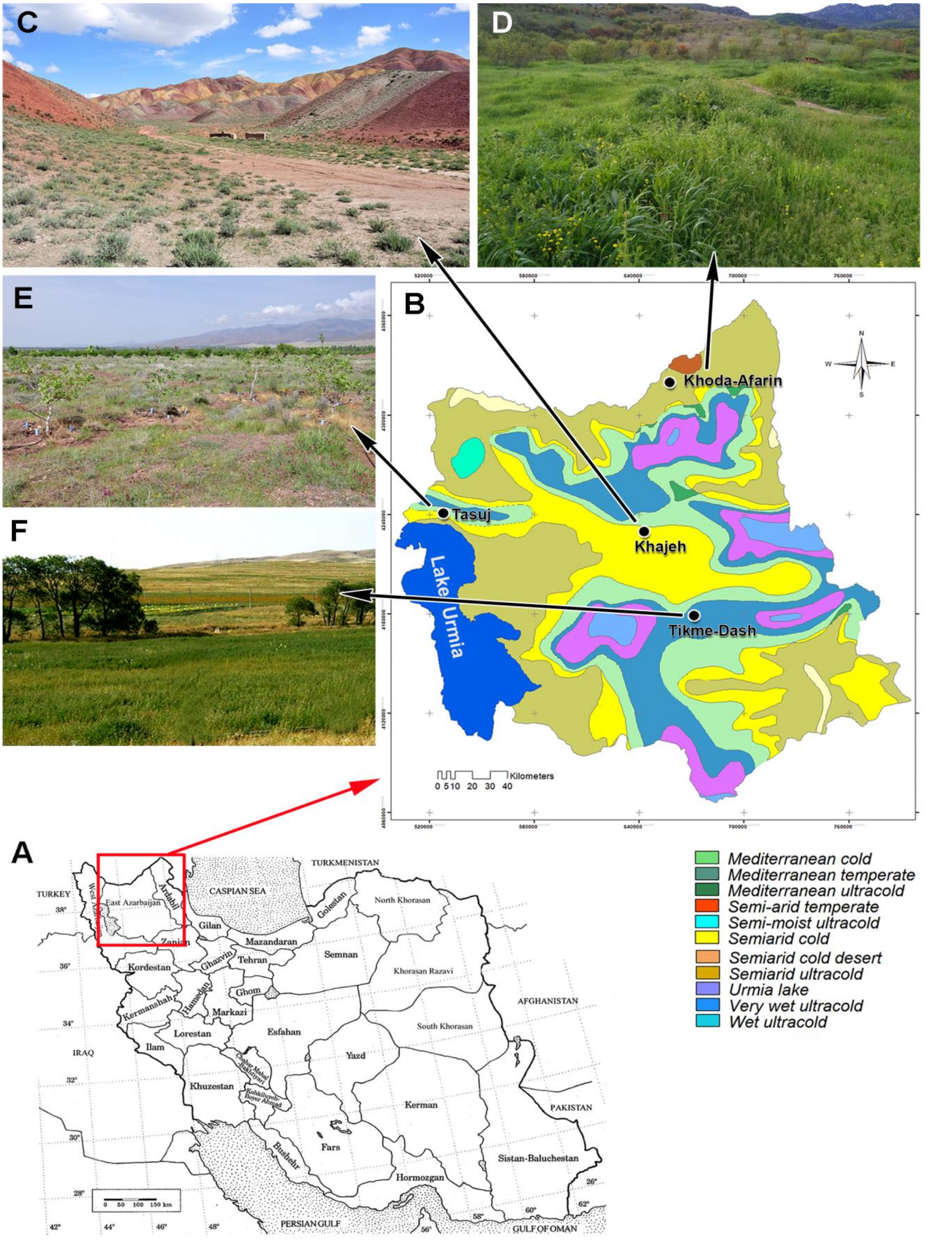

Figure 1. Sampling stations in the northwest of Iran: **A.** Map of Iran; **B.** Northwest of Iran and their climatological conditions, including sampling stations; **C.** Khajeh (K); **D.** Khoda-Afarin (KA); **E.** Tasuj (T); **F.** Tikme-Dash (TD).

RESULTS

The Malaise trap samples yielded a total of 512 chalcidoid specimens (Fig. 3). The majority of the specimens belonged to the family Mymaridae (25%) followed by Encyrtidae (22%) (Table 2). The means comparison number of chalcidoid families was significantly different (df=3, $p \leq 0.005$) (Table 2).

Chalcidoidea families

The following eleven families with a total frequency of 512 belonging to the superfamily Chalcidoidea were identified in the four study stations: Aphelinidae, Chalcididae, Encyrtidae, Eulophidae, Eupelmidae, Eurytomidae, Mymaridae, Ormyridae, Pteromalidae, Torymidae and Trichogrammatidae (Table 3). The family Aphelinidae were observed in low density in T, TD, and K stations, and was not found in KA station, which may be attributed to the low density of its hosts there. In T and K stations, Chalcididae was found only during July, but it was present in TD and KA stations (most frequently in KA). The presence of this family in the reported stations declined substantially from mid-September. Moreover, it is widely distributed in the warmest and most humid habitat, and within four studied stations, KA has the warmest and most humid climate (see Table 1).

Table 2. Means comparison number of chalcidoid families (±SE) among studied stations in/out Lake Urmia basin by Tukey test (in the northwest of Iran during 2015).

Parasitoid Families	Number*	Composition (%)
Aphelinidae	4 ±1.5 d	1
Chalcididae	50±2.6 b	10
Encyrtidae	108±3.1 a	22
Eulophidae	64±2.2 b	13
Eupelmidae	6±1.9 d	2
Eurytomidae	48±3.0 b	10
Mymaridae	125±4.9 a	25
Ormyridae	5±1.9 d	1
Pteromalidae	45±4.2 b	10
Torymidae	25±2.0 c	5

* Means with different letters in column (Number) are significantly different at 5% level (Tukey's test).

Table 3. Status of the chalcidoid families in four studied stations (+: presence; -: absence).

Families	Stations*				Remarks
	K	KA	T	TD	
Aphelinidae	+	-	+	+	Low frequency in all stations.
Chalcididae	+	+1st	+	+	Most frequency in KA
Encyrtidae	+ 3rd	+2nd	+1st	+	Highest frequency in T
Eulophidae	+2nd	+	+3rd	+3rd	Highest density in T
Eupelmidae	-	+	+	+	Most frequent in KA (Aug.-Sep.)
Eurytomidae	-	+	+	+3rd	Highest frequency in T
Mymaridae	+1st	+3rd	+2nd	+1st	Most frequent in TD & T
Ormyridae	-	+	+	+	Rarely collected family
Pteromalidae	+	+	+	+2nd	-
Torymidae	-	+	+	+	Most frequent in TD
Trichogrammatidae	-	-	+	-	-

* 1st: the highest frequency; 2nd: the second place of frequency; 3rd: the third place of frequency.

The family Encyrtidae were abundantly found in the studied stations and had the greatest frequency in T. This family ranked as the second and third most frequently observed one in KA and K, respectively. However, it exhibited a low frequency in TD. It is noteworthy that this family had the same frequency in the four stations during September, and its high frequency in most of the stations indicates favourable living conditions and the presence of its hosts (mostly Hemiptera). The family Eulophidae were abundantly found in all four stations and ranked as the second most frequently found wasp family in K after the family Mymaridae. In mid-September, Eulophidae exhibited the lowest frequency in T and KA stations and its greatest number was caught in TD and K stations. Eupelmidae were rarely trapped in the studied habitats and were found from T and TD stations during late September and the first of October. However, it was most frequently found in KA during August -September. Eurytomidae were trapped in all stations except K. Its greatest frequency was observed in T during July. In TD, the number of collected wasps reached a peak during the first of September and tangibly reduced during the first of October, because of non-suitable climatic conditions. In KA, this family was found throughout the summer and had the same frequency in all samples. The family Mymaridae were found in large numbers in all four stations, but these were most frequently observed in TD and K and peaked in the first September. However, the hosts of mymarids are mostly found in warm and dry climates, hence their abundance in these habitats seems to be logical. The family Ormyridae were rarely collected and few specimens were observed in the last two samplings at TD and in the first two samplings at KA. Pteromalidae has a high frequency in TD and was ranked as the second most frequent family after Mymaridae. In September, at the last sampling, its frequency decreased almost as much as the Mymaridae family. The Pteromalidae family was also present in the other stations but at relatively lower incidences. Its frequency in K dropped to a minimum in June and August. While during July it has a considerable amount in T. The family Torymidae were collected from all stations except for K. However, it has a relatively low frequency in T and KA. While these were the most frequently found family in TD. Trichogrammatidae were only trapped in the samples taken at T. The low frequency of Trichogrammatidae may have two reasons: low populations abundance of hosts, and their small size that makes difficult their recognition and separation from other insects caught in Malaise traps. Therefore, it was removed from our analysis.

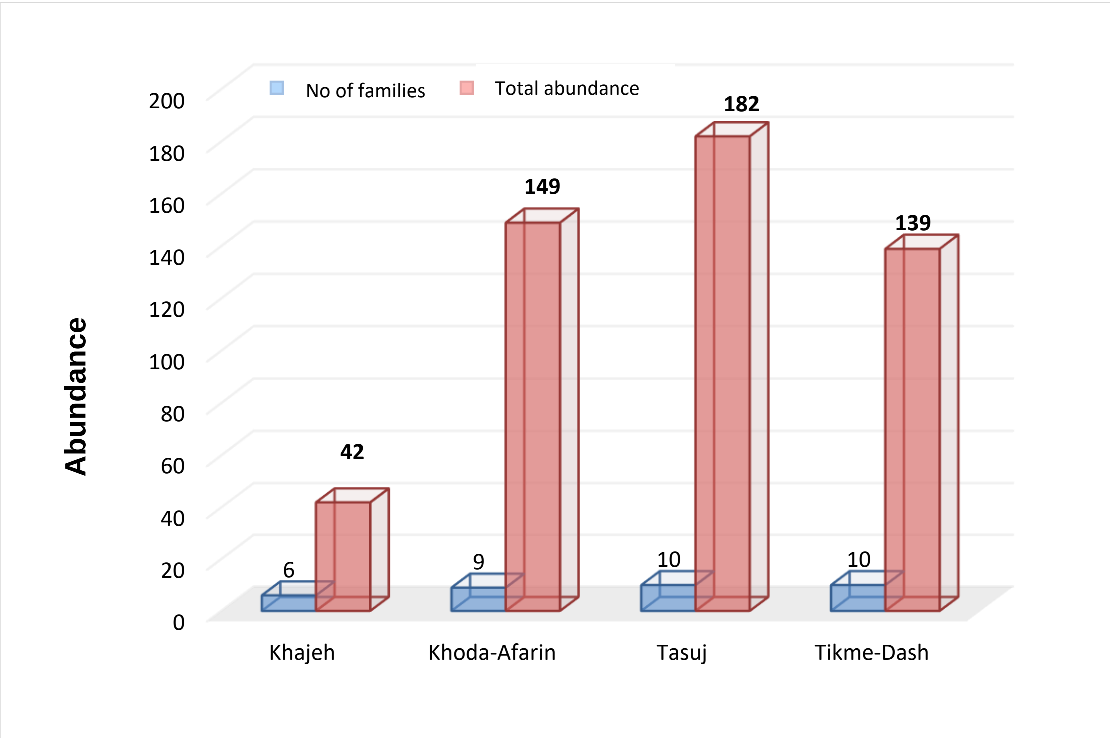

Figure 2. Overall frequencies and the number of the Chalcidoid families found for each of the four stations.

Frequency of the Chalcidoids

Considering the high overall frequency of the Mymaridae family in the TD station, it was the dominant family among the parasitoids collected at the stations. Moreover, despite the low frequency of the families at K station, compared to the other three stations, Mymaridae was also the dominant family observed at K station. In T station, the Encyrtidae family with 71 specimens was the most frequently found in all stations. Chalcididae was the family with the lowest overall frequency at K and TD stations. In KA, where higher diversity levels were observed, Chalcididae was the dominant family with a slightly higher diversity level than the Encyrtidae family. It was due to the warmest and most humid climate of this station that seems to be suitable for this family. The greatest Simpson index of the families during the sampling period, was 83% at T station in July, 81% at TD in late August, 48% at KA in June, and 24% at K in the first September. Therefore, the greatest activity levels of the parasitoid wasps at the four stations were observed during July and September. Among the four stations, the lowest overall frequency was recorded at the K, and the lowest frequency at this station was observed in October with only one specimen of the family Mymaridae. The numbers of the families and their overall frequencies in the four stations were presented in Figs 2 & 3. Considering the samples taken from the traps installed at the stations, the greatest frequency, and the largest number of families were observed at the T.

Diversity and evenness indices

LUB$_{in}$ - Khajeh (K) – At this station, all diversity indices had their greatest values on the first of July. However, all of these indices had a declining trend in August but then increased in September (Table 4). The largest value calculated for Shannon's evenness index (0.971) was in August. Therefore, the frequencies of the various families in this station were approximately 97% similar. The lowest value of this index (0.822) was recorded the last July (Table 4). This station has the maximum Camargo index, especially during August (0.901). Simpson's diversity index at K reached a maximum (0.758) in July (P_2RSI=76%).

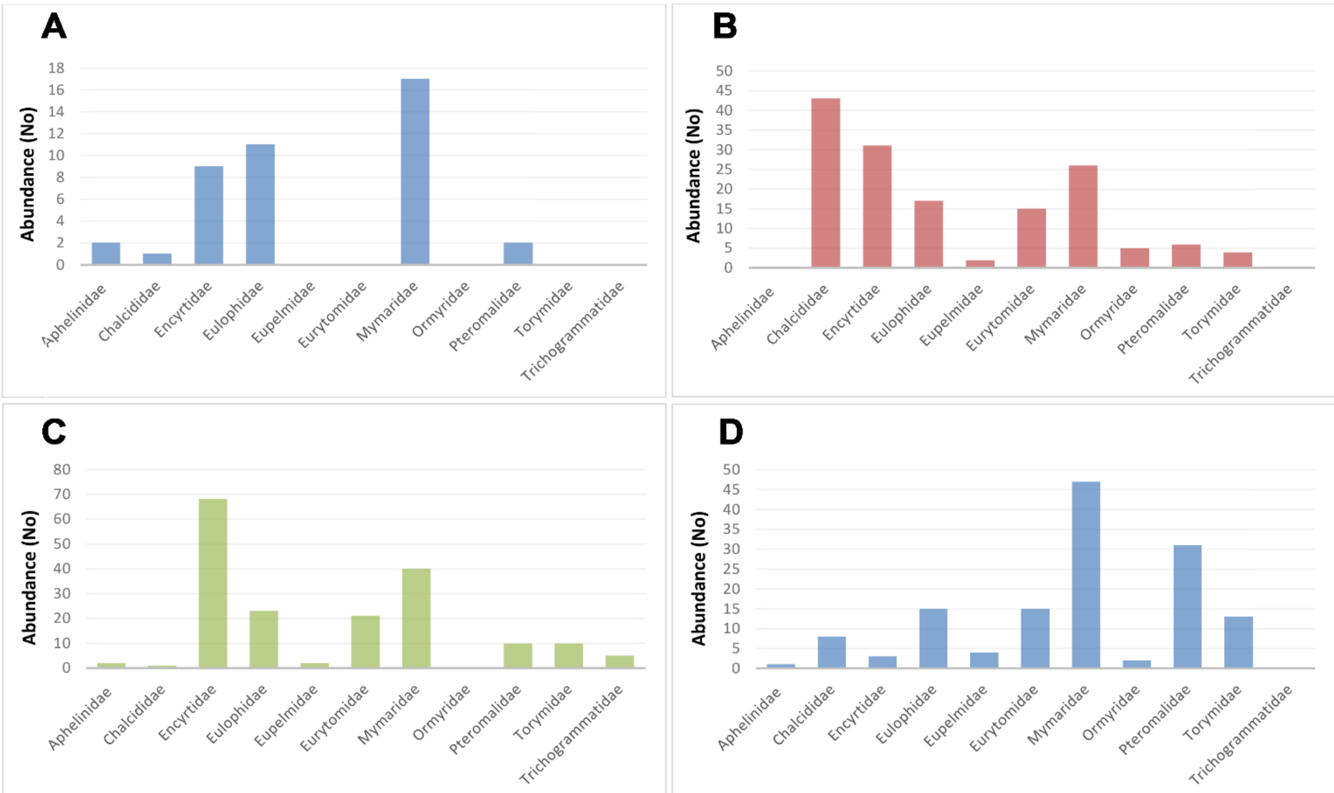

Figure 3. The abundance of the collected families from four studied stations using the Malaise trap in the northwest of Iran. **A.** Khajeh (K); **B.** Khoda-Afarin (KA); **C.** Tasuj (T), **D.** Tikmeh-Dash (TD).

LUB$_{in}$ - Tasuj (T) – The greatest value of diversity indices at the T station was observed in July, with a descending trend from August, and then showed an ascending trend in September and October. The largest value of Shannon's evenness index in this station was recorded on the first of July (0.877), therefore, the frequencies of the species had about 88% similarity. Its minimum was on the first of September at about 0.647. Brillouin and Camargo indices were the greatest values during July with 2.418 and 0.622, respectively (Table 4). The maximum value of Simpson's diversity index was 0.828 in the first July (P$_2$RSI=83%).

LUB$_{out}$ - Khoda-Afarin (KA) – All diversity indices at the KA exhibited the greatest values in July, with a descending trend from August to October, and reached a low level in September. The greatest and lowest values of Shannon's evenness index were recorded 0.855 and 0.708 in June and September, respectively (Table 4). The maximum value of Simpson's diversity index (0.833) was in July (P$_2$RSI=83%) (Table 5). During July, the Brillouin and Camargo indices were the greatest values with 2.242 and 0.578, respectively.

LUB$_{out}$ - Tikme-Dash (TD) – Shannon, Simpson and Brillouin's diversity indices were the greatest values during September, 2.590, 0.815 and 2.374, repetitively. The greatest value of Shannon's evenness index was 0.863. Therefore, the frequency of the various species collected in these stations had about 86% similarity. The lowest value of this index (0.779) was recorded in late September (Table 4). The largest value of Simpson's diversity index of the TD station was 0.815 and its P$_2$RSI was 82%. Camargo's evenness index has the greatest value with 0.597.

Table 4. Diversity and evenness indices of Chalcidoidea in four sampling sites (1-July, 2 August, 3-September, 4-October).

Indices		Sampling sites												
		Khod-Afarin (KA)				Tasuj (T)				Khajeh (K)			Tikme-Dash (TD)	
		1	2	3	4	1	2	3	4	1	2	3	3	4
Diversity	Shannon	2.564	2.401	1.991	1.743	2.631	1.157	1.673	2.117	2.126	0.971	1.766	2.589	2.590
	Simpson	0.809	0.775	0.701	0.661	0.828	0.484	0.582	0.741	0.758	0.0601	0.721	0.815	0.794
	Brillouin	2.247	1.902	1.731	1.451	2.418	0.957	1.444	1.819	1.529	0.664	1.506	2.374	2.279
Evenness	Shannon	0.855	0.801	0.708	0.751	0.877	0.729	0.647	0.819	0.822	0.971	0.883	0.863	0.779
	Simpson	0.601	0.483	0.452	0.546	0.688	0.617	0.386	0.596	0.545	0.962	0.809	0.639	0.455
	Camargo	0.578	0.527	0.448	0.521	0.622	0.601	0.413	0.563	0.611	0.901	0.771	0.597	0.459

Table 5. Diversity and evenness indices for the superfamily Chalcidoidea during the sampling period in the four stations, in the northwest of Iran.

Indices		Sampling sites			
		LUB$_{in}$		LUB$_{out}$	
		T*	K	TD	KA
Diversity	Shannon's	2.534^{a}	2.057^{b}	2.228^{ab}	2.744^{a}
	Simpson's	0.781^{ns}	0.734^{ns}	0.805^{ns}	0.833^{ns}
	Brillouin's	2.402^{a}	1.806^{b}	2.499^{a}	2.583^{a}
Evenness	Shannon's	0.763^{ns}	0.794^{ns}	0.803^{ns}	0.867^{ns}
	Simpson's	0.446^{ns}	0.588^{ns}	0.498^{ns}	0.643^{ns}
	Camargo's	0.438^{ns}	0.548^{ns}	0.486^{ns}	0.584^{ns}
No. of families		11	6	10	9
Total No.		182	42	139	149

*a, b: Means with similar letters in each row are not significantly different using Tukey's test (*a*=5%).

Table 6. Comparison the similarity of Chalcidoidea between four studied stations, in the northwest of Iran.

Sampling stations	K	KA	T	TD
K	-	42%	47%	42%
KA	-	-	45%	60%
T	-	-	-	47%
TD	-	-	-	-

Sorensen similarity index

Based on the Sorensen similarity index, a high community similarity was observed between TD and KA (60%), and its minimum was observed between KA and K (42%) (Table 6). Therefore, TD and KA share high numbers of the chalcidoid families. However, the greatest amount of Sorensen similarity index between these two habitats can be attributed to some of their climatic parameters, especially mean precipitation.

DISCUSSION

The result of this study as the first biodiversity study in the Lake Urmia basin indicated a great diversity of chalcidoids wasps, while the whole sampling extended through a short period of a single year. The detailed indices fluctuate along the regions represented by each station. Our study proves the diversity of chalcidoid wasps in LUB_{out} is more than LUB_{in} (Table 5), which can be resulted from the low diversity of host plants of LUB_{in} flora (mostly including halophyte plants). Similarly, Lockwood et al. (1996) revealed differences in Hymenopteran species diversity and similarities between burned and unburned habitats. It seems fragile vegetation, saline soil, and drought with cool weather of LUB_{in}, affected the population of chalcidoids. The greatest value for all of the diversity and evenness indices was estimated for the KA (LUB_{out}). Shannon's evenness index, which is focused on dominant species was 0.867 in this station, therefore, the frequency of the various species collected in this station had 87% similarity.

The greatest value for Simpson's diversity index 0.833 was observed at KA station (LUB_{out}) (P_2RSI = 83%). Biodiversity studies showed that the KA has the greatest values of diversity, evenness, and richness levels for these parasitoids. The high value of Brillouin's diversity index in the KA station was 2.583. This means that the diversity of Chalcidoidea in LUB_{out} can be more diverse than LUB_{in}. The two LUB_{out} habitats had greater community similarity (60%) than found between K and LUB_{out} habitats (42%). Based on Lockwood et al. (1996) evenness was slightly different between two burned and unburned habitats; they showed diversity and richness of parasitic wasps in burned sites were less than in unburned sites. They report higher species evenness for unburned habitats with differences during the spring that are consistent during the summer. The majority of the species were belonging to the family Mymaridae (25%), in TD (LUB_{out}) which peaked at 47 specimens during the sampling period, while the corresponding habitats peaked at 40 specimens in T (LUB_{in}). Two families, Encyrtidae and Chalcididae have maximum abundance in T and KA stations, respectively. Similarly, the family Encyrtidae was computed as an abundant group in sugarcane and rice ecosystems in India (Abhishek et al., 2022).

The relatively saline soils, poor vegetation, and water scarcity in LUB_{in} can cause the lowest values of diversity, evenness, and richness of Chalcidoidea. These factors influence directly the plantation and indirectly populations of insects and parasitoids during the growing season, and their effects may be intensified as the cold seasons and cold weather approach. The greatest diversity level among all the families was observed at LUB_{out} (especially KA) because of its relatively warm and humid climate and forest ecosystem that provides suitable shelters for insects in the forest and agricultural ecosystems on the margins of the Aras River. However, parasitoid abundance was higher in the LUB_{out} stations. The presence of more dense and structured vegetation in these stations probably influenced the result. Therefore, the vegetation composition of the basin was affected by the lake and it influences the insect fauna of the habitat, such as the superfamily Chalcidoidea which was our objective. Our preliminary survey forms a basis for further studies aiming at the use of surrogate higher-level taxa instead of species-level to evaluate and monitor the diversity and distribution of parasitoid wasps in Lake Urmia Basin, as well as the applied use of hymenopteran parasitoids in programs of integrated pest management in Lake Urmia Basin agricultural and non-agricultural ecosystems.

AUTHOR'S CONTRIBUTION

The authors confirm contribution to the paper as follows: A.P. Collecting and writing of manuscript. H.L. Designing research plane, writing of manuscript. M.Z. Analyzing of ecological parameters. S.L.: Separating and counting Chalcidoidea specimens. All authors approved the final version of the manuscript.

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AVAILABILITY OF DATA AND MATERIAL

Not applicable.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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تنوع زیستی زنبورهای بالاخانواده Chalcidoidea در حوزه دریاچه ارومیه چه می‌گوید؟

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چکیــده: زنبورهای بالاخانواده Chalcidoidea نقش مهمی در کنترل بیولوژیک آفات مهم کشاورزی ایفا می‌کنند. در تحقیق حاضر تنوع زیستی این زنبورها در چهار اکوسیستم در حوزه دریاچه ارومیه بررسی و مورد مقایسه قرار گرفت. این دریاچه به عنوان بزرگ‌ترین دریاچه شور دنیا، دارای حوزه آبریز بزرگ با تنوع اکولوژیک بالا در شمال‌غرب ایران واقع شده است. این ایستگاه‌ها شامل خواجه (K) و تسوج (T) در داخل حوزه آبریز (LUB_{in}) و خداآفرین (KA) و تیکمه‌داش (TD) در خارج از این حوزه (LUB_{out}) می‌باشند. چهار ماه تله‌گذاری با استفاده از تله مالیز منجر به گردآوری ۵۱۲ نمونه از ۱۱ خانواده مختلف از این بالاخانواده شد که به ترتیب ۶، ۹، ۱۰ و ۱۰ خانواده در ایستگاه‌های خواجه، خداآفرین، تسوج و تیکمه داش جمع‌آوری شد. حداکثر فراوانی در ایستگاه تسوج با ۱۹۲ نمونه و حداقل در خواجه با ۳۸ نمونه مشاهده گردید. دو خانواده Encyrtidae و Chalcididae به ترتیب در تسوج و خداآفرین بیشترین فراوانی را داشتند. بیشترین تعداد نمونه در طی نیمه دوم خرداد تا نیمه اول مرداد مشاهده شد. اغلب گونه‌های جمع‌آوری شده در این تحقیق به خانواده Mymaridae متعلق بودند (۲۵٪) که در خارج از حوزه آبریز دریاچه با ۴۷ نمونه در تیکمه‌داش مشاهده شد، در حالی که در داخل حوزه آبریز با ۴۰ نمونه نیز این خانواده در تسوج مشاهده شد. دو ایستگاه داخل حوزه آبریز دریاچه بیشترین مشابهت (۶۰٪) را در مقایسه با سایر ایستگاه‌های داخل و خارج حوزه (۴۲٪) داشتند. همچنین تنوع زنبورهای این بالاخانواده در خارج از حوزه آبریز دریاچه خیلی بیشتر از داخل حوزه بود. مطالعه تنوع زیستی حاضر نشان داد زنبورهای بالاخانواده Chalcidoidea در ایستگاه خداآفرین بیشترین تنوع زیستی، یکنواختی و غنای گونه‌ای را داراست. این ایستگاه که در خارج از حوزه آبریز دریاچه واقع شده است با دارا بودن آب و هوای گرم و مرطوب‌تر و اکوسیستم جنگلی در حاشیه رود ارس واقع شده است.

واژگـان کلیدی: تنوع، پارازیتویید، بالاخانواده Chalcidoidea، دریاچه ارومیه، شورپسند