Seasonal changes of the Orthoptera (Insecta) community at the Research Center of Universidad Estatal Amazónica

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Graphical Abstract

Abstract

This work explores the richness and abundance of the Orthoptera family observed at the Center for Research, Graduate Studies and Amazon Conservation (CIPCA), which is located in the Arosemena Tola county, Napo Province, Ecuador. Pitfall traps were used to collect invertebrates in two plots used for forest restoration purposes, with 36 replicates in each one of them. The samples were set in three seasons: the rainiest season (April), the lowest rainy season (September) and a shoulder precipitation season in July. The Orthoptera collected were identified at the family level, and data was processed using R for statistical analyses, with the ARTool package. The results showed a total amount of 897 individuals divided into four Families: Acridiidae, Gryllidae, Romaneidae, and Stenopelmatidae. The highest richness was collected in April, followed by September and July. Acridiidae showed significant variations throughout seasons (F=204.61, p=<0.0001) and plots (F=135.7, p=<0.0001), being significantly higher on April in the higher plot (PA) with 11.03 individuals on average (p=<0.0001).

Gryllidae presented similar patterns as Acridiidae, seasons (F= 10.45, p=0.0001), and plots (F= 9.95, p=<0.01). However, April here was barely significant in PA, with 1.5 individuals (p=0.05). Finally, Romaneidae indicated strong changes among seasons (F= 49.7, p=<0.0001) and plots (F=123.78, p=<0.0001). Its abundance was also significantly higher in PA on April with an average of 3.86 individuals (p=<0.0001). These results provide a meaningful insight about collection seasons. Although a multiyear comparison would be required to analyze the process of forest restoration, this sample give a robust consideration for future sampling seasons towards the finding of bioindication through Orthoptera.
Keywords: Orthoptera, CIPCA, abundance, traps.

Introduction

The order Orthoptera, etymologically means (ortho=straight; ptera=wings). They are animals with two pairs of wings, which are placed above the thorax in resting conditions. Orthoptera is a group of heterogeneous species known as: locust, grasshoppers, and crickets (Moyano, 2014). This order reaches about 20,000 species around the world. They are divided into two main suborders: Ensifera that includes the Gryllidae, Stenopelmatidae (crickets), and Tettigonidae (long-horn grasshoppers) families, and Caelifera, which includes Acrididae (short-horn grasshoppers). The females lay their eggs in different substrates such as leaves, litter, soil, trunks or small bushes. Orthoptera abundance increases in tropical latitudes, due to the high vegetation variability (Triplehorn and Johnson, 2005).

Most of the Orthopterans are fitophagous, although some are predators and others feed on debris, being a few omnivorous. The fitophagous, a big part of it, are considered harmful for agricultural activities, most of which belong to the Acridoidea superfamily (Barrientos-Lozano, 2004). Gryllidae is a family with poor agricultural importance, generally omnivorous or fitophagous with nocturnal habits. However, some Gryllidae can cause damage to maize, rice, and other crops, with species that may be edible (Zumbado and Azofeifa, 2018). The Romaleidae family, with long antennae, feeds on dicotyledons and graminoids species (Martínez and Zerbino, 2008).

Orthopterans are bioindicators of great importance on biodiversity management and conservation in various ecosystems around the globe. It has been shown that Orthopteran individuals are more abundant in rainy periods, used widely as indicators and food due to their heterogeneity and reproductive abundance (Hlongwane, 2018). Regardless their abundance in rainy conditions, its habitat has been experimenting a continuous reduction caused by anthropogenic disturbances that trigger negative effects and the extinction of some populations (Chown and Terblanche, 2006).

The most popular techniques to capture Orthoptera from the soil are pitfall traps, transects, Winkler traps, among others (Luna, 2005). Among all of them, the most utilized methodology are the pitfalls, a technique that provides relative abundances of ground dwelling organisms. (Ríos Guayasamín, et al, 2018). Pitfall traps report the best rates of capture when used without baits in protected forests (Rohyani and Ahyadi, 2017). This was the technique used to conduct the present study.

The aim of this work is to compare the most abundant Orthopteran morphospecies along a year of measurements that were made in three representative periods. With is effort it is proposed to elucidate the best capture period, based on Orthoptera richness, and abundance as a baseline for future studies.

Materials and methods

Study area: The samples were taken at the Center of Research, Graduate Studies and Amazon Conservation (CIPCA), which is located in the Arosemena Tola county, part of the Napo province, in Ecuador. CIPCA is located in the 44Km on the Puyo-Tena road (UEA, 2019). All sampling seasons are
based on precipitation periods averaged since 2008 to 2015. The precipitation periods were: April (444 mm, the rainiest period), July (377 mm, a shoulder precipitation period), and September (261 mm, the lower precipitation period). The sampling localities were two plots (each one with 36 subplots of 100 m², 10 m X 10 m). These plots belong to the Project of Forest restoration and bioindicators identification in the Ecuadorian Amazon -ReFIIBiC- (Ríos Guayasamín, 2018). The plots are located in a Colluvial soil at 580 m.s.n.m. (PA - 1° 14’ 31” S y 77° 53’30” W), and an Alluvial soil at 560 m.s.n.m. (PB - 1° 14’35” S y 77° 53’58” W)

**Field phase:** Orthopteran individuals were captured with pitfall traps without a bait, in containers of 10 cm in diameter by 6 cm in height. Each of the subplots had one pitfall trap, with a total of 72 réplicates (36 for plot A and 36 for plot B) per sampling period (April, July, and September). The containers were placed at floor level during three consecutive days, after which samples were collected in containers with 90% alcohol and taken to the Natural and Applied Tropical Ecology Laboratory (LETNA) for sorting and identification.

**Laboratory phase and data processing:** Once at LETNA, samples were classified and stored, isolating the individuals correspondign to the Orthoptera Order. Identification was done using taxonomic keys (Llucià Pomares, 2002; Triplehorn and Johnson, 2005; Westerduijn and Cadena-Castañeda, 2014). The results were processed with the R program, using the vegan package (Oksanen et al., 2019) for the richness figures, the ARTool package (Wobbrock et al., 2011) for statistical data processing, and the sciplot package (Morales, 2019) for graphical representation of the statistical analyses.

**Results and Discussion**

Figure 1 shows the richness of morphospecies of each sampling period. April, the rainiest period presented the highest richness (19 morphospecies). A similar result was seen for September, the driest period, with 18 morphospecies. The shoulder precipitation period, July, presented the lowest richness, counting only 14 morphospecies. Acrididae, Gryllidae and Romaleidae oviposit in the soil, and climatic conditions (cold and hot temperature) affect the individual development. (Barrientos-Lozano, 2004). This particular feature may be related with the temprature of each collecting month. April is one of the months with high temperature (23.9°C, 1

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1 INHAMI, meteorological yearbooks 2008-2015: https://abeltran94.wixsite.com/inamhi/productos
with the maximum temperature registered for November - 24.5 °C), while July reports the lowest temperature for the whole period (23.1°C)²

The total amount of individuals collected was 897, of which 537 belong to the Acrididae family, 162 to Gryllidae, 165 to Romaleidae, 5 to Stenopelmatidae, and 28 which had not distinctive features to be placed in any category (with broken antennae, broken legs and/or immature stages). Figure 2 shows that the highest mean Orthoptera abundance is hold by Acrididae, which is very abundant in the rainiest season. April is also the month where you found the highest abundance of Gryllidae and Romaelidae. This information contrast with other studies. In Indonesia is Gryllidae the most abundant family that was found in pitfall traps (Rohyani and Ahyadi, 2017), in China, however, is Catantopidae the most abundant family of Orthoptera collected by monoliths (Jiang et al., 2015).

Acrididae showed significant variations among precipitation periods (F=204.61, p<0.0001) and between study plots (F=135.7, p<0.0001). Gryllidae presented similar variations as Acrididae, for the precipitation periods (F= 10.45, p=0.0001), and also for the plots under study (F= 9.95, p=0.01). Nonetheless, the F estimator was much smaller. The difference between plots is the most important for Romaleidae (F=137.75, p<0.0001), even though the precipitation periods show a significant variation (F=48.74, p=0.0001), as it does the interation between the two factors under study (F=56.57, p=0.0001), which can be seen in Table 1.

Even when Acrididae species are considered an agricultural pest in many places around the world, in Ecuador are considered as eventual pest of maize, wheat, and barley, in spite of this, on the Amazon there are no records of agricultural infestations (Zumbado and Azofeifa, 2018). Our findings show the highest population of Orthoptera in the rainiest period (Figure 2, table 3). Similar results were reported from India, where Orthopteran individuals presented the highest abundance and diversity at the monsoon season (Kuruvila, et al., 2019)

![Figure 2. Seasonal variation of Orthoptera throughout the year.](image)

Table 1. Orthoptera significance omnibus test for seasonal and plot variation with the ranks obtained with ARTool

<table>
<thead>
<tr>
<th>Acrididae</th>
<th>Gryllidae</th>
<th>Romaleidae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasons (S)</td>
<td>F=204.61, Df=2, Df.res=208, Pr(F)&lt;0.001***</td>
<td>F=10.45, Df=2, Df.res=208, Pr(F)&lt;0.001***</td>
</tr>
<tr>
<td>Plots (P)</td>
<td>F=135.7, Df=1, Df.res=208, Pr(F)&lt;0.001***</td>
<td>F=9.95, Df=1, Df.res=208, Pr(F)=0.01</td>
</tr>
<tr>
<td>S:P</td>
<td>F=79.92, Df=2, Df.res=208, Pr(F)&lt;0.001***</td>
<td>F=4.137, Df=2, Df.res=208, Pr(F)=0.05*</td>
</tr>
</tbody>
</table>

² INHAMI, meteorological yearbooks 2008-2015: https://abeltran94.wixsite.com/inamhi/productos
The families of Orthoptera also shown meaningful variations due to the soil type (plot A=Coluvial soils and Plot B=Aluvial soil). Acrididae (10.4), Gryllidae (1.5) and Romaleidae (4.9) presented the highest amount of individuals in Plot A on the rainiest month. Only Gryllidae showed a slightly similar abundance between the two plots in the month with the lowest precipitation (PA=1.1, PB=0.9). This may be related with its reproductive mode. Many Orthoptera are directly affected by the soil conditions due to their oviposition habit. This is evident for Gryllidae, a family whose individuals deposit the eggs in the soil (Rohyani and Ahyadi, 2017), a pattern which is also important for some Acrididae species (Triplehorn and Johnson, 2005).

Figure 3. Seasonal variation of Orthoptera for every plot in study

In the interaction tests, it is evident that the rainiest period shows significant values for Acrididae (p<0.001, PA=397, PB=98 – Table 3) and Gryllidae, when compared with the other sampling periods (Table 2). Even when Gryllidae only shows statistical differences between the rainiest and the intermediate-precipitation-periods among Colluvial and Alluvial soil conditions (p<0.05).

Table 2. Orthoptera test of interactions between levels of seasons and plots using ARTool

<table>
<thead>
<tr>
<th></th>
<th>Acrididae</th>
<th>Gryllidae</th>
<th>Romaleidae</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Value</td>
<td>Df</td>
<td>Chisq</td>
</tr>
<tr>
<td>Apr-Sep:PA-PB</td>
<td>153.028 1</td>
<td>103.1206</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>Apr-Jul: PA-PB</td>
<td>174.806 1</td>
<td>134.5598</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>Sep-Jul: PA-PB</td>
<td>21.778 1</td>
<td>2.0885</td>
<td>N.S. (0.14)</td>
</tr>
</tbody>
</table>

Finally, Romaleidae (p<0.001) presented the same results as Acrididae. These results exhibit that the rainiest period may be considered as an important period for Orthoptera evaluation, aiming at displaying the abundance and richness variation of these families (Acrididae and Romaleidae). The high amount of individuals (especially Acrididae) in the Plot A may be related with soil quality parameters, because Plot A has a higher organic matter concentration and better nutritional content in general terms (data not shown). However, a more detailed study need to take place because in Kenya, the Orthoptera abundance was positively correlated with manganese quantity, but negatively correlated with Nitrogen and Carbon (Ayuke et al., 2009).
Table 3. Total Abundance of Orthoptera by plots and rainy periods

<table>
<thead>
<tr>
<th></th>
<th>PA</th>
<th></th>
<th></th>
<th></th>
<th>PB</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acrid</td>
<td>Gryll</td>
<td>Romal</td>
<td>Stenope</td>
<td>NonID</td>
<td>Acrid</td>
<td>Gryll</td>
<td>Romal</td>
</tr>
<tr>
<td>April</td>
<td>397</td>
<td>54</td>
<td>139</td>
<td>0</td>
<td>0</td>
<td>98</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>July</td>
<td>7</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>September</td>
<td>27</td>
<td>39</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>8</td>
<td>28</td>
<td>1</td>
</tr>
</tbody>
</table>

Acrid=Acrididae, Gryll=Gryllidae, Romal=Romaleidae, Stenope=Stenopelmatidae, NonID=Not Identified

Conclusions

- The richness and abundance of Orthoptera are higher in the month with the highest precipitation regime in both soil conditions (Alluvial and Colluvial), therefore April must be considered as the best month for Orthoptera sampling.
- The most representative families in this study are: Acrididae, Gryllidae y Romaneidae. Acrididae presented the most important variations both for precipitation and soil conditions, as a potential indicator for biological studies.

Field study permit

The data collection for this article was possible under the General Agreement for Genetic Resources Access provided to the Program: "Ecosystems, Biodiversity and Species-conservation, Invertebrates and their interactions, with code: MAE-DNB-CM-2018-0087, within the ReFIIBiC project. This program is coorditated by Universidad Estatal Amazónica.

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