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Relationships between species diversity and evenness of necrophagous Diptera and environmental conditions in three habitats of Jordan

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Abstract

Weekly survey of forensically important necrophagous Diptera was conducted using bottle-based baited during, January 2008 to January 2009 in the Balqa Governorate of Jordan. Sampling took place in three habitats: one is urban (Al-Salt), the other rural (Hummra), and the third is a natural habitat (Wadi-Shabi). Species diversity measures were estimated to reveal between habitats the differences that exist in insects and thereafter, a correlation analysis was conducted to associate species diversity with the environmental. The highest species diversity was found to occur in the natural habitat (Wadi-Shabi) when compared with the other two habitats. All measures of species diversity varied significantly between habitats (one-way ANOVA). Additionally, negative correlations between most measures of species diversity and temperature were observed for the natural habitat (Wadi-Shabi) in comparison with urban and rural habitats. To a lesser extent, relative humidity does not correlate with species diversity and species evenness.

Keywords: Species diversity, Evenness, Necrophagous Diptera, Correlations, Environmental conditions, Jordan

1. Introduction

Necrophagous Diptera is among the diverse and important group of insects as they represent important ecological and forensic medicine. These insects, often called carrion insects, are key players in the decomposition process which is associated with decaying human and animal remains and utilized by insects as their micro-niches, thus, forming diverse micro-communities [1, 2]. In addition, as they colonize and decompose carrions rapidly, they have been used recently as scientific techniques in forensic sciences, majorly to establish what is called a Post Mortem Interval (PMI), which is referred to as the time that has elapsed when a human or an animal dies [3, 4]. A diverse fauna of necrophagous species that form an important player in the decomposing process belong to groups such as Coleoptera, Diptera, Hymenoptera and Araneida [5, 6, 7]. These diverse species of insects were found to be related to environmental conditions such as temperature, humidity, and habitat characteristics [8, 9, 10, 11]. Moreover, anthropogenic activities disturb the natural habitat of insects and alter its relationship to the surrounding environmental conditions [12, 13]. Biological processes such as growth, and reproductive success and activities of insects are influenced by the surrounding environmental conditions such as temperature and humidity [10, 11]. Environmental conditions such as temperature and humidity indirectly affect the abundance and diversity of insects and they play a vital role in its survival and reproductive success [11].

Species diversity can be estimated using two facets: "species richness", which gives an indication about the number of species in a given area, and "species evenness", which accounts not only for species number but also for variability in species abundances [14]. It has been shown that species evenness and richness react differently to habitat conditions [15]. One can hypothesize that species diversity and composition of necrophagous insects provide valuable information that can be used in forensic science, for example, such species diversity is often habitat and season specific [16]. Various studies show that insect communities of necrophagous provide valuable, spatial and temporal information, some of which focus on habitat and seasonal preferences of necrophilous insects [17, 18]. As some necrophilous species show clear correlation to seasonality and habitat characteristics. These studies concluded that this correlation can be good potential indicators of the season of death or carrion relocation [19].

Understanding the changes in biodiversity when correlated with urbanization is essential for monitoring the complex effects of human activity on native ecosystems.

Thus, the present study aimed at studying the species diversity and evenness of necrophagous insects' communities in three environmentally different habitats in Jordan. Its specific objectives were of threefold: (1) To estimate various facets of species diversity (species richness and species evenness) in three varied habitats, (2) To compare the diversity of necrophagous insects between the studied habitats, (3) To correlate the diversity estimates with environmental conditions of temperature and humidity.

2. Material and Methods

2.1. Study habitats and insects sampling

The present study was conducted in Balqa Governorates of Jordan (about 15 km from the capital Amman; 32°02'0"N 35°44'0"E). Three different habitats were investigated: (1) Al-Salt which is an urban habitat with dense private housing and exposure to human activities, (2) Hummra which is a rural habitat with semi-natural vegetation cover and little human activities, and (3) Wadi-Shabi which is largely a natural habitat without human interference. In addition to variation between the habitats in vegetation cover and human interferences, they also differ in air temperature and relative humidity (Table 1). In each habitat, bottle traps were used to collect necrophagous Diptera 2 weeks per month from January 2008 to January 2009. The number of individuals for each species found in each habitat scored averagely per site and per week. Collection method and the trapping bottles are described [20, 21, 22]. This method of trapping is characterized by low cost and the easiness of operation. At each habitat, we reported air, temperatures and relative humidity using data loggers placed near center point between traps.

2.2. Data analyses

The abundance of each species of necrophagous insects in each of the habitats investigated was used to calculate the diversity measures of (1) Shannon-Weiner diversity index, (2) Simpson diversity, and (3) Species evenness in each habitat, using the formulas according to Magurran and Phillip [14]. We used the one-way ANOVA to test for differences between habitats in term of species diversity measures. The Tukey's ASD test was used to compare areas where the F-test was significant. As a result of our data being abnormally distributed most times, we used spearman's correlation coefficient to explore the relationships between species diversity measures (Shannon diversity, Simpson diversity, and Species evenness), temperature, and humidity at each habitat studied. All statistical analyses were carried out using PAST 3.03 data analysis package [23].

3. Results and discussion

The spatial relationship existing between insect diversity and habitat conditions provides valuable information for forensic sciences, as they can be used, for example, to estimate the minimum Postmortem Interval (PMI), to trace postmortem movements of the body, and to estimate possible wounds. Moreover, the diversity - habitat relationship offer an important ecological value, as it represents a key role in maintenance of biological diversity and ecosystem function [24]. Among the insects that are of medical and ecological values are necrophagous Diptera [5, 7]. Presently, our objective is to study and compare the diversity of necrophagous Diptera, between three varied habitats, Al-Salt (urban), Hummra (rural), and Wadi-Shabi (Natural), in Jordan. The results

revealed that the three habitats investigated in this research varied in the levels of species diversity and species evenness of necrophagous Diptera. Table 1 shows analyses of variance ANOVA ($P \leq 0.05$) which indicated significant habitat variation for all fly species examined (*Calliphora vicina*, *Calliphora vomitoria*, *Lucilia cuprina*, *Lucilia sericata*, *Chrysomya rufifacies*, *Sarcophaga carnaria*, *Fannia scalaris*, *Muscina stabulans*, and *Musca domestica*). The results revealed that Al-Salt and Hummra habitat had similar diversity levels as reported by Shannon and Weaver diversity, Simpson diversity, and species evenness. On the other hand, these two habitats differed significantly from Wadi-Shabi habitat when examined with the three measures of diversity (Table 1). This pattern of variation observed in necrophagous Diptera possibly reflects the variation in the three habitats with regard to human interference. For example, Al-Salt (urban) and Hummra (rural) habitats are subjected to some human influences as the two habitats are under the influence of urbanization and some small scale agricultural practices. Additionally, as compared with Wadi-Shabi which is a natural habitat and supposedly support higher level vegetation cover and there's a possibility that flora diversity may contribute to such varied levels of diversity we discovered in our. Another reason for this variation in species diversity could be as a result of the agricultural practices, which play a major role in affecting the distribution and frequency of insect species across habitats regions [25]. Some studies, for example [26], have recorded that natural and unmanaged habitats have a positive impact on insect diversity within a heterogeneous environment. It was observed in this study, that despite an unmanaged habitat like Wadi-Shabi, it still recorded high species diversity as well as species evenness (Table 1). The differences in necrophagous diversity between these three habitats could be attributed to variation in the extent of human interferences. For example, it could be fairly established that highly urbanized and rural areas support higher extinction rates of insects as a result of associated habitat fragmentation, in addition to the lower vegetation structure [27, 28, 29]. However, the influence of urbanization on insect diversity is very complex, as it is well documented that the composition and diversity of the necrophilous insects depended on several factors such as geographical location of the study habitat, specific characteristics of vegetation cover, and others [30]. Additionally, other insects showed positive, negative or neutral responses of species richness to increasing urbanisation [27, 29, 31, 32]. Thus, it is difficult to rule out such factors that may have contributed to the varied level of insect diversity in this study. This study was also aimed at correlating the diversity estimates of necrophagous insects with the environmental conditions of temperature and humidity. Significant correlations between most measures of species diversity, temperature and humidity for the natural habitat (Wadi-Shabi) was carried out in comparison with urban and rural habitats. In Wadi-Shabi which is natural habitat, significant negative correlation was found between temperature, Shannon and Weaver diversity, Simpson diversity, and species evenness. Because temperature plays a vital role in the survival and reproductive success of insects, negative correlation could occur, owing to the fact that high temperature act as heat stressor that could result in direct mortality and reduce reproductive success and fitness, and thus influence abundance and diversity of insects [10, 11]. On the other hand, humidity is positively correlated with both measures of species diversity, Shannon and Weaver diversity and Simpson diversity (Figure 1). Families of Diptera have been found to show a variable response to humidity, but it was assumed that several species prefer highly humid environment

[33]. For the other two habitats studies, Al-Salt (Urban) and Hummra (Rural), less significant correlations were found. In Al-Salt, temperature and humidity were insignificant environmental factor that influenced the species diversity of necrophagous insect (Figure 2). In Hummra habitat, temperature had a positive correlation with Shannon and Weaver diversity and a positive correlation between humidity

and Simpson's diversity (Figure 3). As Al-Salt and Hummra habitats are subjected to anthropogenic activities, the lack of correlations between diversity with prevailing temperature and humidity could be attributed to the disturbance of these habitats that influence insects relationships to the surrounding environmental conditions [16, 34].

Table 1: Results of one-way analysis of variance (ANOVA), mean values, and standard errors (in parentheses) of diversity and environmental conditions of the three habitats studied in Jordan.

	Habitat				
Diversity and environment characteristics	Al-Salt	Hummra	Wadi-Shabi	F	P
Shannon and Weaver diversity	1.413 ^a (0.024)	1.469 ^a (0.0148)	1.74 ^c (0.020)	78.24	0
Simpson Diversity	0.695 ^a (0.008)	0.714 ^a (0.005)	0.774 ^c (0.005)	46.11	0
Species evenness	0.669 ^a (0.020)	0.677 ^a (0.006)	0.738 ^b (0.008)	20.88	0
Temperature	25.111 ^a (1.312)	27.957 ^a (1.246)	30.852 ^b (1.241)	5.378	<0.01
Humidity	46.963 ^a (1.762)	48.834 ^a (1.844)	50.741 ^a (2.195)	0.96	NS

Mean values with dissimilar letters indicate significant differences from each other as revealed by Tukey's test $P \leq 0.05$.

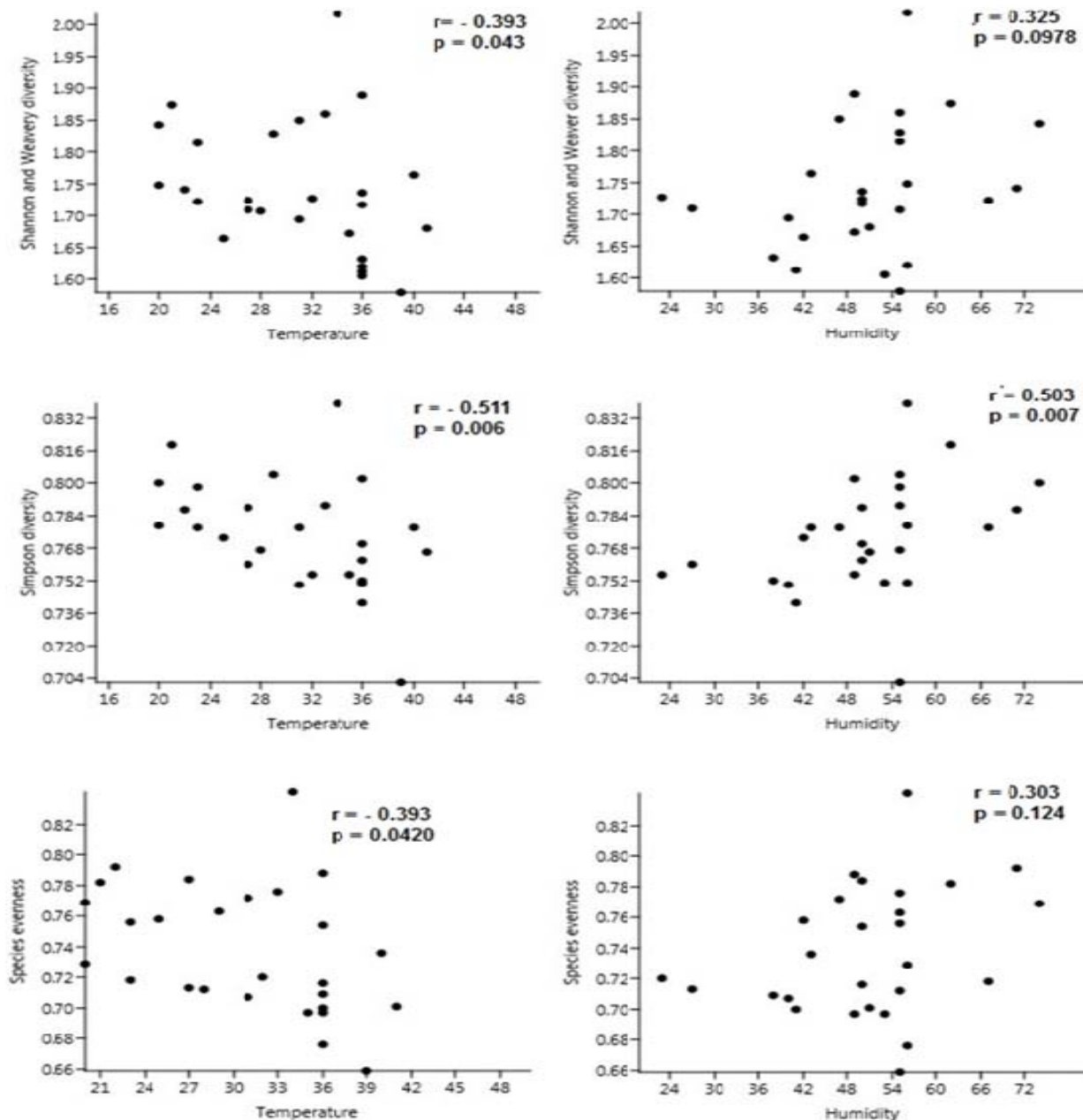


Fig 1: Spearman's correlation (r) between environmental attributes (temperature and humidity) Wadi-Shabi of Jordan and species diversity measures and species evenness of necrophagous Diptera. A p value <0.05 was considered statistically significant.

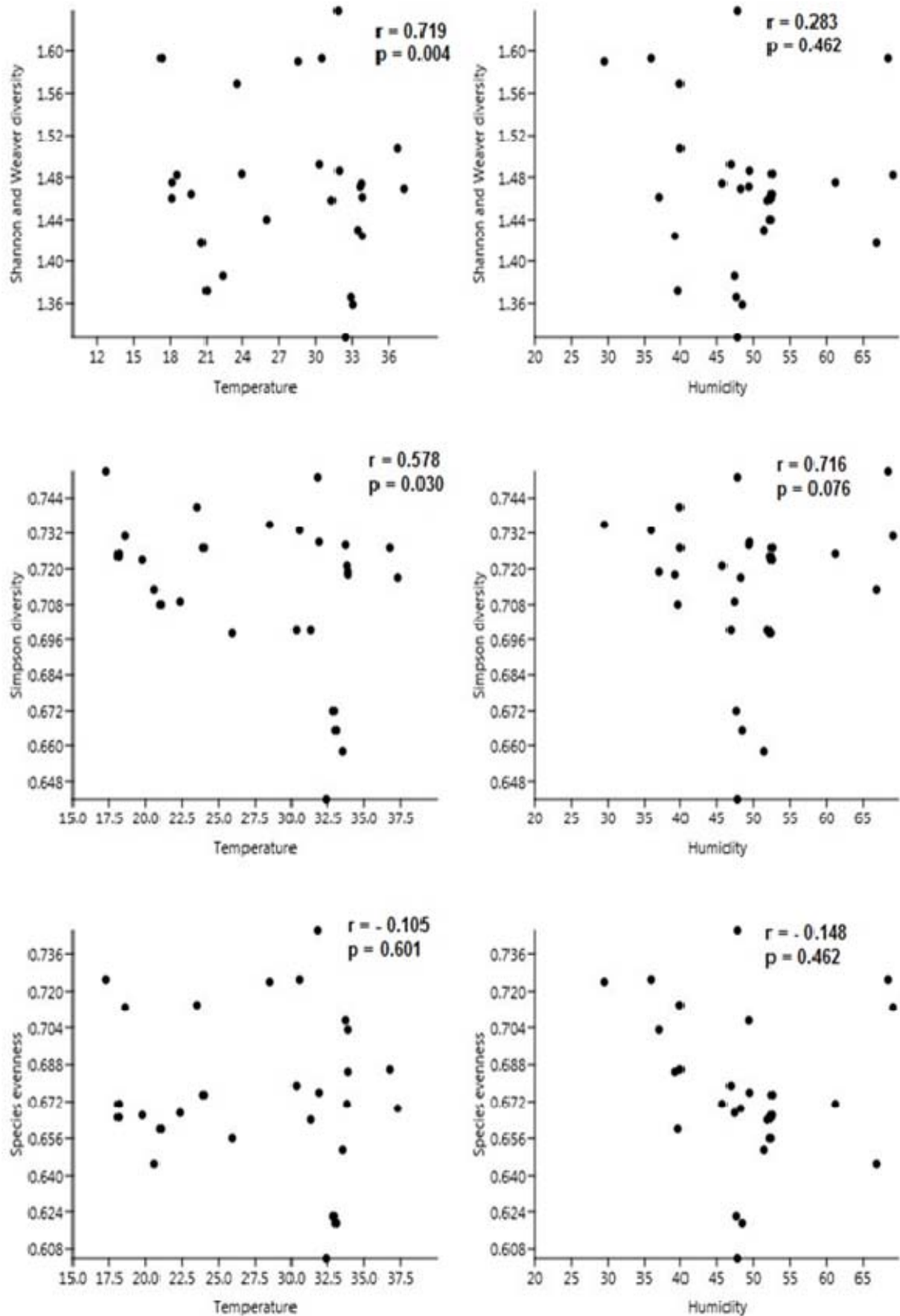


Fig 2: Spearman's correlation (r) between environmental attributes (temperature and humidity) Hummra of Jordan and species diversity measures and species evenness of necrophagous Diptera. A p value <0.05 was considered statistically significant.

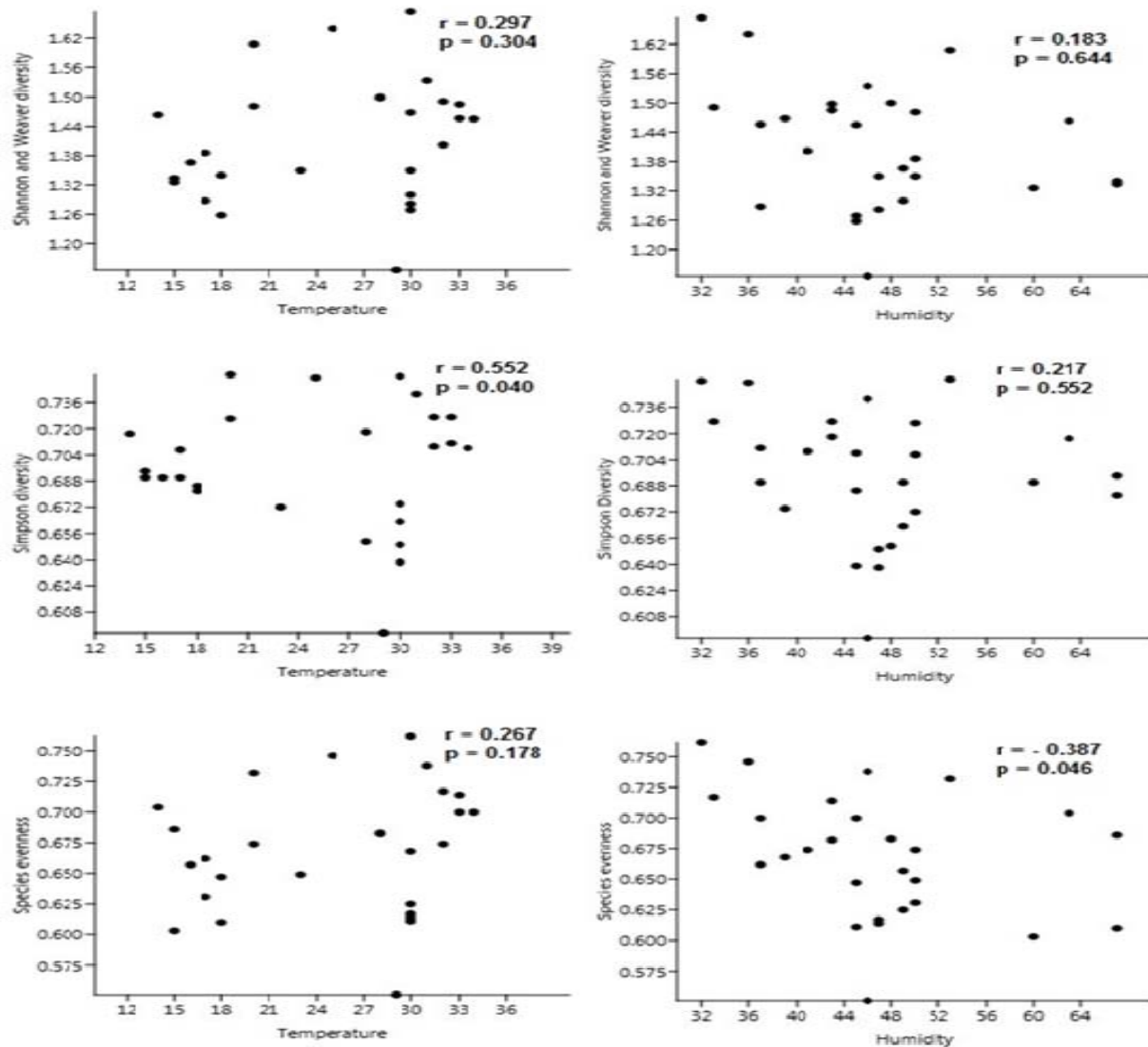


Fig 3: Spearman's correlation (r) between environmental attributes (temperature and humidity) Al-Salt habitat of Jordan and species diversity measures and species evenness of necrophagous Diptera. A p value <0.05 was considered statistically significant.

4. Conclusion

Most measures of species diversity (Shannon diversity, species richness, species evenness) that were investigated in this study were significantly associated with environmental conditions of habitats and the intensity of human management. We conclude that anthropogenic factors play a key role in determining the diversity and the richness of necrophagous insects. However, because environmental and anthropogenic factors may lead to a simultaneously effect on insect diversity, further studies that utilize multi-regional approaches are needed to find general pattern of insect diversity and to disentangle the effect of habitat and anthropogenic factors.

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