INQUIRY & INVESTIGATION

Studying Arthropod Species Richness in a School-Yard Natural Area: Using Inquiry to Engage Student Interest in Scientific Studies

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Abstract

The interdependence of living organisms and related ecology concepts are often difficult for students to grasp if they only study them from textbooks. To really understand how habitat fragmentation affects biodiversity, it is best to allow students to study it in the field. In the activities described here, I used inquiry as a basis for experiential learning. Focusing on two natural areas of unequal size, students investigated the areas to assess arthropod species richness and examine whether it was correlated with the size of the area. By establishing 10 daily observation periods and identifying arthropods in each session, students observed firsthand the relationship of species richness to biodiversity and that the size of the natural area was not significant. This translated to a greater understanding of biodiversity and its role in the relationships of living organisms in a local ecosystem. Students also gained valuable insight into how scientific studies are conducted.

Key Words: *Interdependence; habitat; fragmentation; biodiversity; arthropod; species richness; species diversity; experiential; hands-on; ecosystem; inquiry.*

○ Introduction

The issue of biodiversity has become one of the focal points for conservation efforts. A clear connection exists between levels of biodiversity and habitat fragmentation (Fahrig, 2003). This is especially true in agricultural and urban areas where original habitat is adversely affected by farming and development of buildings and roads, which negatively affect biodiversity (Fahrig, 2003). The importance of appropriate habitat cover can be seen clearly in arthropods, whose species richness is limited by a lack of suitable ecosystem components (Shuey, 2013). Studies have indicated that larger natural areas tend to support a greater variety of arthropod species (Debinski & Holt, 2000). Further studies have specified that in areas where plant species have higher richness and diversity, arthropod populations are also increased and support higher trophic levels (Jones et al., 2011). Therefore, when normal mowing and trimming are ceased in an area and it is allowed to go to seed, it will return to its natural state and support more diverse plant life (Scherber et al., 2006). Allowing a section of grass to grow undisturbed should, therefore, support a greater number of arthropod species.

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The *Next Generation Science Standards* (NGSS) emphasize the role of inquiry in the study of Interdependent Relationships of Living Things. Part of this standard is to "design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity" (NGSS, HS-LS2-7). An important aspect related to population biodiversity is the inverse relationship between species diversity and species richness (Barnosky et al., 2005). Therefore, species diversity can be used to represent species richness when analyzing different areas of habitat. Studying the impact of habitat fragmentation on arthropod biodiversity using school grounds to create natural areas is a positive way to make an impact on students by utilizing the inquiry process (Kishbaugh & Yocum, 2000). Establishing two natural zones of different sizes in unused portions of school grounds allows students an opportunity to study environmental factors affecting biodiversity. Specific benefits of reestablishing natural habitat have been noted, with increased numbers of insect species and the subsequent benefits to other wildlife (Shuey, 2013). However, the issue of how large an area needs to be in order to be effective is not well understood. This student activity focused on comparing the biodiversity of two unmowed areas of different sizes to see if they differed in terms of arthropod species richness. This provided valuable lessons regarding how scientific studies are conducted and the value of biodiversity in a local ecosystem.

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○ Details of Activity

Students were given two main tasks related to assessing the effects of habitat fragmentation on biodiversity (both address NGSS: Life Science HS-LS2-7, HS-LS2-8, and HS-LS4-6). (1) Form a hypothesis – would you expect a larger natural area to have an advantage over a smaller one in terms of species richness and, therefore, greater biodiversity? (2) Assess arthropod species richness, comparing the two areas by using a biodiversity calculator to test your hypothesis. Since this was an inquiry-based lesson, students did most of the design, with some teacher direction. Similar studies may not be done in exactly the same way.

Two unmowed areas on the school grounds were selected for this lesson. The larger area was 17,980 square feet, and the smaller one was 3600 square feet. First, the students outlined and taped off the area of study, after which a meter-wide strip was mowed to separate the unmowed zones and allow for access by foot to the areas. Next, students chose separate 3 m^2 study plots within each of the two natural areas and staked them off for study (Figure 1). This assured study continuity even though the two areas were different in size. A 30-minute observation period every weekday for 10 days was established for data collection to assess arthropod species richness, though shorter observation periods for even just one to three days would be sufficient for data collection/evaluation if time is a factor.

Observation periods began each day with a student sampling the plot using a sweep net (a solid cloth net with no mesh holes) designed for capturing arthropods for study. Students were instructed to start sweeping the outside of the plot, once around the perimeter; and then to repeat the sweep, reaching into the center as far as possible from the perimeter. Once the sweep was completed, the net was closed at the top and then opened slowly to inspect arthropods that had been trapped. Most arthropods were identified on the spot, using several books obtained from the Ohio Department of Natural Resources, and recorded on an observation chart. Photos of various insects in nets were taken to be used later for additional identification or verification. All arthropods were released back into the unmowed areas unharmed, to preserve the areas' ongoing development as a natural site.

Figure 1. Image of the plot layout in the larger natural area, staked and taped off. The hook with flystick is shown. The pitfall traps are hidden by grass. Mowed strips can be seen on the back side of the natural area, separating it from a surrounding fencerow.

Students also used pitfall traps to capture arthropods in the plots. Each plot had two pitfall traps consisting of plastic cups placed in a hole dug with a garden trowel. The cups were then covered with plastic lids and secured with ten-penny nails inserted through the lid into the ground close to the top of the cup for protection, but not close enough to hinder access by arthropods. For consistency, traps in both plots were located on the northwest and southeast corners. As suggested by Schirmel et al. (2010), the traps were examined at least weekly for maximum effectiveness. Each trap was visually examined during every other observation period but left for one week. At the end of that week the contents of each trap were identified, emptied, and replaced into their original position. Lastly, fly sticks (sticky cylinders) with a plastic well at the bottom were filled with honey and hung over each study plot on a metal shepherd crook normally used to hang plants and bird feeders. The fly sticks were observed daily for arthropods, which were keyed out and/or photographed.

Although most arthropods were keyed on site as daily observations were completed, those species not identified in the field were charted and compared by projecting images on the Smartboard and allowing students to identify them using books or descriptions in the text. Arthropod orders and representative families were identified first, followed by species. Genus names were left off the charts because there were multiple species recognized within the same genus. Species were identified as letters of the alphabet, so if different arthropod families were found in the two separate plots, the letters were changed in the tables to represent species within those families. Therefore, species in the tables may have letters out of order, since they represent species within the different families represented. Species replicates were recorded by number in each observation period. In order to make the chart manageable, and reduce the numbers of repetitive arthropod species, some things (e.g., small gnat-like arthropods) were not counted. This was also true for spiders that were too small or immature to identify. Since this was a comparison analysis, bar graphs were used to compare species numbers, while pie charts were used to compare percentages of species in the represented orders in each plot.

Students used a biodiversity calculator for both the Shannon and Simpson indexes. This process was used in order to compare the two sites being evaluated. Students simply typed in the family represented in each area, followed by the number of species represented by number count. In order to make the learning experience more relevant, the concepts of food webs (Figure 2), energy flow through ecosystems, and biodiversity within ecosystems were taught alongside the study before, during, and after the observations of the areas. Although students have studied concepts such as food webs before, actually studying them in the natural environment seems to facilitate understanding. It is surprising how few students have actually gone outside to study any of these concepts. According to Orr (1994), this may indicate that they have not really learned the material. Students were encouraged to consider the particular environment of the school property and local ecosystems as they worked through the concepts.

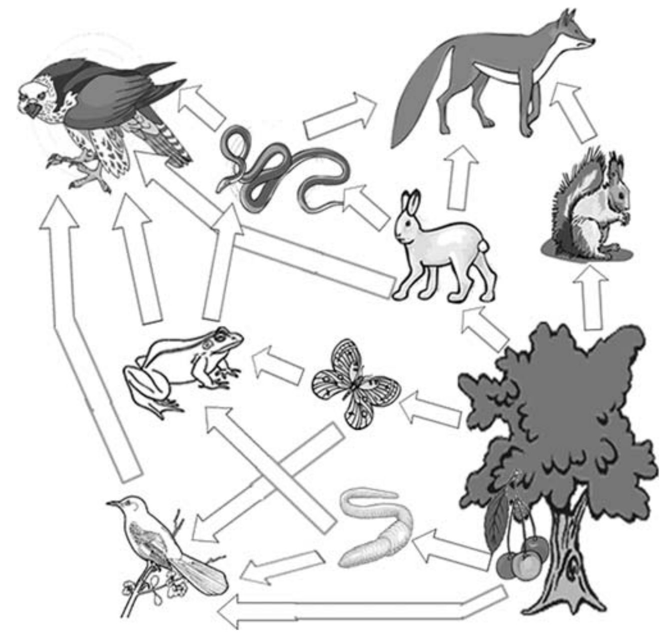


Figure 2. Food web model. Students first labeled each organism (some may have more than one label) as a producer (p), primary consumer (1), secondary consumer (2), tertiary consumer (3), or quaternary consumer (4). They then labeled each animal as either an herbivore (H), a carnivore (C), or an omnivore (O). They were asked to use this diagram as a model for the study area. (Source: http://thebiologycorner.com.)

○ Results

Daily observation periods yielded significant numbers of arthropods in the orders Coleoptera, Diptera, Hemiptera, Hymenoptera, Orthoptera, and Araneae. These were taken from the daily chart and then transferred to a more comprehensive totals chart (Table 1) for each natural area. Species diversity was demonstrated by the number of arthropods trapped per day by sweeping through both the larger and the smaller area. In addition, the overall variation of insect orders recorded during the study period was significant. Arthropod families and species varied slightly in each of the two areas within the same orders, but with similar numbers of species within the orders.

The arthropod orders represented in each area are shown in Figure 3. Although each area had the same representative orders, the numbers of species varied slightly in each plot. As shown, Coleoptera were more numerous in the smaller area. This was also true for Hymenoptera and Araneae. This process did not necessarily produce more total species, but the abundance of arthropods caught by these methods was significant in terms of both numbers and variety for each representative area studied. The overall abundance of arthropod species matched student expectations related to species richness for the larger area but exceeded expectations for the smaller area.

Each observation period had replicates as well as different families but did not necessarily produce more species. When the same data are presented as percentages in the form of a pie chart (Figure 4), the results are consistent in terms of each order and species documented. Both areas also showed arthropod numbers and family percentages that were similar, suggesting that the difference in size of the two plots was negligible in terms of species richness.

Results obtained from the biodiversity calculator for both the Shannon and Simpson indexes were also comparable. The Shannon index for the larger area was 4.21, while that for the smaller area was 4.33. The Simpson index for the larger area was 0.085, while that for the smaller plot was 0.093. These numbers support the fact that species richness translated into biodiversity of equal value for the two areas of unequal size. Other calculations on the biodiversity calculator had similar values, which also demonstrated equality between the two areas studied.

○ Discussion

This lesson was built on the foundation of Kishbaugh and Yocum's (2000) study that compared an unmowed natural area on school grounds to the mowed areas that comprised the majority of the site. While the comparison of arthropods was similar, the present study compared two different natural areas to determine whether the difference in size would affect arthropod species richness. Moreover, the study area was completely mowed and allowed to grow again the following year by Kishbaugh and Yocum (2000), whereas this study was part of an ongoing project to develop a more permanent natural area for future classes to enjoy.

The actual outcome of a lesson like this is not the primary objective – just allowing students to see firsthand evidence of biodiversity in a natural area is the focus. An inverse relationship between species diversity and species richness, as discussed by Barnosky et al. (2005), is clearly seen here. However, it seems that the suggestion made by Debinski and Holt (2000) regarding the importance of plot size may not always hold true. While close proximity to large fields might have compensated for the smaller study-plot size in relation to the larger natural area, the data suggest that the smaller unmowed area was equivalent to the larger one in terms of overall species richness. This would seem to indicate that natural-area size alone is not a significant factor affecting arthropod species richness, which may help students realize that even a small area on the school grounds, or in their own yard, can help overcome some habitat fragmentation and restore some biodiversity.

During subsequent classroom studies focusing on the NGSS Interdependent Relationships in Ecosystems, students demonstrated a higher interest level and ability to understand the concepts. Awareness of local ecosystem homeostasis and biodiversity in relation to food webs and their importance to the community was also increased, which helped students understand more difficult environmental concepts such as energy flow through the ecosystem. These concepts were confirmed by subsequent evaluations once the module was completed. This serves to substantiate the positive relationship between inquiry and learning in science.

A comprehensive listing of all arthropods found in both plots is available upon request. Comprehension of the material was assessed by tests that were combined with other aspects ofthe NGSS for Interdependent Relationships in Ecosystems and were not based solely on this inquiry project. Other materials related to the studies of food webs were obtained from the Biology Corner (http://biologycorner.com). The biodiversity calculator used is available online (http://www.alyoung.com/labs/biodiversity_calculator.html).

Table 1. An example of the comprehensive chart on which students compiled data for the 10 observation periods. Arthropod order was placed first, followed by the families in that order. The species were listed by letter for differences and replicates.

Arthropod Order/ Family	Species		Number of Replicate Species in 10 Observations								
Coleoptera:	Total:	0	2	0	1	2	0	1	1	1	1
Carabidae	Sp. A		1								1
Chrysomelidae	Sp. C				1			1	1	1	
Silphidae	Sp. D					2					
Scarabinidae	Sp. E		1								
Diptera:	Total:	1	3	2	3	4	2	4	2	1	4
Muscidae	Sp.A					3	1				2
Tachinidae	Sp. C		1	1	1			2	1	1	1
Syrphidae	Sp. D	1	2		1	1		1			1
Tabanidae	Sp. K			1	1		1	1	1		
Tephritidae	Sp. F										
Hemiptera:	Total:	11	6	0	5	7	3	4	7	3	7
Membracidae	Sp. H	1	3		1			1			2
Cicadellidae	Sp. I	4	1		3		1			1	1
Pentatomidae	Sp.C	6	2		1	7	2	3	7	2	4
Hymenoptera:	Total:	2	2	0	1	1	2	0	1	1	2
Braconidae	Sp. A		1								1
Ichneumonidae	Sp. F	1	1								
Typhidae	Sp. C	1			1	1					
Orthoptera:	Total	5	2	4	2	3	6	3	5	2	5
Acrididae	Sp. A	3	1	1	1	2	2	1	1	2	3
Tettigoniidae	Sp. B	2	1	3		1	3	2	1		2
Gryllidae	Sp. C				1		1		2		
Araneae:	Total:	5	6	1	4	1	1	4	1	2	3
Lycosidae	Sp.A	2	1		1				1		1
Salticidae	Sp.C	1			2		1	1			1
Araneidae	Sp.E		1	1	1			2		1	

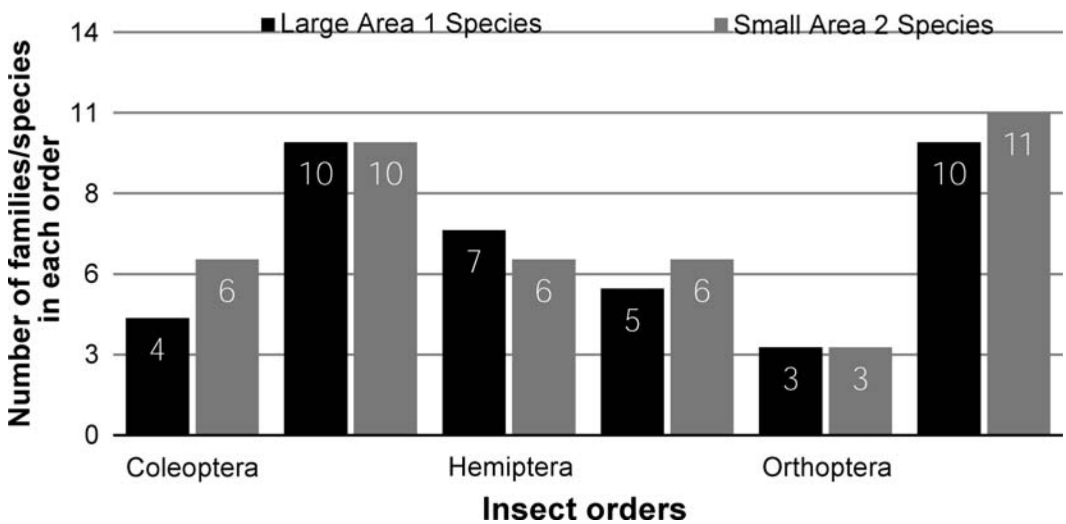
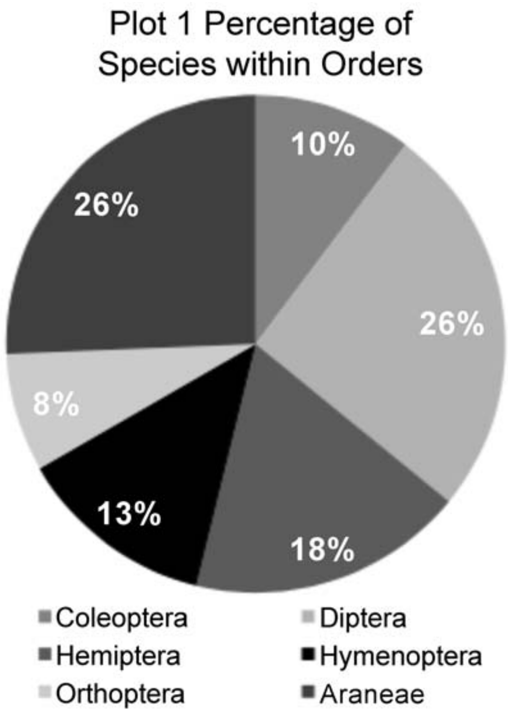


Figure 3. A summary of the insect orders and species represented from each order, for each natural area, from two 3 m^2 plots labeled 1 and 2. Data were collected during 10 separate observation periods.



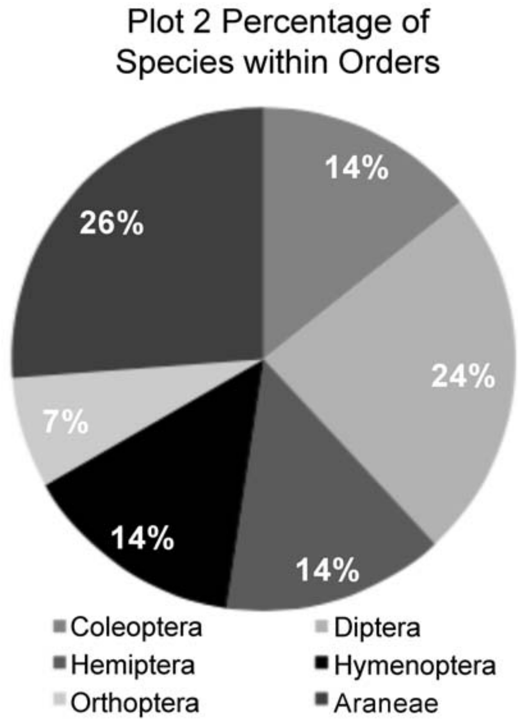


Figure 4. These pie charts show the relative percentages of species in each plot per order represented. Each plot had similar numbers of species identified within each order during the study period, with negligible variation.

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