Arthropod community response to nitrogen deposition
Eliza Hernández
Research Mentor: Erin Questad, Ph.D.
California State Polytechnic University, Pomona

Abstract
Insects play key ecological roles by providing services such as pollination and decomposition. Anthropogenic activity threatens the conservation of beneficial insects and is partly responsible for the observed decline in insect diversity. Nitrogen deposition, a human-accelerated process, poses a threat to insect diversity and thus, their valuable services. Increased N levels have been found to increase insect abundances yet decrease their species richness. The primary focus of this project was to determine the effects of N on the taxonomic richness, diversity, and evenness of insects and other arthropods in a managed grassland experiment at the South Coast Research & Extension Center in Irvine, California. I sampled from ten experimental grassland plots, five of which were treated with elevated levels of N and the other five were exposed to ambient levels of N. The plots contained grasses typical of Southern California grasslands, such as the California native grass, Stipa pulchra, and the invasive grass, Bromus hordeaceus. To sample soil and litter-dwelling arthropods throughout the growing season, each plot contained two pitfall traps. Arthropods were identified to the family taxonomic level. I expected to find greater arthropod richness, diversity, and evenness in the plots with ambient N compared to elevated N. However, this project indicates that fertilized plots host a greater richness of soil and litter-dwelling arthropod groups.

Introduction
Anthropogenic N deposition has more than doubled inputs of N to terrestrial ecosystems worldwide via the transformation of unreactive atmospheric N into biologically available forms on land (Vitousek et al., 1997). N deposition has negative ramifications for ecosystems and acts as a driver of accelerated biodiversity loss. N deposition is being addressed from a global perspective since developing countries with rapid industrialization are starting to emit large quantities of N into the biosphere via N fertilization and fossil fuel combustion (Matson, Lohse, & Hall, 2002). These emissions poses a threat to biodiversity hotspots around the world, especially since the average deposition rate across biodiversity hotspots is fifty percent greater than the global terrestrial average and could more than double by 2050 (Phoenix et al. 2006). This study by Phoenix et al. (2006) has also identified that areas with higher floral diversity are likely to receive N deposition at greater rates in the near future and that some of these areas may already be receiving high rates of N deposition.

Effects of N deposition on plant communities are well known with a consensus that N addition decreases plant species richness, increases plant productivity and plant tissue N, and shifts plant communities to a few dominant species (Haddad, Haarstad, & Tilman, 2000; Stevens et al., 2004). A decrease in plant species richness as a consequence of N deposition has implications on the organisms dependent on affected ecosystems. Long-term N loading has been shown to simplify insect communities, decreasing total insect species richness, as a response to decreased plant species richness (Haddad et al., 2000). This study by Haddad et al. (2000) showed that long-term N addition may alter the entire food chain, simplifying both plant and
insect communities. The Quino Checkerspot Butterfly (*Euphydryas editha quino*) exemplifies the effects of N deposition in a California ecosystem. The Quino Checkerspot Butterfly was once considered one of the most abundant species of butterflies in southern California. However, it is now locally extinct because its host plant *Plantago erecta* was outcompeted by exotic grasses that were better adapted to higher levels of N (USFWS 2003). In fact, most extinctions estimated to have occurred or predicted to occur are of insect taxa (Dunn 2004). Furthermore, only seventy modern insect extinctions have been documented when thousands are estimated to have occurred (Dunn 2004). Therefore, extirpations such as that of the Quino Checkerspot Butterfly are of significant conservation concern.

Insects are among the most diverse and abundant groups of animals to be found in almost every environment on the planet. They significantly contribute to a number of critical ecological services including pollination, decomposition, biological control, and nutrition for wildlife (Losey & Vaughan, 2006). However, the extinction rates mentioned in Dunn (2004) may affect beneficial insects and thus place the services they provide at risk. These ecological services are imperative to ecosystem function and human well-being. Their combined worth is an estimated $57 billion value per year (Losey & Vaughan, 2006). Continuing studies on the effects of N deposition on trophic structure are extremely important to conserving insects and the ecosystem services they provide. The objective of this project is to observe the direct effects of N addition on soil and litter-dwelling arthropod communities without plant species richness playing a role as seen in previous studies. In this project I test the hypothesis that insect family richness, diversity, and evenness will decrease as a result of N deposition.

**Methods**

*Research Site*

The experiment was conducted at the South Coast Research & Extension Center in Irvine, California where ten experimental grassland plots replicating different N conditions (ambient N vs. added N) served as the basis for this project.

*Experimental Design*

The plots in this experiment consisted of the California native grass, *Stipa pulchra*, and the exotic grass, *Bromus hordeaceus*, in varying levels of abundance. Five of the plots were exposed to ambient levels of N and the remaining five plots received elevated levels of N in the form of granular calcium nitrate. The five plots simulating elevated levels of N were treated with 3.5 g/m² of N on November 19, 2013 and on January 27, 2014, giving a total rate of 7 g/m²/yr of N. Pitfall traps were used to sample arthropod communities. Pitfall traps were constructed and installed as described by Cobb, Delph, and Higgins (2010). Two pitfall traps were installed in each plot, giving a total of twenty pitfall traps.

*Data Collection*

A test tube containing propylene glycol was placed in each pitfall trap to collect and preserve arthropods throughout the growing season. Test tubes were first placed on December 23, 2013 and collected on January 23, 2014. Test tube samples were subsequently replaced and collected
three more times on the following dates: January 23, 2014 – February 14, 2014; March 16, 2014 – April 9, 2014; April 9, 2014 – May 11, 2014. Once the test tube samples were brought back to the laboratory, arthropod specimens in each test tube sample were counted and identified to the family taxonomic level using a dissecting microscope and an insect identification key.

Data Analysis
A general linear model was used to analyze the effects of block, date, N, and N x date on family richness. Additional analysis included counting the number of “N added” plots and “ambient N” plots each arthropod family occurred in across sampling dates. All analyses were conducted with Minitab version 16.2.4 (Minitab, Inc. 2010) using the data gathered from the latter half of the growing season (March 16, 2014 – April 9, 2014; April 9, 2014 – May 11, 2014). These samples had the highest abundance of arthropods and depicted a more representative picture of the arthropod communities present within the plots.

Results
Block showed a significant effect on family richness (Table 1). More importantly, N showed a significant effect on family richness, indicating a significant difference between fertilized and unfertilized plots (Table 1). Specifically, N addition had a significant, positive effect on average family richness (Fig. 1). Date and N x date did not have a significant effect on family richness. In addition, the occurrence of the family Staphylinidae, also known as the rove beetle family, was higher in plots with added N, suggesting they positively respond to N (Fig. 2).

Table 1 General linear model results of factors block, date, N, and date x N on family richness

<table>
<thead>
<tr>
<th>Factor</th>
<th>F-statistics $^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2.42*</td>
</tr>
<tr>
<td>Date</td>
<td>0.25</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>38.85**</td>
</tr>
<tr>
<td>Date x Nitrogen</td>
<td>0.09</td>
</tr>
</tbody>
</table>

$^1$ * P < 0.05; ** P < 0.001; Model $R^2 = 0.69$

Fig. 1 Average family richness between plots of varying levels of N and sampling dates
Discussion

The results found in this project are similar to those in short-term N deposition studies. In this project, N addition had a significant positive effect on arthropod family richness. Kirchner (1977) also found that arthropod diversity significantly increased in response to N. Conversely, the long-term N addition study conducted by Haddad et al. (2000) found that total insect species richness decreased where changes in the insect community were significantly correlated with changes in the plant community. On the short term, a significant increase in arthropod diversity may be observed because N increases plant tissue quality and plant productivity but does not have any effect on plant species richness. However, on the long term, although plant productivity still increases, plant species richness significantly decreases. This observed decrease in plant species richness in turn simplified insect communities (Haddad et al., 2000). However, Haddad et al.’s (2000) study investigated the effects of N addition on insects indirectly through changes in the plant community. My project allowed for observing the direct effects of N deposition on arthropod communities, correcting for any changes in plant species richness. The experimental grassland plots in this project modeled simplified systems, consisting of only two species of grass, B. hordeaceus and S. pulchra. In this case, N addition increased soil and litter-dwelling arthropod family richness. Therefore, in this experiment, nutrient enrichment increased arthropod family richness by possibly having increased plant tissue N and plant productivity, thereby increasing resource quality of the habitat (Kirchner 1977).

Although in Haddad et al.’s (2000) study total insect species richness significantly decreased, not all trophic groups responded negatively to N. Specifically, detritivore species richness significantly increased as N addition increased. In this project, I focused on arthropods residing in the soil and litter, commonly where detritivores are found since they consume decomposing plant and animal material. Similarly, I found that specimens belonging to the family Staphylinidae, also known as the rove beetle family, responded positively to N addition. Species in this family of beetles have relationships with habitats consisting of decomposing plants, dung, and carrion, where they prey upon other insects. Many staphylinids are also important predators on other invertebrates including mites, fleas, and other insects such as flies and mosquitoes. Thus, staphylinids are important to humans as biological control to suppress
invertebrate pest populations in numerous crops. More well-known known species of rove beetle
in California include the Hairy Rove Beetle (*Creophilus maxillosus*) and the Pictured Rove Beetle (*Thinipinus pictus*). The Hairy Rove Beetle is found on carrion along lakeshores and rivers where they feed on the maggots of flies whereas the Pictured Rove Beetle are found in burrows on the beach where they feed on invertebrates such as sand fleas (Evans & Hogue 2006).

Most importantly, Staphylinidae form a substantial part of the world’s biodiversity, being
the largest family of beetles with over 54,000 known species worldwide (University of Florida 2012). In addition, it is the largest beetle family in California, with an estimated 1,200 described species (Evans & Hogue 2006). It is estimated that there are probably 300,000 species of Staphylinidae, which is more than a five-fold increase over the number of described species today (Gaston 1991). As of now, the specimens identified to family Staphylinidae in this project are not identified to species. If these specimens are identified to species, which responded positively to N addition in this project, their ecological role can then be determined and further analysis can be done.

N deposition has negative implications for the insect biodiversity crisis we face today. Addressing this insect biodiversity crisis comes with its fair share of challenges. Currently, there are more than one million described species of insects. However, it is estimated that there may be between ten and thirty million species of insects inhabiting the planet. There are a myriad of insects left to be described, yet unfortunately, many of them may never be known to exist due to the extinction rates accelerated by anthropogenic activities such as N deposition. Although there is a significant effort in discovering all insect species possible, it is difficult to pinpoint the ecological roles these described insects play. Discovering the ecological roles insect species play is important in emphasizing the need to conserve insect biodiversity. Furthermore, insect conservation efforts are lacking despite the overwhelming evidence that large numbers of insect species are facing extinction (Spector 2009). Invertebrate species conservation is also hindered by the public’s aversion to insects even when the benefits derived from insects are described to them (Kellert 1993).

Despite the challenges insect conservation faces today, we are at a progressive turning point where national and international institutions are interested in protecting insect biodiversity (Spector 2009). As a result, this will allow many scientists to conduct research that will stress and elicit the necessary actions to conserve insect biodiversity. In my project as well as in the study conducted by Haddad et al. (2000) shows that N addition favors certain groups of insects. In the future, as N deposition increases, insects that respond positively to N will have an advantage over those which do not and this may accelerate the loss of biodiversity of insect taxa; this provides further emphasis that insect biodiversity needs to be protected.

**References**


Kirchner, T.B. 1977. The effects of resource enrichment on the diversity of plants and arthropods in a shortgrass prairie. Ecology 58: 1334-1344


