Sara Barnas, Kate Heflick, Daniel Kowalsky, Joanna Solarewicz

INSECT COMMUNITIES IN INTERDUNAL SWALES:

TESTING THE SUCCESSIONAL THEORY

Abstract:

The purpose of this study was to determine insect species diversity and abundance in interdunal wetlands (swales) located off the coast of Lake Michigan in Wilderness State Park, Sturgeon Bay, Michigan. The first five swales found consecutively from the lake had their water, soil and insect populations tested for composition. We are in search of support for a relationship between insect populations and interdunal swale age. While it was hypothesized that the highest diversity would be found at the intermediate successional stages, we were not surprised to discover it was the second beach pool from the lake that provided the highest richness of insects.

Introduction:

Succession is one of many major ecological theories formed to explain changes in community composition. Succession is defined as the change of species composition over time as a result of abiotic and biotic agents of change (Bowman, et al. 2008). Primary succession occurs when a new substrate is deposited, allowing for initial vegetation to move in. As succession progresses, the detritus buildup forms new soil over time. More species are then able to move in, creating new communities. The formation of sand dune ecosystems is an example of this.

Dune formation occurs during periods of repeated drops in water level and glacial rebound. Water levels that decrease expose new area, allowing dune grass (*Ammophila*) to move in. As this grass thickens and branches out, it acts as a barrier against erosion, catching windblown sand and stabilizing the area to essentially form new land to shape a primary dune. Swales are the interdunal wetlands located between most ridges and fed by groundwater and rain. This process has repeated itself over many years to form the whole dune ecosystems such as those found along the western shores of Lake Michigan. In this region, the combination of rebounding and fluctuating water levels leads to prograding dunes.

The prograding dune system at Sturgeon Bay in Wilderness State Park, in Emmet County bordering Lake Michigan provides an opportunity to study successional change since the Holocene era (Lichter, 1995). The uniqueness of this site provides access to hundreds of years of environmental changes to be observed at one time (Cowles, 1899). The dunes are approximately 2.5 km long, 10-30 meters wide, and generally 3-5 meters in height as measured in 1987 (Lichter, 1995). Lichter estimated the dunes are formed in approximately 50-75 year intervals by conducting accelerator mass spectrometry (AMS) dates of herbaceous plant macrofossils (Lichter, 1995). The dominant focus of past dune successional studies have been on resource-ratio of light and nutrients effecting vegetation and vegetation diversity (Tillman, 1985. Lichter, 1995, Cowles, 1899.). At this site, water nutrients and soil composition are sampled with the purpose of aiding in the explanation of species diversity present at the swales.

In order to better understand effects of swale succession on overall species diversity and abundance, the core of this study is on insect communities present at each of the first five swales at Sturgeon Bay encountered. Insect populations should reflect ecological theories on successional diversity, with diversity changing with the ratios of light and nutrients throughout the five swales. In intermediate successional stages, light and nutrient levels offer a resource equilibrium allowing for high diversity (Tillman, 1985). We expect this broad ecological theory to hold true for insect populations, and should thus be able to predict biodiversity at swales to maintain the highest species richness at middle successional states, which would follow the intermediate disturbance hypothesis (Connell, 1978). This study anticipates the highest diversity to be found at the third of five total swales sampled.

Materials and Methods:

The collection of insects at five swale sites was conducted at Wilderness State Park off the shore of Lake Michigan's Sturgeon Bay. To collect insect samples, 25 6.5''x8.5'' paper flags painted with tanglefoot adhesive, a sticky, glue-like substance used to trap insects onto paper, were manufactured. To construct each flag, 11''x8.5'' pieces of light yellow construction paper were folded in half and taped to the top of two 0.75 meter metal rods to the center line of the paper. The paper was folded over the rods and stapled along the rods to keep the paper stable during sampling. Each set of five flags were labeled "A,B,C,D,E" according to which swale they would be deployed in, "A" closet to the lake, "E" the farthest away, etc., and each flag in the set was numbered 1-5 (ex. A1,A2…E4,E5).

Enough tanglefoot was spread, 2-4mm thick, on each side of the paper flags to completely cover the paper, immediately before arranging the flags in each area. The flags were arranged approximately 2 meters apart from each other, 1-2 m from the edge of the water, with the bottom of the flags approximately 0.3 meters above the water level. They were set out during a period of low precipitation. Throughout the two days that the flags were set out, there was about 0.4 inches of rain. 48 hours later the samples were collected. Upon collection, Saran™ wrap was used to cover the flags in order to retain their integrity. Insects were sorted into 19 distinct categories based on morphology of what could be seen by the naked eye (size, color, shape, etc).

At the center of each swale, the collection of water samples was performed from the surface layer into acid-washed 50 mL Nalgene sample bottles. Samples were analyzed for % phosphorus and % nitrogen levels using a 1994 Seal Auto Analyzer.

To compare the organic composition of the benthic layer in the center of the swales, soil samples were collected from 0.2 meters into the ground with a soil corer. The samples were dried in an oven for 72 hours and then ground in a ball grinder to homogenize the soil. Aluminum trays were weighed and filled with 3-4 grams of soil. Each sample was burned in a Muffler Oven at approximately 500 degrees Celsius for 15 hours to burn off the organic matter. The weight of the burned sample (inorganic matter) was then weighed and that measurement was subtracted from the total dried weight to produce the weight of organic matter. The calculation $\frac{\text{Weight organic matter}}{\text{Weight total sample}} \times 100$ gives the percent organic matter for each sample.

The Shannon diversity index, H', was used to calculate the species diversity of each population at each beach swale. Since the data was collected randomly from each beach swale community, the formula $H' = -\sum(p_i \times \log p_i)$ in which $p_i = \frac{\text{Total number of individuals in species } i}{\text{Total number of individuals}}$ was used. Three ANOVA comparison tests were performed on the total number of insects per pool, the number of distinct species per pool, and the H' of each pool. Results were determined to be significant if the p value < .05.

Results:

Water samples were taken from each of the five swales and Lake Michigan (control) to determine water nutrients and pH (Table 1). Phosphorus levels ranged from 4.9 ug P/L at Swale B to 200 ug P/L at Swale E. Nitrogen levels ranged from 0.264 mg N/L at Swale A to 0.575 mg N/L at Swale E. PH levels ranged between 7.77 at Swale E and 8.69 at Sale D. Both Phosphorus and Nitrogen levels were decreased at early swales (Phosphorus is lowest at Swale B and Nitrogen at Swales A and B) and then increase throughout Swales C-E. PH also lowered at Swale B, and then continued to fluctuate, decreasing and increasing throughout Swales C-E. Soil samples were also taken and dried to determine the proportion of organic matter to inorganic matter of soil present at each swale (Table 2). The percent of organic matter in the soil ranged between 0.29% of Lake Michigan's soil to 4.15% of Swale D. The percent of organic matter increased with distance from the lake with the exception of Swale E.

In ANOVA Test 1, a comparison of swale versus total number of insects was run using five samples from each swale. This test showed the second swale (Swale B) off Lake Michigan had significantly more insects compared to all four others (all P values > .05). It was the only swale to produce significant differences to the others (See Table 3).

ANOVA Test 2 is a comparison of swale versus total number of species present using five samples from each swale. This test showed the first swale off the lake (Swale A) had a marginally significant P value in relation to the fourth swale off the lake (Swale D). Swale A to Swale D produced a P value of 0.057. No other swales showed significance in total number of species present (See Table 4).

In ANOVA Test 3, Shannon diversity Index (H') was used to determine if there was a significant difference present among the swales. The H' was found for each of the five samples of the five tested swales. A significant difference was discovered between Swales A and D.

Discussion:

The general correspondence between the age of an interdunal wetland and the existence of insect populations indicate that intermediate states generally hold the winning medal for highest species richness (Connell, 1978). The results indicate that this theory did hold true in our experiment when it came to insect abundance when the traps at the second swale of the beach did catch the most insects. This does, however, go against our prediction that this would occur at a slightly older dune. The results are not surprising, however, since the second swale that we came across appeared to have everything necessary for organisms to thrive. According to Tillman's Resource Ratio Theory (Tillman, 1985), this must have been the swale that was most stable in the fight for equilibrium between nutrients and light. The second swale's pioneer species, such as dunegrass, were still present throughout the valley of the two ridges even though woody plants, such as pines, had come in.

The results support a relationship between diversity and water composition in a positive way. The pools with more phosphorus and nitrogen appear to have a more diverse species range, however not as abundant in insects. This may show that fewer species specialize on nutrient rich

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	Total Phosphorus	Total Nitrogen	pH level
Lake Michigan	11	0.383	8.08
Swale A	11.8	0.264	8.21
Swale B	4.9	0.271	8
Swale C	10.8	0.335	7.89
Swale D	48.6	0.383	8.69
Swale E	200	0.575	7.77
Units	ug P / L	mg N /L	-
detection limit	3 ug P /L	0.05 mg N / L	-

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Table 1 Total Phosphorus, Total Nitrogen, and pH level obtained from water samples taken from Lake Michigan and Swales A-E. All measurements dip at the earliest swales. Phosphorus and Nitrogen then increase while pH fluctuates.

Sample	% Organic Matter
Lake	0.29
A	0.55
B	0.61
C	2.11
D	4.15
E	3.39

Table 2 Proportion of organic matter in the swale soils obtained with the burning of soil samples. The percent of organic matter increases throughout the lake and Swales A-D.

Swale versus Number of Insects		
Swale	Compared Swale	P Value
A	B	0.003
	C	0.926
	D	0.599
	E	0.926
B	A	0.003
	C	0.019
	D	0.000
	E	0.001

C	A	0.926
	B	0.019
	D	0.198
	E	0.510
D	A	0.599
	B	0.000
	C	0.198
	E	0.964
E	A	0.926
	B	0.001
	C	0.510
	D	0.964

Table 3 ANOVA Test 1. Swale B is significantly different than Swales A, C, D, and E in the overall number of insects present.

Swale versus Total Species Present		
Swale	Compared Swale	P Value
A	B	0.863
	C	0.999
	D	0.057
	E	0.596
B	A	0.863
	C	0.946
	D	0.324
	E	0.988
C	A	0.999
	B	0.946
	D	0.092
	E	0.740
D	A	0.057
	B	0.324
	C	0.092
	E	0.596
E	A	0.596
	B	0.988
	C	0.740
	D	0.596

Table 4 ANOVA Test 2. Swale A is Swale D have a marginally significant difference of total species present.

Swale versus Shannon Diversity Index		
Swale	Compared Swale	P Value
A	B	0.265
	C	0.988
	D	0.044
	E	0.990
B	A	0.265
	C	0.510
	D	0.867
	E	0.500
C	A	0.988
	B	0.510
	D	0.114
	E	1.000
D	A	0.044
	B	0.867
	C	0.114
	E	0.110
E	A	0.990
	B	0.500
	C	1.000
	D	0.110

Table 5 ANOVA Test 3. Swale A has species diversity (H') significantly different than Swale D.