

Diversity of Butterflies associated with Brassicaceae crops in Basra, Iraq

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ABSTRACT

The study aimed to investigate the seasonal presence and characterization of the group of butterflies (abundance, richness and biodiversity) in the agroecosystem of Brassicaceae plants in the Basra province. Two different ecosystem sites (Karmat Ali at the sedimentary habitat and Al-Zubair region at the desert habitat) were sampled during the growing season of 2020/2021. There are 823 and 507 individuals at the Karmat Ali and Al-Zubair sites, respectively; the specimens consist of 9 butterflies belonging to four families. The most abundant family was Nymphalidae (60%), followed by Lycaenidae (28%) and Pieridae (9%), while Hesperidae recorded the lowest relative abundance of 3%. The highest butterfly population was recorded for *Vanessa Carudi*, while *Pieris rapae* had the lowest density. The results showed differences in abundance, species richness, and Diversity of butterflies at the sites. The highest values of Diversity and richness were at Karmat Ali, compared to the Al-Zubair region. The study of butterflies' abundance and biodiversity indices indicated that environmental factors and the polyculture plantations support the butterfly population in agricultural habitats.

Keywords: Basra; Biodiversity; Brassicaceae; Butterflies; Shannon index; Richness.

INTRODUCTION

Butterflies are considered adequate ecological representatives for the invertebrates¹⁻⁴ and clear evidence of the changes in the environmental quality. Butterflies also play critical ecological roles in natural and agricultural habitats; they perform basic ecosystem services⁵⁻⁷ by recycling essential nutrients (nitrogen, potassium and phosphorus) which are required by crops; adult butterflies usually suck the nectar, and larvae feed on the leaves of different plants of the agricultural landscapes, then releasing their feces containing some of these nutrients⁸⁻¹¹. Also, butterflies exist in the food chain of many vertebrates, such as birds and lizards¹², and they host many parasites, which decrease the pest populations^{13, 14}.

In the last few decades, the population of butterfly species has declined dramatically worldwide due to environmental changes and habitat destruction of¹⁵. For example, the number of butterflies in the United States has decreased sharply due to global warming and environmental changes^{16, 17}; the population of the western monarch is declining at an estimated rate of 1.6% annually; and more than 450 species of butterflies, including the western monarch butterflies, have declined by 99.9% since the 1980s¹⁸. A declining population of

butterfly species was also observed in Europe¹⁹; for example, 76% of the 59 species of migratory and endemic butterflies in the United Kingdom between 1976 and 2014²⁰. The development of ecological indices is essential in the field of biodiversity conservation. Butterflies quickly respond to ecosystem disturbance. Thus, they have been specified as significant biological indicators for evaluating the biodiversity of natural and agricultural habitats and monitoring the response of the ecosystems to environmental change and degradation²¹.

Globally, the decline in the number of butterfly species and habitat losses has led to an increased consciousness of conserving butterflies and their habitat²². Due to the critical role of butterflies, which provide essential environmental services to crops and native wild plant species in many ecosystems, extensive research on the habitat requirement of butterflies is essential to promoting conservation efforts^{23,24}. Therefore, the conservation and the Diversity of butterfly species (especially the pollinators) requires a broad understanding of their foraging behavior and their spatio-temporal distribution in agricultural habitats²⁵; however, most specialized butterfly species usually depend on a limited set of host plants for their larval stage, or they use a limited number of nectar sources, even when a large number of nectar-producing plants are available^{26,27}; butterflies also tend to use areas within the site where host plants are located near nectar sources or chose the host plants for laying eggs on the host plants close to the nectar sources; thus the correlation of egg laying and feeding on nectar must be studied according to the abundance of the host plants and nectar sources²⁸. Despite the Diversity of butterflies in many natural habitats and their importance, especially concerning their ecological, behavioral, and functional role (especially pollination)^{5,8}, little research has been done about the role of butterflies on the Biodiversity in Iraq²⁹⁻³². In agricultural ecosystems, many butterfly species play an essential role as pollinators of several crops that humans depend on for their livelihoods^{33,34}; and no published data describe the Diversity of butterflies present in agricultural habitats in Iraq. The current study aimed to investigate the seasonal presence and characterization of the group of butterflies (abundance, richness and biodiversity) in the agroecosystem of Brassicaceae plants in the Basra province.

MATERIALS AND METHODS

Study Sites

Two sites were chosen to study butterflies' seasonal activity and Biodiversity in Basra Province, southern Iraq, during the 2020-2021 growing season. The first site represented the agroecosystem of the sedimentary plain habitat³⁵, at the region of Karmat Ali; a field in agricultural station of the College of Agriculture at the University of Basra, close to Shatt Al-Arab river, was chosen as a permanent station No. 1 (30 25 45.1" N, 47 55 52.1" E), Where different crops are grown annually, in addition to the presence of trees such as date palm and Jujube. The second site represented the agroecosystem of the desert habitat³⁵, which was designated for the cultivation of the tomato crop and some leafy crops, mainly in Basra province; a field was chosen in Al-Zubair region as a permanent station No. 2 (30 39 5.47" N, 47 42 34.32" E). Each field (12 x 60 m²) was prepared, divided into plots, and planted with seven Brassicaceae crops (White radish *Raphanus sativus* subsp. *acanthiformis*, Arugula *Eurica Sativa*, rapeseed *Brassica napus*, mustard *Brassica carinata*, broccoli *Brassica oleracea*, variety *italica*, cauliflower *Brassica oleracea*, variety *botrytis*, cabbage *Brassica oleracea*, variety *capitata*).

Butterfly community composition and seasonal activity

During the butterfly flight season, Butterflies were monitored and collected for each species at each site biweekly during the sampling period of the growing season of 2020/2021 by using the insect net. Butterflies were sampled between 8:30 and 12:30 am and transferred to the laboratory for identification; specimens were kept in the insect collection box after hardening and recording all the necessary information. Butterfly species

were diagnosed using taxonomic keys^{36,37}. Butterfly Relative abundance was estimated for each species at both studied sites³⁸.

$$Ra (\%) = (N/Ns) \times 100 \dots \dots \dots (1)$$

Where Ra= Relative abundance, N = the number of individuals of one species in the sample, Ns = the total number of individuals.

Biodiversity indices

Four ecological indices were used to measure the biodiversity of the butterfly community in the agroecosystems of Brassicaceae plants. The values of the biodiversity indices for the butterflies were calculated during the agricultural season from 1/11/2020 to 1/4/2021:

Shannon Diversity Index (H)

The diversity index values were calculated according to the equation mentioned in³⁹.

$$H = -\sum P_i \ln P_i \dots \dots \dots (2)$$

Where H = the value of Diversity, P_i = the ratio of the number of individuals of each species to the total number.

The Shannon-Wiener index value usually is between 1.5 and 3.5 for ecological data and rarely exceeds 4.0.

Richness index (D)

The value of the Richness index was calculated according to the equation given in⁴⁰:

$$D = S/\sqrt{N} \dots \dots \dots (3)$$

Where D = the value of Richness, S = number of species, N = total number of individuals in the sample

Evenness index (J)

The Evenness index was determined according to⁴¹:

$$J = H/\log(S) \dots \dots \dots (4)$$

Where J = the Evenness value, H = value of the index of Diversity, S = number of species

Dominance index (d)

This index was calculated according to the equation in⁴²:

$$d = N \max / N \dots \dots \dots (5)$$

Since d = the value of Dominance, N max = number of individuals of the dominant species, N = total individuals in the sample.

The reciprocal of the index, 1/d, is often used so that an increase in the index's value is accompanied by an increase in Diversity and a decrease in dominance.

Statistical analysis

The results of Butterflies-seasonal activity were analyzed according to ANOVA; then, the averages were compared using the least significant difference at a probability level 0.05.

RESULTS

Butterfly community composition and seasonal activity

The study of the community composition of butterflies showed that the total numbers of individuals collected were 823 and 507 individuals at the Karmat Ali and Al-Zubair sites, respectively; the specimens consist of 9 species of butterflies belonging to four families of the order Lepidoptera (Table 1); the results of Table (2) indicated that there were significant differences ($P < 0.05$) among the butterflies populations associated with Brassicaceae plants; butterflies showed highest population of 4.71 individuals/ month at Karmat Ali, compared to 3.28 individuals/ month in the Al-Zubair region. However, the highest butterfly population was recorded for *Vanessa cruda*, which reached 12.73 individuals/ month. At the same time, *Belenois aurora* had the lowest density, with an average of 0.2 individuals/ month during the growing season. *V. cardui* recorded the highest rate of 15.55 individuals/ month in the Karmat Ali site, while *B. aurora* had the lowest rate of 0.2 individuals/ month at both study sites.

Also, the results showed significant differences ($P < 0.05$) in the densities of butterfly species during the growing season in the two study stations (Table 3); the highest population of butterfly species was in March, with an average of 4.21 individuals/month, while the lowest density was found in January, reaching 3,065 individuals/month in both study sites. The highest rate of butterflies was recorded in the Karmat Ali area in March, with an average of 5.73 individuals/month, compared to the lowest number of 2.08 individuals in December. However, in the Al-Zubair area, the highest and lowest populations of 5.58 and 1.37 individuals were found in December and February, respectively.

Butterfly	Family
<i>Danaus chrysippus</i>	Nymphalidae
<i>Vanessa cardui</i>	Nymphalidae
<i>Colias croceus</i>	Pieridae
<i>Pieris rapae</i>	Pieridae
<i>Belenois aurora</i>	Pieridae
<i>Tarucus callinara</i>	Lycaenidae
<i>Zizeeria karsandra</i>	Lycaenidae
<i>Lampides boeticus</i>	Lycaenidae
<i>Parnara guttata</i>	Hesperiidae

Table 1. Butterflies associated with Brassicaceae crops in Basra Province.

Species	Population Density (Indiv./month)		Mean
	Karmat Ali	Al-Zubair	
<i>Danaus chrysippus</i>	8.35	4.3	6.33
<i>Vanessa cardui</i>	15.55	9.9	12.73
<i>Colias croceus</i>	2.40	1.10	1.75
<i>Pieris rapae</i>	0.75	0.65	0.70
<i>Belenois aurota</i>	0.20	0.20	0.20
<i>Tarucus callinara</i>	3.80	2.25	3.03
<i>Zizeeria karsandra</i>	5.40	8.15	6.78
<i>Lampides boeticus</i>	4.30	1.65	2.98
<i>Parnara guttata</i>	1.60	1.30	1.45
Mean	4.71	3.28	
LSD	0.55		1.24

Table 2. Population density of butterfly species in the two study sites during the growing season 2020-2021.

L.S.D. for interaction butterflies and regions (1.759).

Site	Population Density (Indivi./month)				
	Nov.	Des.	Jan.	Feb.	Mar.
Karmat Ali	3.80	2.08	4.63	4.95	5.73
Alzuber	3.60	5.58	1.50	1.37	2.70
Mean	3.70	3.83	3.06	3.16	4.21
LSD	0.88				

Table 3. The seasonal activity of butterfly species in the two study areas 2020-2021.

L.S.D. for interaction Months and sites (1.24).

The results of Table (4) showed that there were significant ($P < 0.05$) differences among the populations of butterfly species; the butterfly *V. carudi* was numerically superior during the growing season; the density was 16.88 individuals in March; however, the species *Belenois aurota* has not been recorded during the season except in November, with an average of 1.00 individuals/month.

Butterfly	Population Density (Indivi./month)				
	Nov.	Des.	Jan.	Feb	Mar.
<i>Danaus chrysippus</i>	5.75	6.62	8.75	6.12	4.37
<i>Vanessa cardui</i>	4.00	14.37	12.37	16.00	16.88
<i>Colias croceus</i>	4.75	1.62	0.75	1.12	0.05
<i>Pieris rapae</i>	1.25	1.12	0.37	0.37	0.37
<i>Belenois aurota</i>	1.00	0.00	0.00	0.00	0.00
<i>Tarucus callinara</i>	0.00	3.75	3.37	3.12	4.87
<i>Zizeeria karsandra</i>	13.75	5.50	2.75	3.00	8.88
<i>Lampides boeticus</i>	3.75	3.37	1.87	1.75	4.12
<i>Parnara guttata</i>	2.75	1.87	0.37	0.12	2.12

Table 4. The seasonal activity of butterfly species in Basra province during the growing season 2020-2021.

L.S.D. for interaction Butterflies and Months (2.78).

Relative abundance

The results of Table (5) showed that the highest relative abundance was recorded for the butterfly *V. cardui* on the crops of the Brassicaceae during the growing season 2020-2021, at a rate of 38.72%, followed by the butterfly *Danaus chrysippus*, with the relative abundance of 16.76%; while the lowest relative abundance was recorded for the *Pieris rapae*, with an average of 1.05%. The results of the study also showed that the family Nymphalidae was the most abundant, reaching 60%, followed by Lycaenidae (28%) and Pieridae (9%), while Hesperidae recorded the lowest relative abundance of 3% (Figure 1).

Butterfly	Karmat Ali	Al-Zubair	Relative abundance %
	Captured butterflies		
<i>Danaus chrysippus</i>	157	124	16.76
<i>Vanessa cardui</i>	311	140	38.72
<i>Colias croceus</i>	9	20	2.93
<i>Pieris rapae</i>	14	20	1.05
<i>Belenois aurota</i>	50	0	5.03
<i>Tarucus callinara</i>	104	112	12.93

<i>Zizeeria karsandra</i>	73	80	7.14
<i>Lampides boeticus</i>	76	52	12.03
<i>Parnara guttata</i>	29	16	2.18

Table 5. The relative abundance of butterflies associated with the Brassicaceae crops in Basra during the growing season of 2020-2021.

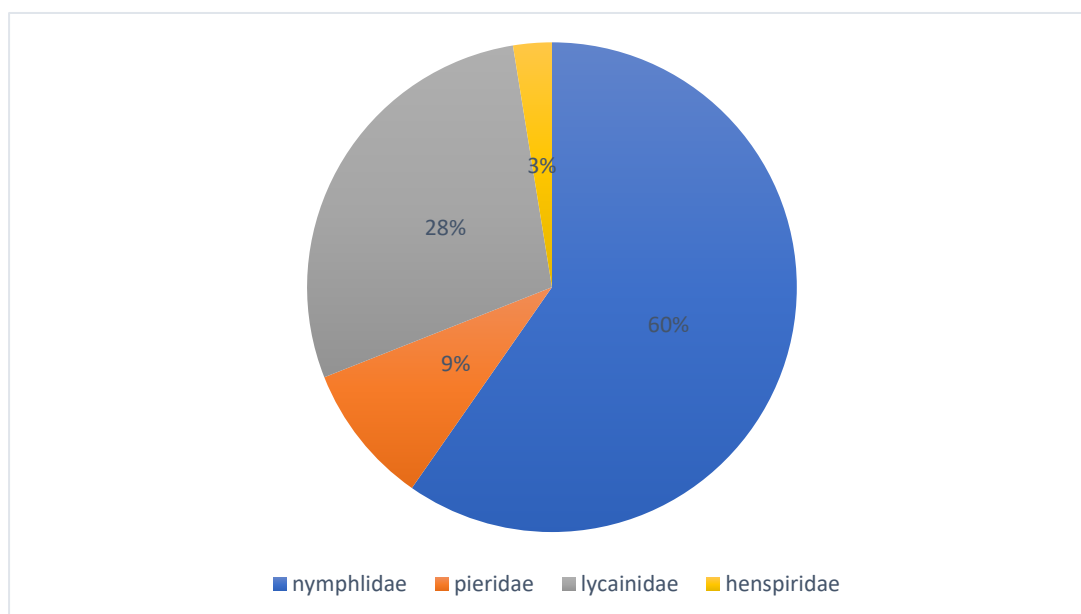


Figure 1: Relative abundance of butterflies' families associated with the Brassicaceae crops in Basra during the growing season of 2020-2021.

Butterflies Biodiversity (Ecological indices)

Spatial Diversity

The results of Table (6) indicated that the ecological indices had a slight variation between the study stations; the highest values of Diversity and richness were 1.79 and 1.19 at Karmat Ali, compared to the values of 1.65 and 0.96 in the Al-Zubair region. The highest values of dominance and Evenness were 0.40 and 0.75 in the Al-Zubair region, and the lowest values of 0.38 and 0.66, respectively, were in Karmat Ali.

Ecological index	Karmat Ali	Al-Zubair
Taxa_S	9	7
Individuals	823	507
Shannon_H	1.79	1.65

Evenness_e^H/S	0.66	0.75
Richness	1.19	0.96
Dominance	0.38	0.40

Table 6. Butterflies Biodiversity in Karmat Ali and Al-Zubair regions, 2020-2021.

Temporal Diversity

The results of the temporal Diversity of butterfly species in the Karmat Ali region (Table 7) indicated that the butterflies' highest value of Diversity was 1.80 in November; however, the lowest value was 1.45 in February. The highest value of richness (1.47) was recorded in March, and the lowest (1.19) was in November. The results revealed butterflies' lowest degree of dominance (0.29) and highest evenness value (0.86) in February. In contrast, the highest value of dominance (0.53) and lowest value of Evenness of species (0.54) was found in November.

Ecological index	Nov.	Des.	Jan.	Feb	Mar.
Taxa_S	7	7	8	8	9
Individuals	152	77	187	198	229
Shannon_H	1.80	1.66	1.59	1.45	1.73
Evenness_e^H/S	0.86	0.75	0.61	0.54	0.63
Richness	1.19	1.38	1.34	1.32	1.47
Dominance	0.26	0.39	0.41	0.53	0.43

Table 7. Butterflies biodiversity during the growing season at Karmat Ali region, 2020-2021.

At the Al-Zubair region (Table 8), the temporal Diversity of butterfly species differed from that of the Karmat Ali site; the highest and lowest values of Diversity were 1.80 and 1.21 in January and February, respectively. The lowest value of richness was recorded in January (1.32), while the lowest was found in November (0.52). In December, the highest degree of dominance (0.46) and lowest Evenness (0.72) of butterflies were recorded. However, the lowest value of dominance (0.28) and highest Evenness (0.96) was found in November and January, respectively.

Environmental index	Nov.	Des.	Jun.	Feb	Mar.
Taxa_S	3	7	7	4	4
Individuals	47	215	93	53	99

Shannon_H	1.06	1.62	1.80	1.21	1.31
Evenness_e^H/S	0.96	0.72	0.86	0.84	0.93
Richness	0.52	1.12	1.32	0.76	0.65
Dominance	0.43	0.46	0.28	0.45	0.34

Table 8. Butterflies Biodiversity during the growing season at Al-Zubair region, 2020-2021.

DISCUSSION

The community composition of butterflies associated with Brassicaceae plants was very similar depending on the butterfly species at the Karmat Ali and Al-Zubair sites; nine species of butterflies were recorded belonging to four families of the order Lepidoptera; the results of the study indicated that the family Nymphalidae was the highest relative abundant, followed by Lycaenidae and Pieridae; while Hesperidae was lower abundant (Figure 1); Nymphalidae is represented by two important species, *V. carudi* and *Danaus chrysippus*, which prefer open field cultivations compared to greenhouses⁴³; in this study, *V. carudi* which is one of the relative generalist species⁴³ had the highest butterfly population and was the most abundant throughout the sites, while *P. rapae* was less abundant and had low density during the growing season. The current study's findings indicated that a small number of butterfly species occurred in Brassicas fields in both sites of the sedimentary and desert habitats. Several investigations indicated that agroecosystem habitats usually supported poor communities of butterfly species^{44,45,46} explained that the agroecosystem usually supported very few butterfly species (generally 5–50), which is characterized by a high population of butterflies. However, another study about the butterflies in Dohuk Province, northern Iraq, showed the presence of 49 species belonging to seven families: Papilionidae, Pieridae, Libytheidae, Nymphalidae, Satyridae, Lycaenidae and Hesperidae³².

The seasonality results indicated that the highest rate of butterflies was recorded in the Karmat Ali area in March, and the lowest number was found in December. In contrast to the Al-Zubair site, the highest and lowest populations of butterflies were observed in December, and the lowest populations were recorded in February (Table 3-5). Depending on field observation, the most abundant butterfly, *V. carudi* (Nymphalidae), a generalist species, was regularly recorded collecting floral resources on several weeds in the blooming stage; they were observed making extended visits to flowers of Malow Malva parviflora in December in Al-Zubair. The results of this study confirmed that the 1st site (Karmat Ali), cultivated with different plantations and located at the river edge, had high Diversity and population densities. In contrast, the 2nd site (Al-Zubair), which had an enormous monoculture plantation, stressed fewer species of butterfly community^{47,48}. However, the seasonal variation of butterfly species populations at these two different sites could be attributed to the cyclic changes in climate elements of temperature and precipitation monthly⁴⁹⁻⁵¹. The butterflies' seasonal activity usually coincides with the peak of the flowering stage of host plants⁵²⁻⁵⁴.

Overall, butterflies' Diversity and richness varied between the study sites; the Karmat Ali site hosted a higher diversity and richness of butterfly species than the Al-Zubair site. The differences in butterflies' richness and Diversity were attributed to the differences in region characteristics (agricultural landscape, plantations, and river vicinity of Brassica plants), in addition to the influence of environmental factors⁵⁵.

CONCLUSIONS

The lack of large areas of natural habitats in Basra province and the incidence of rare and uncommon butterfly species pushes it urgent that efforts should be focused on conserving biodiversity through the maintenance and improvement of natural and agricultural habitats; it was noticed that *P. rapae*, which was abundant years ago in Basra, is the least abundant now. The current study offers specific encouragement that the Brassicaceae plants support the butterfly's community even with a small number of butterfly species; nine species belong to Nymphalidae, Lycaenidae, Pieridae, and Hesperidae associated with the above plant family. Due to the findings, the butterfly species have specific habitat requirements; the species diversity of butterflies in the agroforestry systems of Karamat Ali (sedimentary habitats) is much higher than that of the Al-Zubair region (desert habitats); the study of butterflies abundance and biodiversity indices indicated that environmental factors and the polyculture plantations support the butterfly's population in the natural and agricultural habitats. Depending on the present study, the use of butterfly species indicates the agricultural landscape's biodiversity.

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