Density Dependent Scavenging of Aquatic Insects in a Dune Ecosystem

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Abstract

The purposes of this study were to determine if scavenging of aquatic insects in a dune ecosystem is density dependent, and from where in the dunes scavengers prefer to obtain their food. Dead aquatic insects were placed out in different density groupings and habitats within the dune ecosystem. Samples were weighed before and after a scavenging period of 24 hours. The difference between these values was used as the amount scavenged from a given sample. Our data showed a trend of scavengers having a slight preference for higher densities of aquatic insects, however this trend was not found to be statistically significant.

Introduction

Nutrient flow from aquatic to terrestrial ecosystems can provide needed nutrients such as nitrogen, phosphorous, and magnesium to coastal communities **(**Nakano and Murakami, 2001). This is especially important when the inland community's growth is limited by one such nutrient. In dune ecosystems availability of nitrogen has been shown to limit success and distribution of plant species (Willis, 1963). This limitation of nutrients in dune ecosystems is likely due to leaching of the soil (MDNR, 2008). Inland biological productivity has been shown to be affected by the addition of nutrients. One such source of these nutrients can be a neighboring aquatic ecosystem **(**Nakano and Murakami, 2001). The dune ecosystem provides a harsh setting for plants to struggle for survival. Plants in coastal dunes must cope with high winds, intense sunlight, poor soil, and blowing sand (MDNR, 2008).

Aquatic insect's emergence and subsequent movement from aquatic to terrestrial ecosystems can provide nitrogen and other critical nutrients to inland communities (Vallentyne, 1952). Emergence of aquatic insects, such as certain species of mayflies and caddisflies, could contribute to inland productivity by providing a nutrient source for scavengers (Vallentyne, 1952). Synchronous emergence and a short adult life stage can cause a large number of mayflies and caddisflies to be available to scavengers within a narrow time period (Corbet, 1964).

The sand dunes of Sturgeon Bay provide an ideal location for a study of scavenging of aquatic insects. Many species of caddisflies and mayflies emerge from Lake Michigan and their bodies often wash up on the beach in the summer months. There is a population of scavengers present on the dunes including birds, mammals, and terrestrial insects (MDNR, 2008). Scavenging can occur during both day and night, and also likely depends on weather.

Scavengers could potentially move nitrogen and other nutrients into the dunes by consuming aquatic insects and depositing waste further inland. Scavengers have been shown to prefer areas of higher seed density (Kunin, 1994). If scavengers preferred areas of higher densities of aquatic insects, then inland biological productivity could potentially be predicted by aquatic insect density. There has been little research concerning the scavenging of aquatic insects in nitrogen poor ecosystems. It has also been shown that foraging in animals can show a preference for risk avoidance (Caraco, 1980). The different habitats within the dune ecosystem may vary in riskiness for scavengers. The purposes of this study were to determine if scavenging of aquatic insects in a dune ecosystem is density dependent, and from where on the dunes scavengers prefer to obtain their food. If scavengers prefer higher densities of aquatic insects, then a higher proportion of biomass should be scavenged from areas of high aquatic insect density. If scavengers prefer to obtain food farther inland, then more aquatic insects will be scavenged from habitats at a greater distance from the shore.

Materials and Methods

The study site was within Wilderness State Park in Emmet County, Michigan along the Sturgeon Bay sand dunes. Aquatic insects were collected from the University of Michigan Biological Station on Douglas Lake in Cheboygen County Michigan. Aquatic insects of interest were defined as any species of mayfly or caddisfly. Collection took place over the course of several weeks in July of 2008 using mercury vapor and ultraviolet lights. Approximately 20 grams of aquatic insects were collected and frozen immediately to prevent decomposition. A large majority of collected insects were adult stage caddisflies.

Placement of aquatic insects was designed to test if scavenging is density dependent. Petri dishes with one of three densities of aquatic insects were placed along the beach. The petri dishes had either, .05 g, .15g, or .3g of aquatic insects placed in them. A weak adhesive consisting of diluted Elmer's glue was placed along the bottom of each dish to prevent loss of biomass due to wind. A control petri dish representing each density group was placed out with the top closed. These control petri dishes were used to calculate average biomass loss due to drying. Groups of petri dishes were placed in one of three habitats. These habitats were along the water's edge, in a low lying area between successive dunes, and at the forest's edge. These locations were used because they represent the diversity within the dune ecosystem, and the broad range of several meters to several hundred meters from shore. Petri dishes were kept out between 4:00 PM July 26^{th} and 4:00 PM July 27^{th}. Each possible density-habitat combination was repeated 10 times for a total of 90 petri dishes.

A 24 hour period was chosen to allow for scavenging during both day and night. Total remaining mass of aquatic insects was measured using the same digital scale that was used prior to placement. Measurements of mass were taken immediately after collection, to prevent differential drying from affecting results. All remaining biomass in the petri dishes was weighed.

In addition to the mass measurement, each sample was categorized as either completely scavenged with only legs and wings embedded in glue remaining, or as having substantial aquatic insect remains. This categorization was found to be necessary due to the high percentage of petri dishes that were completely scavenged. These data sets were later analyzed both together and separately. Amount of biomass scavenged was defined as the difference between biomass measured prior to placement and the amount that was measured upon collection. A scavenger's preference for a given density and location was assumed to be the percent of biomass scavenged, or the mass taken by scavengers divided by the total mass placed out at the beginning of the experiment.

Microsoft Excel was used to perform linear regression analysis on collected data. A linear regression was performed using total biomass before scavenging and percent biomass scavenged. A linear regression was also performed using only incompletely scavenged data points. Incompletely scavenged data points were considered separately to deemphasize zero values within the data sets and better visualize trends. Linear regression analysis was also used to analyze data from each habitat individually.

SPSS was used to perform several One-Way Analysis' of Varince (ANOVA). One-way ANOVA's with Scheffe Post-Hoc Tests were performed between percent scavenged and original density, as well as percent scavenged and habitat. These tests were repeated separately for data points with incompletely scavenged biomass.

Results

Linear regression analysis using both incomplete and complete scavenging data yielded an R^2 value of .0289 (Figure 1). The line of best fit for this analysis had a positive slope, increasing from low to high density. This very low R^2 value tells us that our data are very poorly described by a line. Linear regression analysis using only incomplete scavenging data yielded and R^2 value of .2906 (Figure 2). This R^2 value is substantially higher than the R^2 value including complete scavenging data, meaning that our incomplete scavenging data were better described by a line than our whole data set. The slopes of these lines also varied considerably. The slope of the line of best fit when considering both complete and incomplete scavenging data was found to be .0901. The slope of the line of best fit using only incomplete scavenging data was found to be .414 (Figures 1 and 2). This larger slope value suggests that percent scavenged in the incomplete scavenging data set on average increased more dramatically from low to high density than the data set considering all data points. Linear regression within each habitat yielded slightly varying results. All trendlines had positive slopes, and R^2 values below .1, however the beach data gave a substantially smaller R^2 value and lower slope. This tells us that the beach data were more poorly described by a line, and that there was less of a difference between low and high density scavenging at this location.

A one-way ANOVA considering both incomplete and complete scavenging comparing percent scavenged between the different density categories yielded a significance value of .103 and an F-value of 2.330. A significance value this high told us that we could not assume a statistically significant difference between percent scavenged from different levels of densities.

A one-way ANOVA considering both incomplete and complete scavenging comparing percent scavenged between the different habitats yielded a significance value of .053 and an F-value of 3.032. This told us that we could not assume there was a significant difference between habitats, but the differences between habitats approached significance.

Two additional one-way ANOVA's were performed in similar fashion using only incomplete scavenging data. The ANOVA comparing variation of percent biomass scavenged between the different density groupings yielded a significance value of .002 and an F-value of 8.718. These values told us that there was a significant difference in percent scavenged between the density groupings when only considering dishes that were incompletely scavenged. The significance value for the ANOVA comparing percent scavenged between different habitats was .663 and an F-value of .418. These values told us that there was no significant difference of percent biomass scavenged between different habitats when considering only incompletely scavenged dishes.

Discussion:

Our results cannot definitively show that scavenging in the dune ecosystem is density dependent. In figures 1 and 2 our data is plotted with a line of best fit and displayed R^2 value. These figures demonstrate that within our data there is a trend for a higher percentage of scavenging at greater densities of insects.

Results of statistical analysis varied considerably between the two data sets. This made it difficult to determine if a statistical difference in scavenging existed between density groups because all densities had a high percentage of near zero values, making means of groups more similar than they would otherwise be. There is a dramatic increase in R^2 value when performing a linear regression using only data points with significant remains, suggesting that there may have been a relationship between density and percent scavenged.

The ANOVAs using the entire data set showed that there was nearly a statistically significant difference in scavenging rates between different densities and localities. Although no ANOVA test using the entire data set could produce results that could definitively demonstrate statistical significance, the results did approach statistical significance.

The second ANOVA using only data points with significant remains serves as a demonstration that our data could have more clearly demonstrated variations between densities and percent scavenged if so many petri dishes weren't scavenged to near emptiness. This test also demonstrated that in order for future research to be more successful, a different strategy of presenting food to scavengers should be used.

Future experiments would likely obtain better results if a shorter time period of scavenging were allowed or if scavenging were limited to select organisms. A data set would likely show a larger significance between different densities if a lower percentage of data points were completely scavenged. A different approach to answer the question of whether aquatic insects are a significant source of nitrogen for plants in the coastal dunes could be stable isotope analysis. One could obtain nitrogen isotope ratios from emerging aquatic insects and determine if that nitrogen was later incorporated into dune plants.

Neighboring aquatic ecosystems can have a dramatic effect on coastal communities by providing both water and nutrients (Jackson and Fisher, 1986). Nitrogen is well known limiting nutrient in dune communities, and further study is needed to determine how much nitrogen moves from aquatic communities (Willis, 1963). Emergence of aquatic insects could be one of many ways that nitrogen is moved from aquatic to coastal ecosystems (Vallentyne, 1952). Although our study could not significantly relate density or locality of aquatic insects to a preference of scavengers, we did demonstrate a likely trend of scavengers having a preference for areas of higher insect density. Our study also demonstrated high levels of scavenging of aquatic insects in the dune ecosystem, which suggests that there could be a significant flow of nutrients from the lake onto the dunes. Further study is necessary in the preferences of scavengers in dune habitats and whether their behavior has significant effects on coastal communities.

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

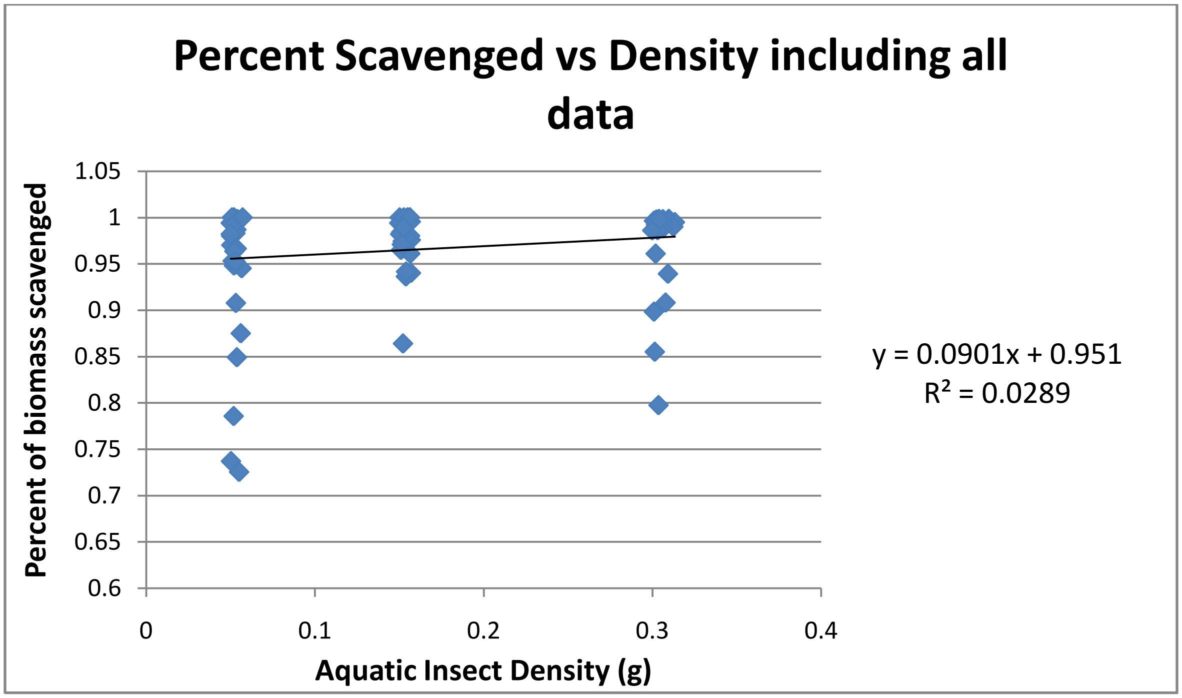

Figure 2: Percent Biomass Scavenged vs. Aquatic Insect Density (significant remains only)

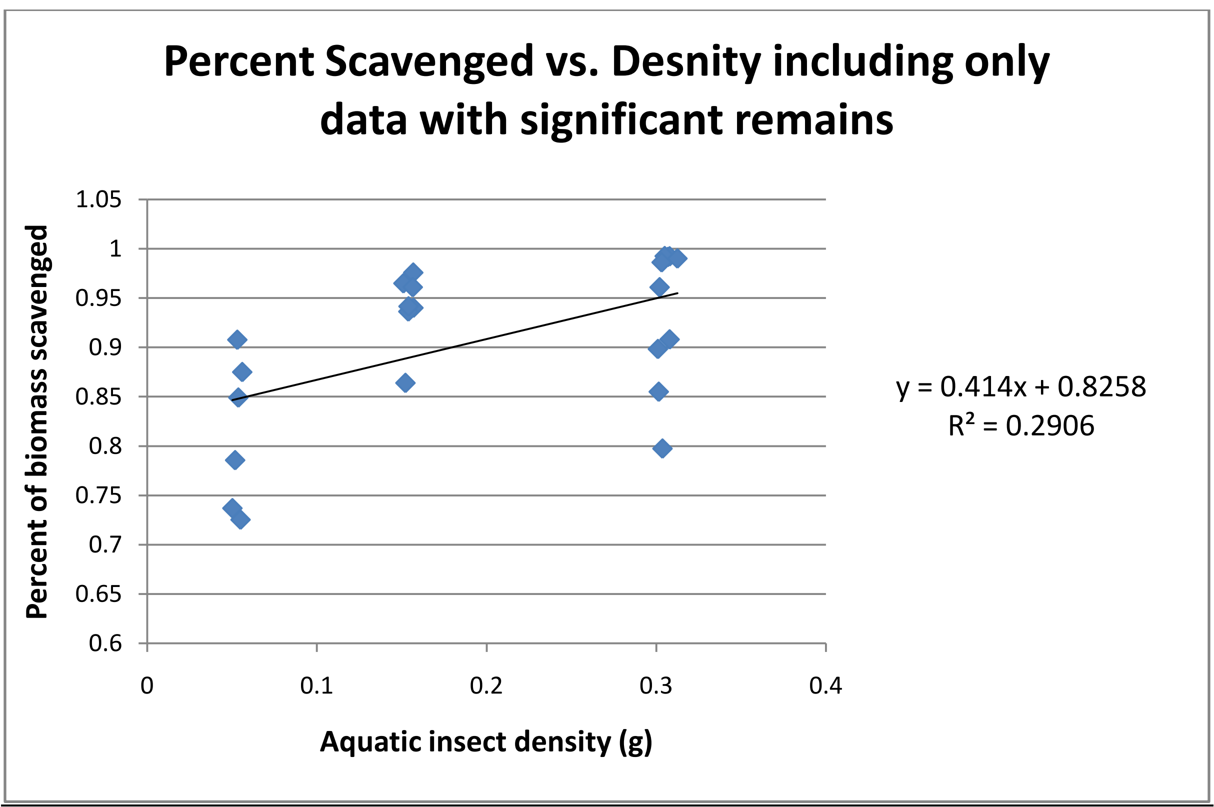

Table 1: Basic Summary of Data

	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