



Original article

Species richness and composition of Neuroptera in the forests fragments of the Taurus Mountains Range, Turkey

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ABSTRACT

In this study, diversity, species richness and composition of Neuroptera has been studied in the forest edges and fragments in the Taurus Mountain Range, southern Turkey. Sampling for species collection was carried out from April 2017 to September 2018 at different distances from the forest center, i.e., (0–500 m), forest mid-interior (501–1000 m), and forest edge (1001–3000 m). A total of 975 adults were collected frequently belonging to the families Ascalaphidae, Coniopterygidae, and Hemerobiidae from the forest edges while Chrysopidae and Myrmeleontidae were most common along the mid-interior regions of the forest. Majority of adults caught from the mid-interior region comprised of female adults while the males of most species were abundant along the forest edges. Although the forest center shows the largest value for the Dominance species-diversity index and the smallest value for the Shannon index, forest edge was found highest for the Simpson index. The abundance of Neuroptera decreased with wind speed but increased with the temperature in the edge regions. Principal Component Analysis (PCA) indicated that some environmental and habitat variables, e.g. wind speed, temperature, and distance to the forest center, mid-interior and edge, accounted for species distribution patterns in Neuroptera. In the forest center, a linear correlation between wind speed, temperature and specimen abundance was recorded, while these factors were found negatively correlated with specimens abundance in the mid-interior regions of the forest.

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1. Introduction

Neuroptera are distributed worldwide and are recognized as important biocontrol agents of many pests of economic significance. While most adult neuropterans feed on insect by products such as honey dew and on nectar from flowers, their larvae prey on many soft-bodied arthropods including aphids, whiteflies, small lepidopteran caterpillars and eggs. Habitat types and shapes can determine and influence the diversity, abundance, and distribution of lacewings in forests. To understand the efficiency of lacewings as natural control agents of forest and other agricultural pests, it is necessary to evaluate the influence of habitat type on its natural populations in surrounding forests. Habitat fragmentation has become one of the major causes of biodiversity loss and species

extinction (Fortin and Mauffette, 2001; Vas et al., 2001; Sobrinho and Schoereder, 2007). Since human activities and abiotic factors are largely responsible for the fragmentation of natural habitats, it can substantially increase the edge effect factor, having many immediate consequences, including a reduction in the habitat's shape and size (Julião et al., 2004; Toroğlu and Ünalı, 2008; Güneş et al., 2016).

In the order Neuroptera, the lacewing families Chrysopidae and Hemerobiidae are highlighted for their ability to colonize and adapt to new environmental conditions (Henry and Wells, 1990; McEwen et al., 2001; Badano et al., 2018) and adjusting their foraging areas based on their feeding habits, disjuncting and resource location abilities in the natural habitats (Stelzl and Devetak, 1999; Duelli et al., 2002). That is the reason chrysopidae species colonized not only the forests and field crops, but also can be collected from urban and rural human settlements. Hence their prevalence, distribution and densities are determined not only by geography but also by food availability, habitat type and climatic conditions.

Forest fragmentation is a primary concern for landscape ecologists since it could represent an important threat to the

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preservation of biological diversity. However, faunistic composition, considering presence and relative abundances of various species, may be indicative of environmental condition inside forest fragments, provided that the composition of regional faunas at relatively undisturbed habitats is known (Jung and Lee, 2016; Fortin and Mauffette, 2001). Presently, there is an important mosaic of forest remnants in the TMR region, constituting an ideal system to study the effects of fragmentation. The nutritional status of leaves may also have important implications in population dynamics of herbivores hence indirectly influencing the performance of predatory insects that feeding on herbivores in dense forests (Duelli et al., 2002; Julião et al., 2004; Stone et al., 2018; Gutiérrez-Chacón et al., 2018).

A significant anthropogenic impacts on Taurus Mountain Range (TMR) has been observed due to frequent human settlements happening near the forest ranges where natural forest vegetation, especially at lower elevations and close to human settlements, has been destroyed by a combination of deforestation and grazing (Toroğlu and Ünalı, 2008). But the influence of such anthropogenic and environmental parameters, i.e., air temperature, wind speed and edge effect on the occurrence and distribution of lacewings in TMR have thus far been poorly studied in Turkey (Bozdoğan et al., 2013). This study evaluates how neuropteran communities within TMR forest habitat, from center to interior, and along the forest edge, are affected by distance from the edges of the forest. Moreover, the impact of climatic factors such as temperature, wind speed and local vegetation structure has also been evaluated.

2. Material and methods

2.1. Study area

This study was carried out in the Taurus Mountain Range (TMR), one of the largest biodiversity reserves, harboring more than 1000 plant species, 250 of which are endemic to Turkey or sometimes only to southern Turkey. The TMR rises abruptly in the coastal belt of the Mediterranean Sea, producing radically different habitats along an elevational gradient (Atalay, 2006). Mountainous areas are also very rich in insect species belonging to a large number of different insect orders (Taşdemir and Ustaoglu, 2016).

The study site in the TMR was bounded to the north at 38°14'N-, 36°22'W, to the south at 36°56'N-, 36°12'W, and elevationally between 622 m and 2050 m. Most of the vegetation comprises the plant species *Pinus brutia*, *Cedrus libani*, *Abies cilicica* Carr. ssp. *cilica*, *Quercus pubescens* and *Artemisia santonicum*, occupying 3000 ha. Regional climate is warm and humid with temperatures ranging between 26.1 °C and 38.4 °C in the warm rainy seasons. Mean annual precipitation varies between 600 mm and 1200 mm (Güneş et al., 2016; Öztürk et al., 2018).

3. Sampling method

Considering the biodiversity of survey area, and based on Landsat Thematic Mapper, 15 different sampling sites were selected in terms of plant community in the center, mid-interior and edge of TMR forest regions (Tables 1 and 2). Also, in the center and mid-interior regions, the most central point in each remnant was identified from an aerial photograph their distances from the edges were determined Google Earth Software. Each sampling point was classified based on their distances from the forest center into the center (0–500 m), mid-interior (501–1000 m) and forest edge (1001–3000 m) Field collection of adult Neuropterans using sweep nets and light traps was carried out bimonthly from April 2017 to the end of September 2018 between 8 a.m. and 6 p.m.

A total of 30 traps were set, with four traps in the center and eight in the mid-interior on the same day of sampling while 18 traps around the edge of the forest were placed on the next day of sampling. The specimens were sampled from the herbs, shrubs and trees from ground to 0.5 m high. Air temperature and relative humidity were measured every 30 min with a digital thermo-hygrometer (Protmex MS6508) during all sampling routines. Wind speed and altitude were measured by a hand-held wind meter (SkyMate-SM-18) and GPS tracker (Sunroad FR 500), respectively.

Each light trap consisted of a 2.5 m² white cotton sheet placed in front of a 250 W mercury vapor bulb (powered by a portable generator) held vertically 1 m above the ground. The captured specimens were preserved in 70% ethanol and later were mounted and identified to species level using identifications keys. Specimens were then taken to the Kırşehir Ahi Evran University Entomology Laboratory (KAEUEL) and compared with specimens of the same or similar species from the entomological collection at KAEUEL (Aspöck et al., 1980; Brooks and Barnard, 1990; Aspöck et al., 2001; Dobosz and Ábrahám, 2007).

For this study region, climate data (temperature and wind speed) were confirmed and compared with the Turkish State Meteorological Service from April 2017 to September 2018. Forest information (forest patch sizes, dominant plant species, and forest ages) was confirmed by the forest geographic information service system in Turkey's Forest Management Planning System.

4. Results

During the sampling periods a total of 975 neuropteran specimens were captured, belonging to five families and 26 species. From these, ten species were exclusively prevalent through the forest centers, 17 were found only at the mid-interior regions while and 22 were found both at the edges (Fig. 1). Table 1 shows the absolute and relative abundances of neuropteran species collected at each point during the study period.

To determine statistically significant differences in the center, mid-interior and edge, a non-parametric ANOVA test (Kruskal-Wallis) was applied to the numerical data. A significant difference between sample medians at different regions was recorded ($F_{2,36} = 3.97$; $p = 0.022$). Also the mean abundance of each neuropteran species at each sampling site was calculated that demonstrated that the numbers of species captured from the forest edges were significantly higher than from the center and mid-interior (Table 2). Table 2 shows that the maximum mean abundance in the center was $38 \pm 0.9a$ for *Pseudomallada prasina* and the least abundance was $4 \pm 0.4a$ for *Libelloides macaronius*. *Chrysopa formosa* exhibited the highest mean abundance observed in the edge ($44 \pm 0.63c$). Although *Pseudomallada flavifrons* was not found in the center, it had the highest value ($72 \pm 0.47b$) for the mid-interior.

Principal Components Analysis (PCA) was used to evaluate the similarity among the three sampled regions (center, mid-interior, edge) with respect to the distance into the forest for each neuropteran species. There was a close correlation between the *Chrysopa astarte* and *Chrysopa formosa* (Neuroptera: Chrysopidae) in edge regions of TMR forest. Even though *Chrysopa nigricostata* belonged to the same family (Chrysopidae), in contrast, it had a significant association with the center region (Fig. 2).

The number of specimens belonging to the Myrmeleontidae in the mid-interior regions (89) was significantly larger than in the center and edge regions of the forest when compared with species belonging to Ascalaphidae, Coniopterygidae and Hemerobiidae (Fig. 3).

Surprisingly, we observed the sex-related abundance of lacewings and it was significantly different between the edge and

Table 1

Distribution of the relative abundance of lacewings according to the temperature wind speed from the forest center to the edge.

| Family | Species no | Species | C | MI | E | Wind speed | | | Temperature | | |
|--------------------------------------|------------|---|----|----|----|------------|----|----|-------------|------|------|
| | | | | | | C | MI | E | C | MI | E |
| Ascalaphinae (Myrmeleontidae) | 1 | <i>Libelloides lacteus</i> (Brulle, 1832) | 6 | 4 | 10 | 11 | 18 | 3 | 29.7 | 34.4 | 28.9 |
| | 2 | <i>Libelloides macaronius</i> (Scopoli, 1763) | 4 | 22 | 30 | 7 | 4 | 2 | 31.5 | 34.0 | 28.8 |
| Chrysopidae | 3 | <i>Chrysopa abbreviata</i> Curtis, 1834 | 0 | 6 | 3 | 4 | 18 | 13 | 34.5 | 31.5 | 32.3 |
| | 4 | <i>Chrysopa astarte</i> Hölzel, 1967 | 0 | 14 | 41 | 7 | 9 | 4 | 35.1 | 36.9 | 35.4 |
| | 5 | <i>Chrysopa commata</i> Kis ve Ujhelyi, 1841 | 23 | 51 | 0 | 12 | 2 | 5 | 30.0 | 27.4 | 33.2 |
| | 6 | <i>Chrysopa dorsalis</i> Burmeister, 1839 | 0 | 0 | 20 | 4 | 31 | 38 | 36.7 | 25.5 | 30.6 |
| | 7 | <i>Chrysopa formosa</i> Brauer, 1850 | 0 | 18 | 44 | 5 | 9 | 1 | 30.0 | 29.7 | 30.7 |
| | 8 | <i>Chrysopa hungarica</i> Klapalek, 1899 | 6 | 0 | 0 | 14 | 30 | 3 | 34.6 | 26.8 | 31.5 |
| | 9 | <i>Chrysopa nigricostata</i> Brauer, 1850 | 5 | 14 | 15 | 5 | 8 | 6 | 33.6 | 31.6 | 32.7 |
| | 10 | <i>Chrysopa septempunctata</i> Wesmael, 1841 | 0 | 52 | 36 | 16 | 2 | 3 | 32.0 | 38.9 | 35.2 |
| | 11 | <i>Chrysopa viridana</i> Schneider 1845 | 6 | 0 | 30 | 12 | 34 | 6 | 34.4 | 31.6 | 35.1 |
| | 12 | <i>Dichochrysa clathrata</i> (Schneider, 1845) | 0 | 0 | 25 | 4 | 33 | 3 | 39.6 | 28.6 | 34.4 |
| | 13 | <i>Dichochrysa flavifrons</i> (Brauer, 1850) | 0 | 72 | 4 | 3 | 3 | 25 | 37.1 | 34.1 | 34.6 |
| | 14 | <i>Dichochrysa prasina</i> (Burmeister, 1839) | 38 | 33 | 8 | 7 | 1 | 2 | 29.1 | 31.7 | 35.3 |
| | 15 | <i>Dichochrysa zelleri</i> (Schneider, 1851) | 0 | 0 | 10 | 5 | 39 | 5 | 29.8 | 28.9 | 34.5 |
| | 16 | <i>Nineta flava</i> (Scopoli, 1763) | 0 | 17 | 0 | 15 | 10 | 21 | 29.6 | 30.3 | 28.8 |
| | 17 | <i>Suarius nanus</i> (McLachlan, 1893) | 0 | 0 | 24 | 15 | 32 | 19 | 36.3 | 29.4 | 33.7 |
| Coniopterygidae | 18 | <i>Aleuropteryx loewii</i> Klapalek, 1894 | 12 | 9 | 37 | 20 | 19 | 4 | 34.3 | 30.6 | 38.9 |
| | 19 | <i>Helicoconis (Ohmopteryx) pseudolutea</i> Ohm, 1965 | 0 | 5 | 0 | 7 | 24 | 19 | 33.2 | 27.5 | 26.9 |
| Hemerobiidae | 20 | <i>Hemerobius (Hemerobius) micans</i> Olivier, 1792 | 26 | 5 | 30 | 39 | 26 | 2 | 27.9 | 33.7 | 36.7 |
| | 21 | <i>Hemerobius handschini</i> Tjeder, 1957 | 0 | 0 | 4 | 4 | 33 | 38 | 33.7 | 30.5 | 27.6 |
| | 22 | <i>Hemerobius nitidulus</i> Fabricius, 1777 | 0 | 0 | 16 | 6 | 31 | 5 | 32.6 | 29.7 | 30.2 |
| Myrmeleontidae (except Ascalaphinae) | 23 | <i>Cueta lineosa</i> (Rambur, 1842) | 22 | 30 | 4 | 40 | 5 | 5 | 28.7 | 29.9 | 29.4 |
| | 24 | <i>Delfimeus irroratus</i> (Olivier, 1811) | 0 | 24 | 6 | 4 | 7 | 8 | 34.9 | 29.4 | 27.9 |
| | 25 | <i>Myrmeleon (Myrmeleon) formicarius</i> Linnaeus, 1767 | 0 | 35 | 15 | 6 | 1 | 4 | 33.3 | 32.4 | 27.8 |
| | 26 | <i>Myrmeleon inconspicuus</i> Rambur, 1842 | 0 | 0 | 4 | 2 | 28 | 23 | 32.8 | 32.5 | 33.1 |

C: Center, MI: Mid-Interior E: Edge.

Table 2

Mean abundance of each lacewing species at each sampling site at different distances to the forest edge in the forest on Taurus Mountain Ranges, Southern Turkey during 17 consecutive months (April 2017 – September 2018).

| Family | Species no | Center region | Mid-interior region | Edge region |
|--------------------------------------|------------|---------------|---------------------|-------------|
| Ascalaphinae (Myrmeleontidae) | 1 | 6 ± 0.28a | 4 ± 0.33b | 10 ± 0.63c |
| | 2 | 4 ± 0.4a | 22 ± 0.49b | 30 ± 0.78c |
| Chrysopidae | 3 | 0 | 6 ± 0.57b | 3 ± 0.5c |
| | 4 | 0 | 14 ± 0.73b | 41 ± 0.66c |
| | 5 | 23 ± 0.98a | 51 ± c0.66b | 0 |
| | 6 | 0 | 0 | 20 ± 0.31c |
| | 7 | 0 | 18 ± 0.57b | 44 ± 0.63c |
| | 8 | 6 ± 0.64a | 0 | 0 |
| | 9 | 5 ± 0.25a | 14 ± 0.88b | 15 ± 0.56c |
| | 10 | 0 | 52 ± 0.93b | 36 ± 0.61c |
| | 11 | 6 ± 0.57a | 0 | 30 ± 0.52c |
| | 12 | 0 | 0 | 25 ± 0.36c |
| | 13 | 0 | 72 ± 0.47b | 4 ± 0.33c |
| | 14 | 38 ± 0.9a | 33 ± 0.64b | 8 ± 0.88c |
| | 15 | 0 | 0 | 10 ± 0.63c |
| | 16 | 0 | 17 ± 0.81b | 0 |
| | 17 | 0 | 0 | 24 ± 0.42c |
| Coniopterygidae | 18 | 12 ± 0.86a | 9 ± 0.75b | 37 ± 0.86c |
| | 19 | 0 | 5 ± 0.66b | 0 |
| Hemerobiidae | 20 | 26 ± 0.64a | 5 ± 0.33b | 30 ± 0.71c |
| | 21 | 0 | 0 | 4 ± 0.33c |
| | 22 | 0 | 0 | 16 ± 0.7c |
| Myrmeleontidae (except Ascalaphinae) | 23 | 22 ± 1.11a | 30 ± 0.52b | 4 ± 0.33c |
| | 24 | 0 | 24 ± 0.89b | 6 ± 0.5c |
| | 25 | 0 | 35 ± 0.56b | 15 ± 0.44c |
| | 26 | 0 | 0 | 4 ± 0.33c |

C: Center, MI: Mid-Interior E: Edge.

mid-interior regions with more males along the edges (Fig. 4). Such findings have never been reported earlier in any study that could be used to compare with our findings.

Moreover, the population diversity indices were calculated from the sampling data. The Dominance index (D) demonstrated that the highest abundance of species were found in the center

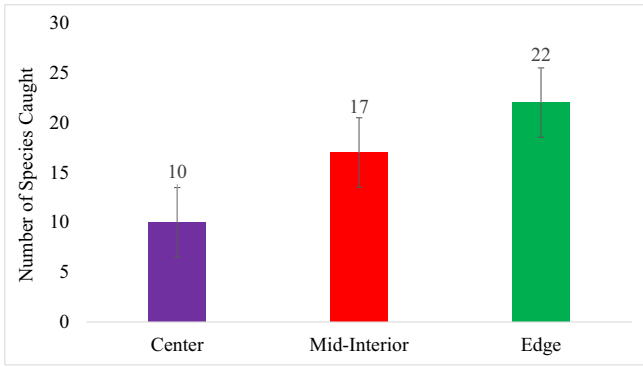


Fig. 1. Lacewings species richness at the center, mid-interior and edge. Forest edges presented higher species richness than mid-interior and center.

while Simpson’s index (1-D) demonstrated the highest value in the edge region of the forest. Shannon-Wiener diversity index (H) was used to describe the distribution of populations in the habitats and species evenness, which was not significantly influenced by rare species (Fig. 5).

Finally the correlation between species abundance and the ecological factors including temperature and wind speed were ana-

lyzed using a generalised linear models (GLM). This correlation was also tested for each of the three regions, individually. It was found that there was a positive relationship of temperature with the abundance in the center and edge (Fig. 6, Fig. 10). On the other hand, a negative correlation was detected in the mid-interior regions for both ecological factors (Figs. 7 and 8). Although temperature had a negative relationship with mid-interior region (Fig. 9) while it was positively correlated with the forest edges.

5. Discussion

Edge habitats may significantly affect species richness in forest ecosystems (Sobrinho and Schoederer, 2007) this has been clearly demonstrated in this study where 22 neuropteran species were found only on the forest edges, while there was no significant relationship between mid-interior and edge in terms of species abundances of Chrysopidae. This is probably because green lacewings are typically quite tolerant of seasonal changes and habitat variation (Canard, 2005; Ventura et al., 2007).

It is surprising to note that temperature has a significant effect in the forest edge rather than in center and mid-interior areas. A possible explanation could be linked to differences in microclimatic conditions, such as air and soil temperatures, soil moisture, and especially solar radiation, between the forest edges and the

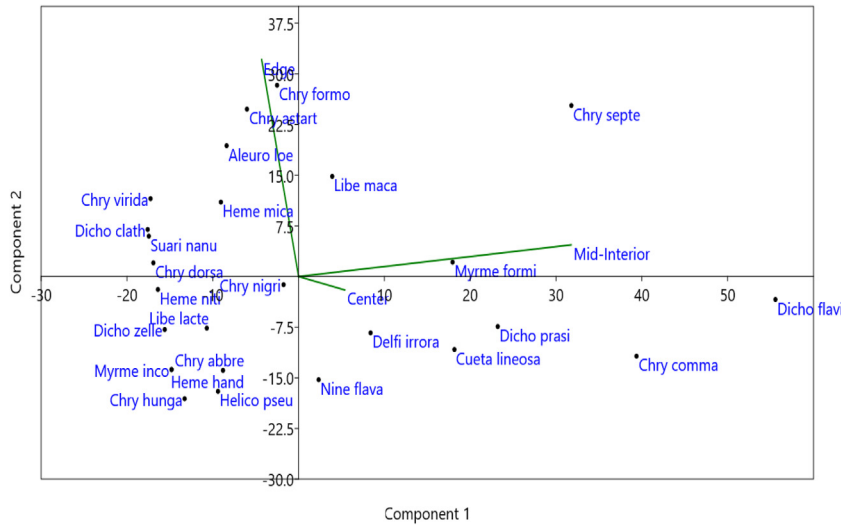


Fig. 2. The principal component analysis (PCA) for 26 lacewings species in the habitats investigated.

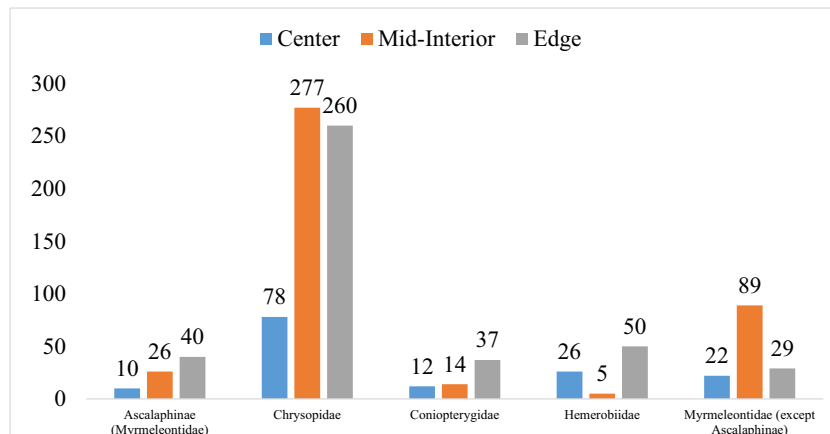


Fig. 3. The abundance of lacewings specimens according to the 4 families.

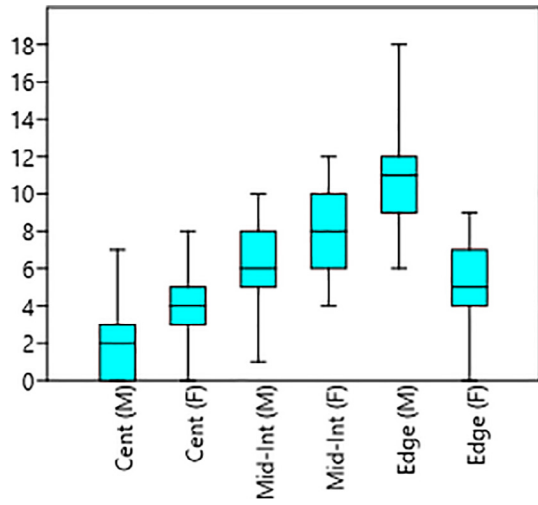


Fig. 4. The average number of species abundance of lacewings according to gender Cent (M): Center (♂), Cent (F): Center (♀), Mid-Int (M): Mid-Interior (♂), Mid-Int (F): Mid-Interior Edge (♀), Edge (M): Edge (♂), Edge (F): Edge (♀).

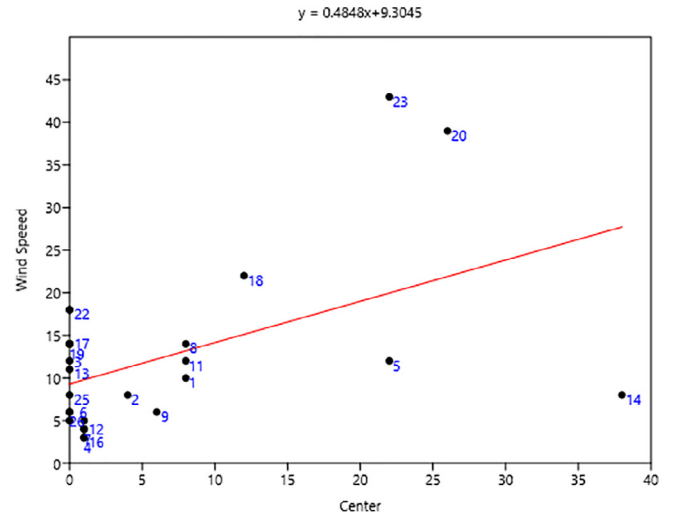
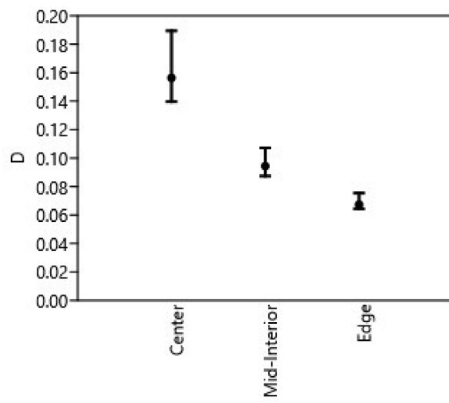
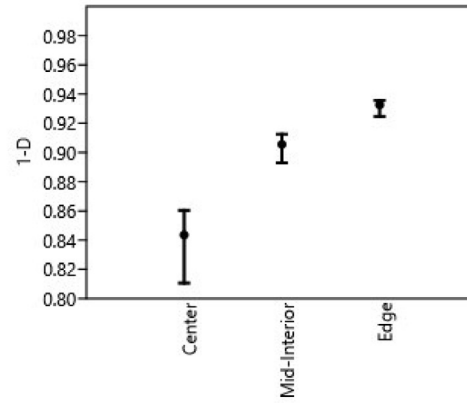


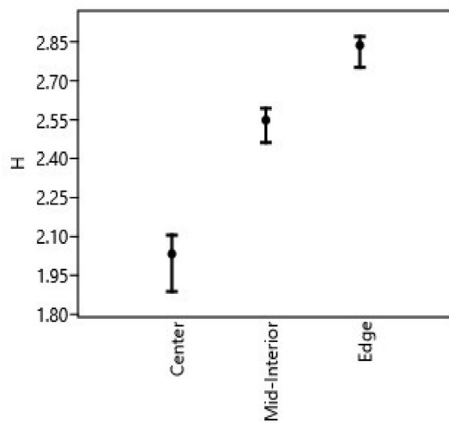
Fig. 6. Generalized Linear Model (GLM) for the relationship between the center species and wind speed, P (slope = 0): 0.0054.



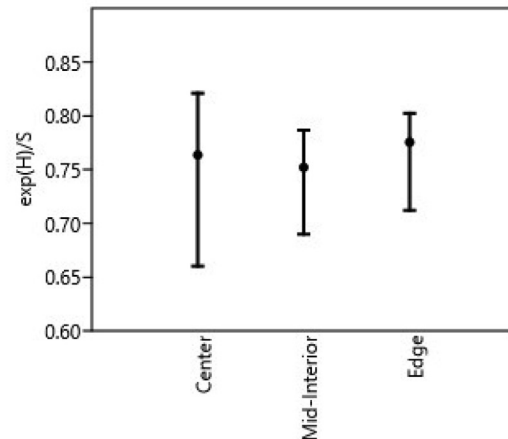
Dominance



Simpson



Shannon



Evenness

Fig. 5. The diversity indices of lacewings in the center, mid-interior and edge of TMA.

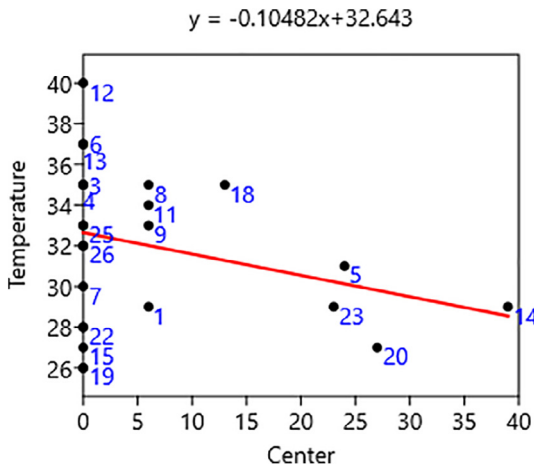


Fig. 7. Generalized Linear Model (GLM) for the relationship between the center species and temperature, $P(\text{slope} = 0)$: 0.0143.

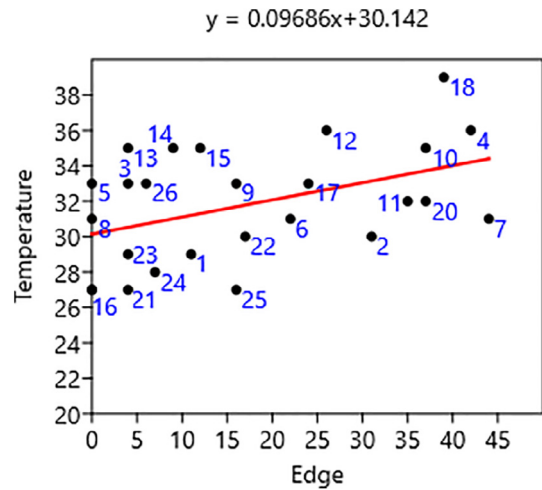


Fig. 10. Generalized Linear Model (GLM) for the relationship between the edge species and temperature, $P(\text{slope} = 0)$: 0.016.

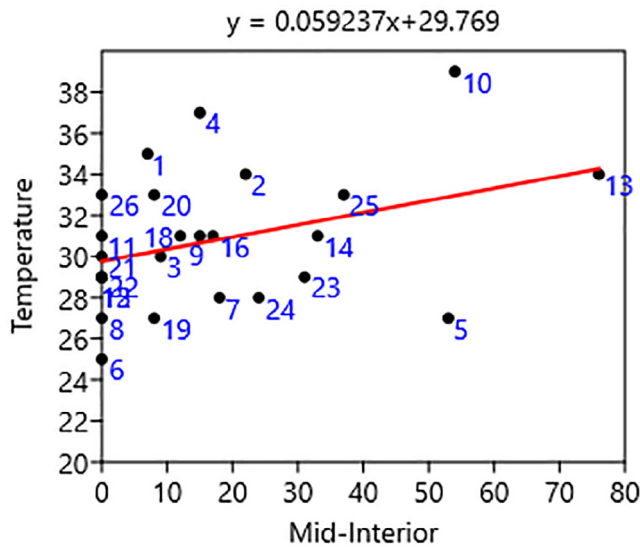


Fig. 8. Generalized Linear Model (GLM) for the relationship between the mid-interior species and temperature, $P(\text{slope} = 0)$: 0.057.

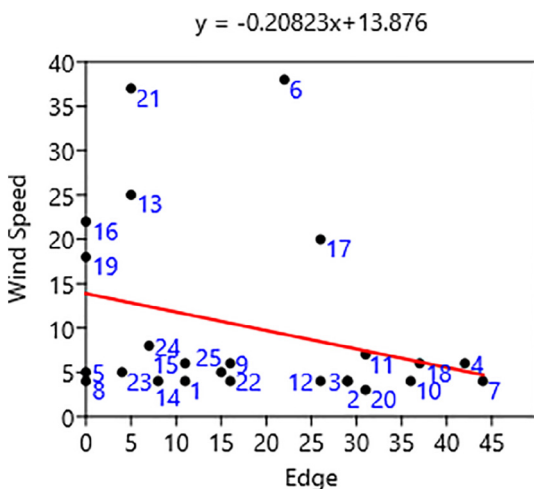


Fig. 9. Generalized Linear Model (GLM) for the relationship between the edge species and wind speed, $P(\text{slope} = 0)$: 0.153.

forest interiors (Duelli et al., 2002). Similarly, Chen et al. (2017) claimed that wind speed and temperature are two critical factors affecting life histories of most green lacewings.

Some lacewing species (*Pseudomallada clathratus* (Schneider) and *Pseudomallada prasinus*) belong to the same genus yet clumped differently in PCA ordinations. Regarding the different climatic factors considered, the presence or absence of species could be influenced strongly from the distance of habitat (Michel and Cadet, 2009; Devetak et al., 2013).

We found that the number of females in chrysopid species is greater than males in the center and mid-interior regions of the forest. This result supports Liu et al. (2011), who reports that flight performance likely differs significantly between the sexes in green lacewings. It could suggest that the females are able to disperse further into the forest than the males can. Species belonging to the genus *Chrysopa* are shown to have habitat preferences in this study. Similar conclusions have been drawn by McEwen et al. (2001) who emphasized that some *Chrysopa* species may need different habitat types for their developmental stages (e.g. eggs, larvae, pupae and adult).

6. Conclusion

Habitat fragmentation has led to an increase in the amount of edges in the TMR, southern Turkey. This will decrease the biodiversity of neuropteran species in agro-forest landscapes, especially in forest edges in highly cultivated and heavily altered landscapes. In conclusion, from the findings of this study it is suggested that the suitability of Neuroptera as a bioindicator should be evaluated by considering the ecological parameters, because just the edge factor may not cause changes in the composition of lacewing communities. And also different forest plots in different plant compositions could impact prey type and abundance. I recommend that these factors be considered when testing the lacewings assemblages for edge effects in forest ecosystems in future studies. In addition, our results could be used to improve the release of lacewings as part of biological control programs in the forest areas. However, further studies are still needed to analyze the influence of edge factors on environmental parameters that govern the distribution and composition of lacewing species, as well as changes to expect due to climate change.

6.1. Statistical analysis

All calculations and statistical analyses were performed with the significance level of 0.05 and 0.001 by using PAST version 3.0.

Declaration of Competing Interest

The author declares no potential conflicts of interest.

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