Density Dependent Scavenging of Aquatic Insects in a Lake Michigan Dune Ecosystem

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Abstract

In nutrient-poor sand-dune ecosystems, there are various means through which nutrients are transferred from the aquatic system to the terrestrial system. Every year, aquatic insects emerge on shore as a portion of their life cycle; along the shore they may provide a food source for numerous foragers inhabiting the dunes or nearby forested areas. This experiment examines the importance of density dependent foraging within such a dune ecosystem on Lake Michigan. Petri dishes with varying densities were placed out along a dunes system and placed away from the shore; they were left out for 24 hours and collected, then the percent scavenged was determined by taking the difference between the initial and final measured weights. ANOVA analysis of percent scavenged was compared with three differing densities and three qualitatively distinct microhabitats. In the complete data set no statistically significant difference was found between the different density or habitat groups. Only when the data values without complete scavenging were inspected was there a significant variation between the densities. There is an observable trend that the percent scavenged increases proportionately with the density of the food source. Nitrogen transfer from emergent aquatic insects to the dune ecosystem is statistically insignificant despite the existence of a very minute, but observable impact. The importance of emergent insects may not be large when considering the total transfer of nitrogen into the terrestrial ecosystem.

Introduction

The nutrient flow within sand dune ecosystems is not very widely understood relative to the unique dynamics that influence the system from outside and within. There could be a transfer of nutrients occurring from the aquatic lake system to the nearby terrestrial community; nutrients such as nitrogen, phosphorus, and magnesium are all very important for regular, daily functioning within the ecosystem. Dune ecosystems have been shown to have nitrogen poor conditions and the availability of nitrogen has been known to limit the abundance and distribution of various plant species (Willis, 1963). Along the shores of Lake Michigan at Sturgeon Bay, the inland community experiences nitrogen as a limiting nutrient. Sandy soil does not hold water very efficiently and when the water drains through, it may also leach the soil and plant roots of nutrients, making for very nutrient poor soil overall (Willis, 1963).

During summer months, the dunes witness many short-lived insects that reproduce and die above the lake or near the shore. These insects, such as mayflies and caddis flies, have aquatic nymphs that emerge on the shore where the adult dead bodies and nymph casings drift onto the shore providing a food source for scavengers in this habitat. Researchers have found in other ecosystems that a significant amount of biomass was being transferred by the emergence of aquatic insects (Jackson and Fisher, 1986). The nutrients necessary for this ecosystem may or may not be attributed to the scavenging of these insect bodies, which is what this study intends to investigate. The relative amount of nitrogen and phosphorous leaving the lake by emerging insects is less than 1% of the amount that annually accumulates in the terrestrial sediment (Vallentyne, 1952). This study may have different implications for the transfer of nutrients through the scavenging of emerging insects, meaning that the nutrients are directly transferred through the consumption of the aquatic insect bodies instead of solely accumulated as sediment in the sand where the nitrogen deposits and can be absorbed by plants.

Due to the leaching nature of the sand and nutrient poor environment, it is evident that an allochthonous input of nutrients can assist in maintaining biological productivity on the inland community. Oftentimes, the emergence of aquatic insects can impact the terrestrial community acting as a source of nutrients for the adjoining ecosystem (Nakano and Murakami, 2001). Provided that scavengers are in fact utilizing the emerging aquatic insects for consumption, nitrogen can be cycled through the ecosystem by way of redistributing nitrogen through scavenger waste, which could add to plant productivity.

Since minimal research exists on the scavenging of aquatic insects in nitrogen-poor dune ecosystems, this study focused on the influence that this relationship has on nutrient availability within a lake-dune ecosystem. The observations will focus on scavenger preference for food source density, as well as location relative to the shore. I expect that scavengers will forage disproportionally more on high density food sources (Hines et al., 1997). Also, I believe that the samples will be more heavily scavenged near the tree line, where there is denser vegetation to provide protection while foraging. If the observations show preferential scavenging on the high density food sources, the nitrogen transfer, and thus, inland biological productivity, could possibly be predicted by the aquatic insect populations.

Materials and Methods

Aquatic insects used to test the scavenging hypothesis were collected using light traps at the University of Michigan Biological Station during two weeks in mid-July. We amassed about 20 grams of aquatic insects, most of which were adult caddisflies. The insects were placed in a freezer immediately after collection for preservation until they were set up at the dunes.

At each location three different densities were tested. The low to high densities were 0.05g, 0.15g, and 0.5g of dead aquatic insects respectively. To ensure that the insects did not blow away with the wind, watered down Elmer's glue coated the bottom of the dishes to provide a semi-adhesive surface to hold the insects while still allowing them to be removed by scavengers. The diluted glue prevented loosing biomass due to strong winds. At each location, density treatments were spaced out at least two meters from each other to ensure that the different densities did not interfere with each other. Ten repetitions of this setup were spaced out along the shoreline at each dune location. Additionally, three control Petri dishes were placed out to determine the amount of water loss experienced by the insect bodies if undisturbed within a loosely lidded Petri dish.

The project site was within Wilderness State Park, Emmet County, MI where Petri dish samples were placed out at the Sturgeon Bay dunes initially during the afternoon of July 26th 2008 and collected after a 24-hour period. The dead aquatic insects were measured on a digital scale before and after placement on the dunes. We waited for 24 hours to supply ample time for daytime and nighttime scavengers to have an opportunity to scavenge the insects placed out. The time did not exceed 24 hours because we guessed that would provide too much time for scavenging and the preference of densities would be more difficult to observe in the case that everything is scavenged. Also, there was less chance that wind or other unforeseen variables may interfere with the data collected. The Petri dishes with insects were placed along the dune in various locations that are representative of habitat diversity within the sand dune ecosystem. These locations were qualitatively determined on site during the experimental setup. The first dishes were placed along the beach where initial vegetation was growing. The second location was on the back side of the first row of sand dunes, just past the peak so that the wind disturbance would be lessened. Lastly, dishes were set out along the tree-line where forest vegetation began, but not within the forested areas because that appeared to be a drastically different habitat environment. The soil was still sandy at the tree-line. The three locations in succession away from the shoreline were labeled as beach, dune, and tree-line.

Each Petri dish was individually weighed on the same digital scale to obtain a final weight. The amount of biomass scavenged was determined by taking the difference between the initial weight and the final weight. After samples were picked up they were qualitatively categorized into one of two groups according to remaining insect body parts, either with only wings and/or legs remaining or having substantial remains.

SPSS was used to analyze the data. Several different One-Way Analysis of Variance (ANOVA) tests were performed with Scheffe Post-Hoc Tests to determine the variation between percent scavenged and density laid out, as well as percent scavenged and habitat. The Post-Hoc Test showed the variation between and within the different groups of densities and locations. These tests were repeated separately for data points with incompletely scavenged biomass. A linear regression was created with Microsoft Excel using the complete data set as well as an incomplete data set that focuses only on the data from the 23 Petri dishes that contained substantial remains.

Results

Of the 90 total Petri dishes laid out 23 of them had substantial remains, while the majority of Petri dishes had been completely scavenged except for what could not be removed because of the glue. Of all 90 Petri dishes set out for this experiment, Petri dish number 59 was not found and was excluded in all the following data analysis; this was a medium-density at the dune location. Throughout the different microhabitats incorporated into our experimental data set a noticeable trend is for greater overall biomass to be scavenged further away from shore. Almost half of the Petri dishes with substantial remains were on the beach, placed within the first signs of vegetation. Only four of the 23 Petri dishes with substantial remains were found at the tree-line indicating that the frequency of foraging is slightly greater near the edge of the forest.

Examining the differences between scavenged density groups there were six low-density, eight medium-density, and nine high-density Petri dishes with substantial remains. A majority of the insect biomass was foraged in every Petri dish and no obvious trend was witnessed of one density grouping being more heavily foraged upon than any other density. For the control Petri dishes the low and medium densities had about 55% of total biomass lost as water loss from sitting out for 24 hours.

While the high density had 64% biomass lost from water evaporating off of the insect bodies as they dry out. The average water loss from the total biomass was 58.2% when in an undisturbed dish.

The linear regression of percent scavenged in relation to the density groups yielded an r^2 value of y=0.0289 in the substantial remains only dataset, which shows the proportional relationship between the percent scavenged and the food source density as a very slight, positive slope increasing from low to high density (Fig. 1). However, when the incomplete dataset of only the dishes with substantial remains was used in a linear regression (Fig. 2) it generated an r^2 value of y=0.2906, which is more accurately described by a line. When considering only the incomplete dataset, the larger r^2 value suggests that there was a greater difference in percent scavenged between densities, increasing more drastically from low to medium to high.

SPSS was used to run several different One-Way ANOVA tests, which were used to determine whether there was a significant difference between the percent scavenged and the different density and locality groupings. The ANOVA test comparing percent scavenged with the density categories had a p-value of 0.103, which is well over the significance level of α (alpha) = 0.05, and also gave an F-value of 2.330. The null hypothesis cannot be rejected based on this p-value. There was no statistically significant difference between the percent scavenged and the various density groupings. In addition to these One-Way ANOVA tests, a Post Hoc Scheffe's Test was performed in order to test the variance between each of the groups. There was the least amount of variance between the medium and high densities with a p-value of 0.963, meaning the percent scavenged of the two higher densities were almost equal and had very minute difference.

The ANOVA test comparing the percent scavenged with the locality categories yielded a lower p-value of 0.053 and an F-value of 3.032, which is just slightly above the significance level. The null hypothesis cannot be rejected based on this significance value, however, there is a slightly stronger correlation between the percent scavenged and the location throughout the dune system. The Scheffe

Test that compared the variance between habitat groups showed that the greatest difference between the habitats was between the beach and the tree-line at a significance value of 0.054 meaning that the percent scavenged between the beach and tree-line was marginally significant data.

An additional ANOVA included only the Petri dishes containing substantial remains in order to further test the accuracy and precision of the experimental setup. The ANOVA of the percent scavenged in relation to the density groupings produced a p-value of 0.002 and an F-value of 8.718, which would have given statistically significant data of definitive differences in scavenging between the densities. The ANOVA test comparing the percent scavenged and the locality of the dishes yielded a p-value of 0.664 and an F-value of 0.418, showing that concerning the incompletely scavenged dishes, there was no significant difference in percent scavenged between the different habitats. Additionally, the mean values for percent scavenged and the standard deviations for the densities and localities were very close, all between 93% and 99% scavenged (Table 1).

Discussion

The majority of samples set out in the dune system were thoroughly scavenged, which could indicate the transfer of organic materials and therefore nutrients from the aquatic system into the terrestrial system. It is difficult to determine whether the foraging preference is for the greater available food at the high density or for the possibility of more food per individual at a lower density because there was very small difference between which density groups were scavenged. There was a definite trend for a greater incidence of scavenging as the samples were placed further away from shore. This could be seen given that the dishes with more substantial remains were found mostly on the beach. The fact that there was a greater occurrence of foraging near the tree-line may be supporting evidence or a basis for future experiments. In the control dishes an average of 58.2% of biomass was lost allowing corrections for water loss to be made in the measurements.

In analyzing the data, an incomplete dataset, specifically, the Petri dishes with substantial remains left upon pickup was also taken into consideration. This data set was employed because the other dishes were completely empty except for the body parts stuck in the glue. It is very likely that if it had not been for the glue, these Petri dishes would have been completely foraged with no remaining biomass to weigh and 100% scavenged would have been recorded. This was one unforeseen flaw in the experimental design that in future experiments should be addressed and altered in order to prevent this from happening because the collected data was not as naturally accurate as it could have been. Other means should be used in the future to prevent wind disturbance while not influencing the collected data values.

Utilizing the complete data set for a linear regression in Fig. 1 there was a very low r^2, indicating that our data did not fit a line very well and the individual sample values within different density groups were almost equal. These values in the linear regression graphs as data points all being clustered near the top of the graph around one (signifying 100% scavenged). One reason that the data may be insignificant is because a majority of the dishes were essentially completely scavenged leaving us very few dishes with enough remains necessary to determine an accurate percent scavenged. Using the incomplete dataset displays a correlation between the percent scavenged and the various density groups with a p-value of 0.002. Between the two graphs in Figures 1 and 2 the incomplete dataset has a steeper slope with a greater r^2 value, which shows a greater difference between the low, medium, and high densities. However, while this alternate dataset yielded more accurate results it provided a much smaller sampling size. Because the percent scavenged increases as the food source density increases, foragers might preferentially choose a higher density food source. On setting out the Petri dishes, ants appeared in the dishes relatively quickly and grasshoppers were viewed in a few dishes. The ants that foraged may have selected the larger densities in order to maintain the colony population, whereas individual foragers may have selected a food source based on different cost and benefit assessments for personal survival. The experimental design did not take into account the behaviors of different scavengers or all the organisms that were foraging.

High p-values were obtained for both the densities and localities ANOVA tests and the null hypothesis cannot be rejected in both cases, since each of the p-values were greater than $\alpha = 0.05$ at a confidence level of 95%. The collected data was not statistically significant; however, there is an evident trend that can be found in the foraging of different densities as a positive association between the amount of biomass consumed by foragers and the density level of the food source. This is merely a weak correlation that can be observed in the data values and linear graphs. The results from the ANOVA test could not definitively show any significant differences between densities or localities. In future experiments, more concrete results would be obtained if the scavenging were allowed for a shorter period of time and/or if the foraging was limited to specific organisms.

Incorporating all the data, the results concerning the placement throughout the ecosystem at three distinct microhabitats was more significant. The p-value of the ANOVA test comparing percent scavenged and locality groupings was 0.053, so the relationship between location and foraging has much stronger evidence, but is rejected nonetheless. The observable trend between percent scavenged and locale is that the further away from shore the greater percentage of scavenging occurred in the Petri dishes. This trend was especially apparent in investigating the Scheffe Post Hoc test, which was used to determine exact variation between each distinct group. The difference between the beach and tree-line was marginally significant at 0.054, which makes sense considering there is a substantial distance between the dishes on the beach and the tree-line. A wider variety of foraging organisms may reside in the forested area and the dishes near the tree-line were easily accessible food sources compared to the open dunes. Scavenging organisms must weigh the costs and benefits in certain foraging behaviors and distance from shelter is a major component. Organisms may also have preferred to forage close to the tree-line because it provided better protection and available hiding spaces than traveling into the open area of the dune and being left vulnerable while foraging.

The additional ANOVA tests performed with the incomplete dataset demonstrate that the data collected of substantial remains only are more visibly representative of the variation between different densities and the percent scavenged. This ANOVA test did have a statistically significant p-value of 0.002. There were definitive differences between the low density and the two higher densities, but not really between the medium and the high density indicating that perhaps the two higher densities were too similar in biomass. Although when scrutinizing the incomplete data set in comparing the localities with percent scavenged there were no statistically significant difference between any of the habitats because all the p-values between locality groups were much greater than 0.5. Overall, the incomplete dataset demonstrates the correlation that we expected to observe in density dependent foraging where a greater supply of food generates higher incidences and rates of foraging.

In future experiments, a different experiment set up could be developed that avoids complete scavenging of the samples and thus creates a wider range of values for data points when investigating the existence of a correlation between density of a food source and rates of foraging. Previous findings have identified nitrogen as a limiting nutrient in dune communities and there could be further studies to determine the exact amount of nitrogen that is transferring and how far it travels into the terrestrial community (Willis, 1963). While the study did show a high rate of scavenging on emergent aquatic insects in dunes; these insects may still be a viable means of transporting nitrogen from the aquatic community (Vallentyne, 1952). More extensive studies are needed to determine actual foraging preferences of scavengers in the sand dune ecosystems. Within different aquatic and terrestrial ecosystems, it is already known that the aquatic insects play a relevant role in providing nutrients and water into the system (Jackson and Fisher, 1986), so future inquiries into this relationship may utilize this data in shaping more specific experimental designs that examine fewer variables simultaneously.

Literature Cited

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Figure 1: Percent Biomass Scavenged vs. Aquatic Insect Density (full data set)

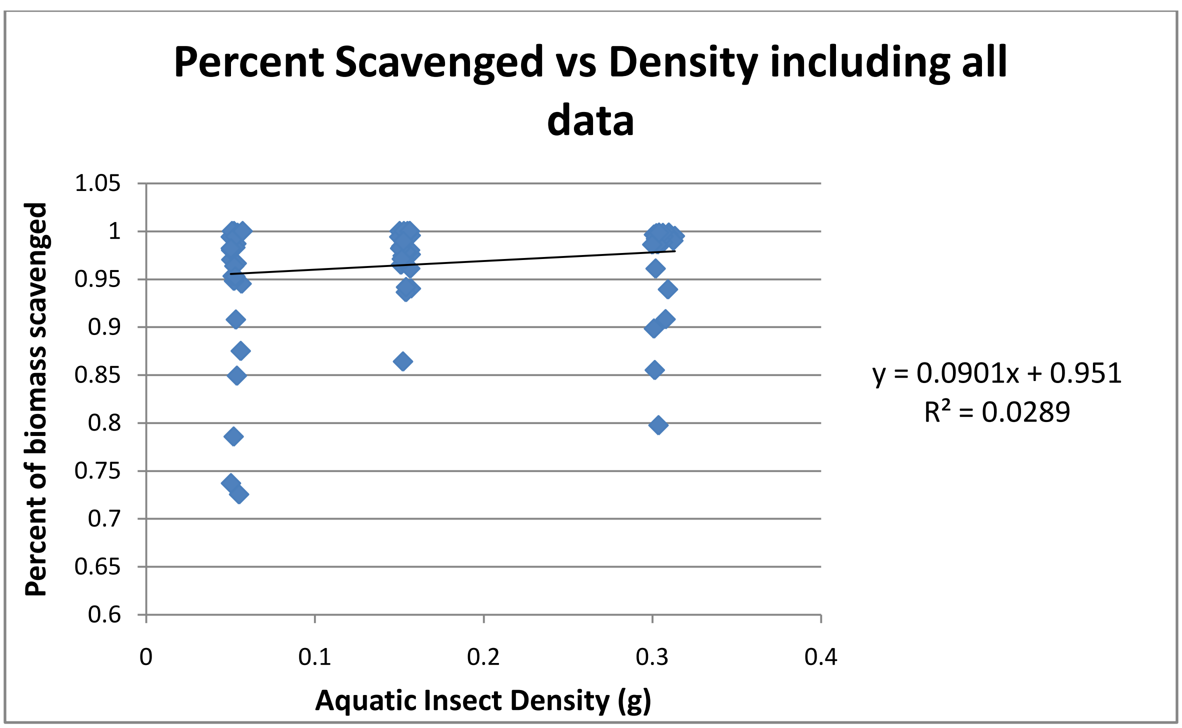

Figure 2: Percent Biomass Scavenged vs. Aquatic Insect Density (significant remains only)

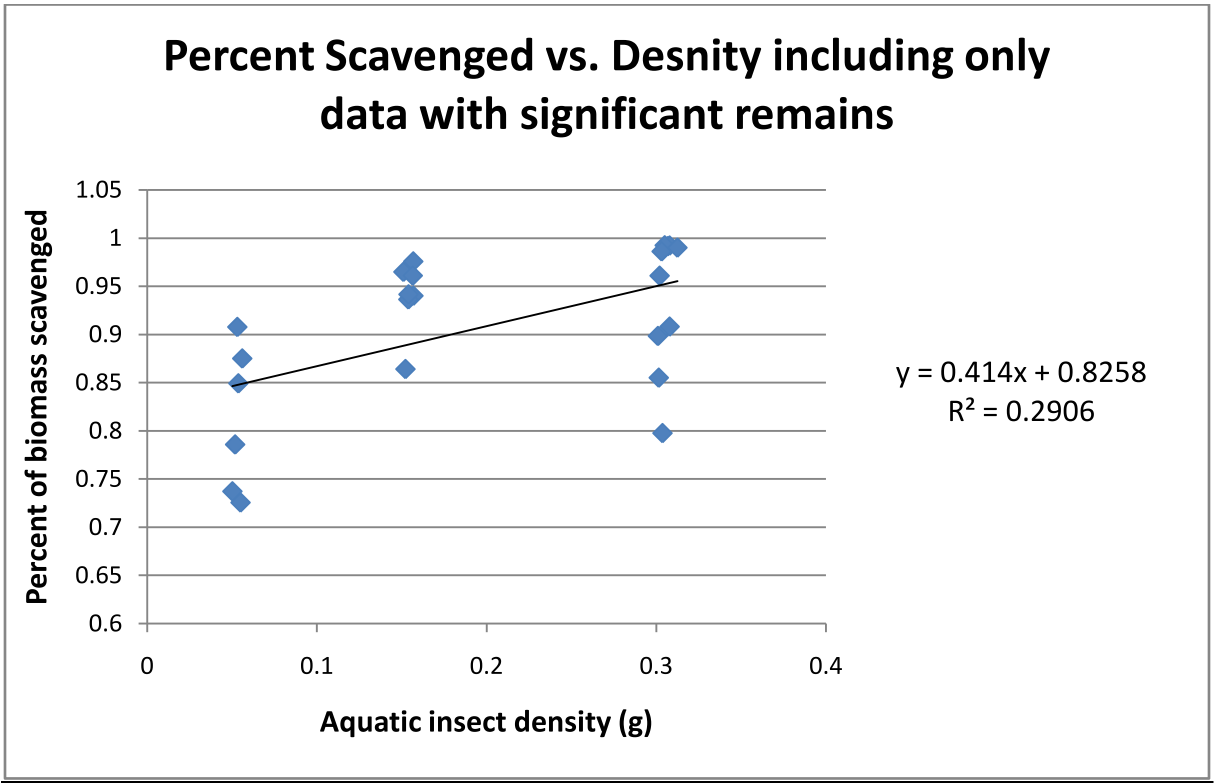

Table 1: Basic Summary of Data; Sample Means and Standard Deviations

	Beach		Dunes		Treeline	
	mean percentage scavenged	standard deviation	mean percentage scavenged	standard deviation	mean percentage scavenged	standard deviation
Low Density	0.935874728	0.069808	0.936994108	0.109318	0.973984558	0.038316
Intermediate Density	0.959615167	0.038373	0.986162199	0.013768	0.987678466	0.018886
High Density	0.950991249	0.073504	0.980192183	0.030734	0.989505102	0.011104