Ecological investigations on terrestrial arthropod biodiversity under different grassland ecosystems in El-Fara'a area (Palestine)

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ABSTRACT


Despite the importance of arthropods in grassland ecosystems, few studies have examined how grassland arthropods have been impacted by disturbances especially in the Wadi Alfara’a area, West Bank. This work was aimed at studying the effects of animal grazing on arthropod diversity, including species composition, species richness and species diversity, in a semi-arid Mediterranean grassland ecosystem at Alfara’a area in the Palestinian West Bank. The field work was conducted at the Tallouza village, located in the north-eastern part of the West-Bank. The experiment was established in 2006 in an area of about 2000 donums of a mainly grassland ecosystem usually used for grazing sheep and goats herds, under different land use management systems: recently fenced grassland, undisturbed natural grassland, and recently reclaimed agricultural land. Terrestrial arthropod communities were sampled seasonally at the three sites using pitfall traps, over the period of Apr 2006 to Apr 2007. Arthropods communities were found to be sensitive to livestock grazing. Overall population levels of arthropods were highest in the undisturbed natural grassland, followed by grazed grasslands, and the recently fenced grassland. Certain insect orders (Coleoptera and Hymenoptera) were generally, negatively impacted by livestock grazing. However, members of the family (Carabidae, ground beetles) (order Coleoptera) especially Carabus impressus, were richer in grazed sites. On the other hand families of Hymenoptera like (Sphegidae, Cephidea and Apidae) were not detected in the grazed grassland. On the other hand the unidentified species (Form 5) of the family (Formicidae) found only in the grazed grassland. A significant seasonal variation pattern was detected for total arthropod populations (P<0.05) at the different study sites, with the highest population levels detected in summer and early autumn, and lowest population levels detected in winter. The fluctuation patterns were comparable in the three sites. Comparable fluctuation patterns were also found for Hymenoptera and Coleoptera. Higher arthropod population levels in summer months coincided with higher air temperatures and lower soil moisture content, whereas, lower arthropod population levels in winter, coincided with lower temperatures and higher soil moisture content. Grazing has a considerable impact on the biodiversity of grassland arthropods in Alfara’a area. Some of the insect components, especially Carabus impressus, are well adapted to grazing disturbance, and therefore can be used as bioindicators of habitat disturbance such as grazing.

Introduction

Arthropods can be used to show the developed changes of ecosystem because they are very sensitive to ecosystem change (Holloway & Stork, 1991). Some react very fast to environmental changes and are ideally suited to act as bioindicators. Arthropods can therefore act as bioindicators of habitat disturbance such as pollution and climate change (Hawkesworth & Ritchie, 1993). Arthropods are abundant and easy to sample, and so, they give more information per unit sample time (Hill, 1995).

Ecologically, invertebrates including arthropods have a great functional importance, and main component within most ecosystems (Wilson, 1987; Samways, 1994; Hill, 1995; Coleman & Hendrix, 2000). They are known for their overall success at proliferating into available niches. Also, they have a main role in food webs which affects the ecosystem function (Erwin, 1982; Niemelä et al., 1993; Kremen et al., 1993; Colwell and Coddington, 1994; McGeoch, 1998).

Arthropods are usually efficiently used in aquatic ecosystems to produce data on environmental quality (Kremen et al., 1993). The importance of arthropod species as indicators for ecosystem monitoring control is that their huge ecological diversity supplies a wide choice for designing suitable assessment programs (Kremen et al., 1993) which can be for both short-term and long-term control.
Arthropods are simply, quickly, and cheaply sampled, therefore giving aids to get timely, cost-effective ecosystem data. Detailed sampling systems are available for practically all groups of arthropods in habitats levels from soils in forest canopies to deep groundwater fauna (Marshall et al., 1994).

Species identification of arthropods is not usually a difficult job compared with fungi or bacteria which needs DNA analysis and fatty acid profiles (Marshall et al., 1994).

The arthropods are very important in grassland ecosystems, but few studies have examined how grassland arthropods have been impacted by disturbances, such as, overgrazing and reclamation.

Both plant and animal biodiversity depends critically upon the level of grazing. Overgrazing may often lead to land degradation and the loss of biodiversity, while too little grazing may lead to succession from grassland to woodland and the loss of the grassland habitat (Watkinson & Ormerod, 2001). Not only is the level of grazing important, but also the timing and the animals species involved.

There has been an increasing concern that the loss of biodiversity caused by intensive practices disturbs ecosystem functioning and sustainability of grazing systems (Reid, 2006). Therefore management practices that modify invertebrate assemblages also risk interfering with these essential ecosystem processes and the sustainability of further production.

The high grazing levels have been reported to negatively affect the abundance and diversity of beetles (Mysterud & Austrheim, 2005), but did not affect the abundance and species richness of Diptera or Hemiptera.

Carabidæ (ground beetles) and Staphylinadae (rove beetles) were considered by some investigators (Byers et al., 2000) as indicators of habitat disturbances, such as drainage of wetlands, or grassland for grazing animals, and that their monitoring could provide one measure of ecosystem sustainability if intensive grazing management systems expand or intensify in the future.

This present work was therefore, aimed at studying the effects of animal grazing on arthropod diversity, including species composition, species richness and species diversity, in a semi-arid Mediterranean grassland ecosystem at Alfara'a area in the Palestinian West Bank.

Materials and Methods

Study area. The field work was conducted at Tallouza village, located in the north-eastern part of the West-Bank (latitude 32.27N, longitude 35.31E, altitude) (Figure 1).

Tallouza village is located in Wadi El-Fara’a area which extends about 30 km from Nablus in the West, to the Jordan River in the east, with an area of 345 Km². The stream Wadi El-Far’a is a tributary of the Jordan River, and is considered one of the most important wetlands in the West Bank. Topography is a unique factor in Wadi El-Far’ a which ranges from 1000 m above sea level in Nablus Mountains in the west to about 250 m below sea level at the point where Wadi El-Far’a meets the Jordan River. These factors have contributed to the high and unique biodiversity, especially endemic plant species, of the region’s ecosystems.

The experiment was established in 2006 in an area of about 2000 donums of a mainly grassland ecosystem, under different land use management systems: grazing systems land, recently fenced grazing land, natural non-grazed grassland, and recently agricultural land.

The topography is hilly, with slopes generally less than 10%. Soils are brown with variable depth, but rarely deeper than 60 cm, and with a rock cover of about 30%. The area has a Mediterranean climate, characterized by wet and mild winters. The average seasonal rainfall is 550 mm, falling mostly in winter. The rainy season begins in October – November and ends in April. Summers are dry and hot. At least 5 months of dry weather characterizes this area. The growing season of the vegetation is closely associated with the distribution of rainfall. Germination of annuals and regrowth of most perennials happen soon after the first rains. Growth is rather slow during the winter months of December-January, but the vegetation is usually well-established by mid-end January. Growth is rapid in spring and peak growth, coincided with seed set, occurs in March-April. By mid-May, most of the herbaceous vegetation is dry and most seeds have been disappeared. The forage quality decreases at the beginning of the long dry summer.
Experimental design. Within this area, three sites (2000m² each) with similar topographic and edaphic features were selected to study the effect of land use management practices on arthropods diversity including species composition, species richness and species diversity.

Site 1 was previously part of a grassland suffering from grazing by mainly sheep and goats herds. In October 2005 the land was fenced and protected from any agricultural practices or grazing (Figure 2A).

Site 2 was under grazing (mainly by sheep and goats herds) for the last 25 years (Figure 2B).

Site 3 was natural grassland where no human activities, agricultural practices or grazing had taken place for the last 5 years. This site was considered as the control treatment (Figure 2C).

Three 250m² (10 x 25 m) sampling plots (replicates) were selected at each site (land use treatment).

Arthropods sampling. The activity and population dynamics of arthropods were recorded using pitfall traps (Ruesink & Kogan, 1994; Hinds & Rickard 1973).

Pitfall Traps were made of about 450 ml plastic containers with 2 containers for each trap placed one in the other (Figure 3).

One container is placed within another and removed and replaced by a new one at the end of the sampling session. The pitfall traps containing ethylene-glycol (to preserve the specimens trapped) will be dug and placed into the ground so that the lip of the trap was flushed with the ground surface, 4 in each plot.

The pitfall traps were opened for two consecutive weeks (day and night) during every season (Winter, Spring, Summer, and Autumn) in order to trap beetles, spiders, and scorpions. After one week the containers were removed and replaced by new containers.
Processing of samples. After removal of pitfall, the arthropods captured were stored in 70% ethanol. The catch from each trap was calculated from the total numbers of arthropods of each group for each 7-day period. These groups were based on broad taxonomic divisions except for the commonest, for which specific determinations were made whenever possible.

Samples were washed through a fine aquarium sieve in the laboratory and the invertebrates were extracted, arthropod catch size per pitfall recorded and preserved in ethyl alcohol (70% for pitfall).

Extracted specimens were stored in 70% ethyl alcohol. Each sample of Arthropods was sorted using a dissecting microscope. Individuals were then identified to the order level and in case of Coleoptera and Hymenoptera insects where identified using taxonomic keys and monographs (e.g., Borradaile et al., 1961; Borror et al., 1981).

Species were initially assigned to morphospecies with a code number for each morphospecies and later identified, where possible, to species using available keys and insect collections.

Soil sampling and chemical analysis. Composite soil samples were collected at the three study sites in mid April 2006 and 2007. At each study site, 2–3 kg composite soil samples at 0–15 cm depth were collected randomly with an auger from four different location within the site. Soil samples were air dried, grounded, sieved with 2 mm mesh sieves and stored in plastic bags at room temperature for chemical analysis. Composite soil samples were analyzed for texture, soil moisture content, pH and soil organic matter.

Soil texture was determined for each soil sample using a hydrometeric method as described by Day (1965).

Soil moisture content was determined by gravimetric techniques (Hesse, 1971).

Soil pH was determined on a suspension of 10 g air dry soil and 10 mL 0.01 M CaCl2 by using a pH-meter (Mclean, 1982).

Soil organic matter was determined by reduction of potassium dichromate by organic carbon compounds and subsequent determination of unreduced dichromate by oxidation-reduction titration with ferrous ammonium sulfate method (FAO, 1974), and later converted to soil organic carbon using a factor of 0.58 (Wang & Zhou, 1999).
The pattern of relative abundance (catch per order expressed as proportion of the total catch) showed that the absolute catch of spiders (2.1%), beetle (2.4%) and other insects (9.5%) were higher in fenced grassland followed by grazed and natural grassland (Table 2). Total insects (98.2%) were including Hymenoptera comprised higher proportion of arthropods in the natural grassland followed by under grazing grassland and the lowest proportion in the fenced grassland land (Table 2).
Species composition:

**Coleoptera (beetls):** In the period of this study, insects captured belonging to Coleoptera can be classified into 6 families (Figure 6) and 16 species (Table 3) of coleoptera. More than ninety percent of the catch was represented by four families: Carabidae, Tenebrionidae, Elatridae and Histeridae.

Beetles belonging to Carabidae were caught in higher number in grazed land than in the other grass lands. On the other hand, more individual insects belonging to Histeridae and Elatridae were caught in higher numbers in natural grassland than the other grassland sites. Tenebrionidae were also caught in highest number in the fenced land. (Figure 5).

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Table 2. Relative abundance of each group of arthropods

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Fenced (F)</th>
<th>Grazed (G)</th>
<th>Natural (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abundance proportion</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Aranaea</td>
<td>2.1</td>
<td>1.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Total insects</td>
<td>97.6</td>
<td>97.7</td>
<td>98.2</td>
</tr>
<tr>
<td>Coleoptera</td>
<td>2.4</td>
<td>2.3</td>
<td>2.2</td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>85.9</td>
<td>86.4</td>
<td>89.2</td>
</tr>
<tr>
<td>Other Insects</td>
<td>9.5</td>
<td>9.1</td>
<td>6.6</td>
</tr>
<tr>
<td>Other Arthropods</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Figure 4. Abundance of arthropodes in the three study sites: A, Abundance of Hymenoptera, other insects, and coleoptera. B, Abundance of the other arthropods and spiders in the three sites.
Seven species (Scarites procerus eurytes, Carabus impressus, carb 1, scar 1, Margarinotus graecus, Zophosis punctata, Conicleonus nigrosuturatus) were found in the three sites, two species (Drasterius bimaculatus, Tanyproctus sauleyi) were found in both fenced and natural grass land, two species (Ela 1, Cur 1) were found in both fenced and grazed land three species(his 1, carb 2, car 3) in the natural and grazed lands one species(scar 2) can find only in the fenced land and one(Ela 2) can found in the natural grass land (Table 3).

Table 3. Abundance of the families and species Coleoptera in the three sites.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>grazed</th>
<th>fenced</th>
<th>Natural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scarabaeidae</td>
<td>Tanyproctus sauleyi</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>scar 1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>scar 2</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Elatridae</td>
<td>Drasterius bimaculatus</td>
<td>0</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Ela 1</td>
<td>5</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Ela 2</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Histeridae</td>
<td>Margarinotus graecus</td>
<td>9</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>his 1</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Carabidae</td>
<td>Scarites procerus eurytes</td>
<td>14</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Carabus impressus</td>
<td>29</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>carb 1</td>
<td>5</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>carb 2</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>car 3</td>
<td>20</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td>Tenebrionidae</td>
<td>Zophosis punctata</td>
<td>10</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>Curculionidae</td>
<td>Conicleonus nigrosuturatus</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Cur 1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Beetls were caught in relatively lower numbers than expected in our samples, probably because we have only sampled a portion of the full beetle diversity at these sites. Pitfall trapping inherently limits our collection to active, ground-dwelling species, although there is an incidental by-catch of families more generally associated with other microhabitats (e.g., Scolytidae, Cerambycidae) (Greenslade 1964, 1973).

Hymenoptera: Hymenoptera caught in this study can be classified into 8 species in 4
families (Formicidae, Sphegidae, Cephidea and Apiddae).

Number of individuals belonging to the Formicidae caught, were higher in natural grassland followed by grazed land and the lowest in the fenced land. Individual of (Cephidea and Apiddae) were only caught in the natural grass land. Members of Sphegidae were however caught in the both natural and fenced land (Table 4).

*Catalgiphus bicolor* and unidentified species (*form 2, form 4*) were present in the three sites, with higher numbers in the natural grassland followed by grazed land and the lowest in the fenced land.

*Cephus tabidus, Apis mellifera* and unidentified species (*Form 3*) present only in the natural grass land. The unidentified species (*Form 5*) was however present in the grazed and fenced land. *Philanthus triangulum* was caught in higher number in the natural grass land followed by fenced land (Table 4).

### Table 4. The families and species of Hymenoptera in the three sites.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Individual numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formicidae</td>
<td><em>Catalgiphus bicolor</em></td>
<td>9</td>
</tr>
<tr>
<td></td>
<td><em>Form 2</em></td>
<td>907</td>
</tr>
<tr>
<td></td>
<td><em>Form 3</em></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><em>Form 4</em></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><em>Form 5</em></td>
<td>1</td>
</tr>
<tr>
<td>Sphegidae</td>
<td><em>Philanthus triangulum</em></td>
<td>1</td>
</tr>
<tr>
<td>Cephidea</td>
<td><em>Cephus tabidus</em></td>
<td>0</td>
</tr>
<tr>
<td>Apiddae</td>
<td><em>Apis mellifera</em></td>
<td>0</td>
</tr>
</tbody>
</table>

Results show that natural grassland supports higher numbers of families and higher population levels of Hymenoptera. This may be attributed to a richer vegetation cover in the natural grassland than in the grazed or recently fenced grassland. Hymenoptera are responding to some combination of these factors. More vegetation cover would mean more pollen and nectar producing flowers, which would be attractive to bees and masarid wasps (pollen collectors) as well as to predators such as ants and wasps, attracted to the shrubs by the flower visitors.

The grazed and fenced sites had fewer ant species than the natural grassland. It is noteworthy to point out that grazed site had however unique species compared to the natural grass land site.

The numbers of specimens per family or species were too small to permit comparisons of density between sites and over seasons to understand the effect of grazing on the diversity of arthropods.

### Seasonal variation in arthropod abundance:

The abundance of total arthropods varied significantly between the seasons (P<0.05) at the different study sites, with the highest abundance detected in summer and autumn and lowest abundance in winter. The fluctuation patterns were similar in the three sites (Figure 6).

The abundance of arthropods increased slightly through spring reaching a maximum abundance in summer, followed by decrease in autumn, and reached lower value in winter then increased gradually to the spring 07.

Significant differences were also detected between seasons for total insects and Hymenoptera in the three sites (P<0.05) except the total insects on the grazed grassland (P=0.095) this related to presence of other insects. The seasonal fluctuation pattern of Hymenoptera and total insects was similar to that of total arthropods pattern because the hymenoptera form higher proportion (>97%) of insects and (>85%) of total arthropods. This pattern was also similar on each site for both total insects and Hymenoptera (Figures 7, 8).
The seasonal fluctuation pattern of Hymenoptera was noted, with higher numbers in the natural grassland and total insects on the grazed grassland increasing gradually to the spring 2007. The numbers of specimens per family or order differed significantly between the seasons (P<0.05) at the three sites, with the highest abundance of spiders detected in summer and autumn and lowest in winter. Rainfall levels of Hymenoptera were higher in the natural grassland than in the grazed or recently fenced grassland. Over 39000 individual arthropods were trapped, with more than 87% of the total catch in all three sites. Ants (Hymenoptera) comprised particularly ants (Hymenoptera) which comprised most prevalent of the arthropod groups collected, followed by dung and low vegetation cover.

The low numbers of arthropods detected in the fenced land may be attributed to the lack of food sources of arthropods, e.g., the absence of dung and low vegetation cover. The low levels of arthropods in the fenced land can be attributed to the lack of availability of food sources, particularly ants (Hymenoptera) which comprised most prevalent of the arthropod groups collected, followed by dung and low vegetation cover.

Figure 6. Seasonal variations of Arthropod and edaphic environmental factors in the three study sites.
Figure 7. Seasonal variations of insects and edaphic environmental factors in the three study sites.
The differences of Coleoptera between seasons were not significant in both grazed and natural land (P>0.05), but it was significant in fenced land (P=0.041). Coleoptera generally increased during the summer and autumn and there was a slight reduction in abundance during winter. The pattern of natural grassland and recently fenced were similar and differed from the under grazing land. (Figure 9).
Differences between seasons of population levels of other insects were not significant in both recently fenced land and natural grassland (P=0.05), and significant in the under grazing land (P=0.001).

The maximum abundance of other insects were detected in the spring 06 and in summer, but the minimum abundance detected in the other seasons (autumn, winter, spring07) this pattern were similar for the three sites (Figure 10).
Significant differences for spiders and other non-insects arthropods not insects between the three sites (p<0.05), but no clear pattern were detected because the abundance of these groups were low.

**Correlation of arthropod abundance with environmental factors:**

Soil moisture and temperature were chosen as the two environmental correlation variables because they have been identified as the two most important determinants of insect phenology (Uvarov, 1931).
To assess the effect of soil moisture and temperature on the abundance of arthropods, linear regression parameters were determined for the comparison of average number of each group for each season sample. There was no significant effect of moisture content of soil cores on the abundance of each group (P>0.05), with a weak negative correlation (r²<0.5) in each site except spiders and other arthropods. The effect of temperature on the arthropods group (total arthropods, total insects, and Hymenoptera) were significant (P< 0.05) on the grazed land only with appositive strong correlation (r²>0.5) on the three sites. The other insects, spiders and other arthropods had a negative correlation. The effect of temperature on arthropods is however difficult to predict as the habitat in which they live is already harsh and highly variable (Coulson et al., 1996).

Theoretically, the increase in temperature should cause an increase in the length of the growth season, allowing for faster physiological development and a potential increase in food sources, leading to greater fitness and fecundity and, therefore, a larger population (Kennedy, 1994). This may be related to the activity of hymenoptera in the summer because the hymenoptera were cold-blooded. Removal the grasses by the grazers cause the direct effect of temperature on the arthropods on the under grazed grassland increase the abundance of arthropods in autumn than the other sites.

The lack of correlation between soil moisture and arthropod abundance suggests that the arthropods may be able to tolerate wide range of moisture levels.

However higher abundance of arthropods including insects and Hymenoptera in the low and moderate soil moisture compared with the high soil moisture (Holway, 1998), and there were higher abundance of arthropods in the high temperature compared with the low temperature, ants are not tolerant of high temperatures and are restricted to habitats with relatively cool and moist conditions.

Several species show a delayed reaction to precipitation, their numbers increasing in the summer proportionally to precipitation in the previous winter.

A relation between precipitation and arthropod abundance is consistent with precipitation causing increased plant productivity that in turn allows greater consumer and predator abundance later in the season.

Grazing has a considerable impact on the biodiversity of grassland arthropods in Alfara’a area. Some of the insect components, especially Carabus impressus, of the family Carabidae (order Coleoptera) are well adapted to grazing disturbance, and therefore can be used as bioindicators of habitat disturbance such as grazing.

Acknowledgments

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References


دراسات في التنوع الحيوي لفصيلات الأرجل في أنظمة عشبية بيئة مختلفة
في منطقة الفارعة (فلسطين)

محمد سليم علي (أستاذ) 1, 2, واصف محمد بيب علي 3, رنا ماجد جاموس 4

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ملخص

تعد مجموعات الأرجل مهمة ومتنوعة في المناظر الطبيعية. تشمل هذه المجموعات الأرجل الغير الأحادية الأرجل الشكلية مثل الأرجل المسطحة، الأرجل الرأسية، الأرجل العريضة، الأرجل التقوية. تشمل هذه المجموعات الأرجل التي تتوافر في المناطق الطبيعية المختلفة.

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