PRIMARY SUCCESSION ON DUNES AT STURGEON BAY, MICHIGAN: PLANTS AND ARTHROPODS

by Timothy A. Pearce 25 Aug. 1993

INTRODUCTION

Succession is the pattern of change that an assemblage of species undergoes over time. Assemblages of many kinds of taxa, at a variety of temporal and spatial scales, undergo succession. In primary succession, organisms colonize previously uncolonized, often newly formed substrate. Study of primary succession can provide clues about the physical and biotic factors that influence the distribution and abundance of organisms.

While the particular path that succession takes may be unpredictable, certain general processes are predictable. Species richness (= number of species) and diversity, which are low early in primary succession, tend to increase as initial colonizers make the habitat more favorable for other species. Species richness and diversity may decrease in a more climax community where competitive exclusion occurs.

Colonization of and succession on sand dunes devoid of organic matter is primary succession. A series of sand dunes at Sturgeon Bay in Wilderness State Park, in the northwestern part of Michigan's lower peninsula, provides a unique opportunity to study temporal patterns of species richness and diversity during primary succession. The dunes range from about 20 to 4000 years old (J. Lichter, pers. comm.), with the younger dunes being nearer to Lake Michigan. I report here the results of a class study on the species richness and diversity of plants and arthropods on sand dunes of different ages at Sturgeon Bay.

METHODS

To examine temporal patterns of species richness and diversity during succession, the General Ecology Class at the University of Michigan Biological Station examined vascular plants and leaf litter arthropods on nine sand dunes at Sturgeon Bay, Emmet Co., Michigan, on 1 June 1993. Sampled dunes range from about 20 to 500 years old (J. Lichter, pers. comm.).

To determine species and abundance of vascular plants on each of the dune ridges, teams of four observers identified and counted plants in equally sized quadrats (about 4.5 square meters). Each team then noted the presence of additional plant species for 100 m along the dune ridge.

To determine the taxa and relative abundance of arthropods, I collected about 10 liters of leaf litter from each dune ridge, attempting to sample from the variety of microhabitats present. Because leaf litter depth was not uniform, the surface area represented by 10 liters of litter is not equivalent amcng dunes. In berlese funnels, arthropods crawled downward out of the leaf litter into jars of ethanol. Students counted and identified the arthropods to the lowest taxonomic category practical.

Shannon-Weiner diversity is calculated as $H' =$ negative sum of $P_i(\log P_i)$, where P_i is the proportion of the sample represented by species i. Diversity is calculated on plant data from quadrat samples only (excluding incidentally observed plants) because the diversity index requires abundance information.

RESULTS

The students identified 17 species of plants in the quadrats, and 10 additional plant species on the dune ridges outside the quadrats (Table 1). Students found 18 taxa of arthropods in the samples (Table 2).

Total plant richness was significantly correlated with dune age, while richness and diversity of plants in the quadrats showed non-significant increasing trends with increasing age of the dunes (Figs. 1-3).

Plant species were non-randomly distributed across dunes (Fig. 4). For example, the beachgrass *Ammophila* was the most abundant vascular plant at the first (ca 20 year old) dune and its abundance declined in older dunes, willows (*Salix* spp.) were abundant at the second (ca 50 year old) dune and less abundant on dunes 1 and 3, and goldenrod (*Solidago* sp.) was the most abundant plant at dune 3 (ca 140 years old), and was less abundant on younger or older dunes. Similar patterns exist for sand reed grass (*Calamovilfa longifolia*), juniper (*Juniperus* spp.), white pine (*Pinus strobus*), and other species not shown in Fig. 4.

Richness, abundance, and diversity of arthropods did not show significant trends with age of the dunes (Figs. 5-7). Arthropod richness showed a slight increasing trend. Arthropod abundance increased in intermediate aged dunes, then decreased again on older dunes. Arthropod diversity decreased with increasing dune age, and appeared to increase on the oldest dune sampled. Overall, mites and springtails (= Collembola) were the most abundant taxa on the dunes. Dune 4 (170 years old) had the greatest number of arthropod taxa identified.

DISCUSSION

Total plant species richness showed a significant increase with increasing dune age, as predicted, and plant richness in quadrats, as well as plant diversity showed trends in that direction. For plants, none of these measures tented to decrease on older dunes.

Dunes of certain ages seemed to be characterized by certain plant species, a pattern that is consistent with the idea that different stages in succession are characterized by certain plants. This pattern suggests that as dunes get older, established plant species drop out and are replaced by other plant species. People who are managing for plant species of special concern that occur on dunes should find this information relevant.

Arthropod richness did not correlate to dune age. Arthropod abundance showed an increasing trend from young to intermediate aged dunes, with a decrease in the oldest dunes. Arthropod diversity showed a decreasing trend with dune age, with a possible increase in the older dunes. Because older dunes have more plant species, I expected to find greater arthropod diversity on older dunes. Perhaps if arthropods had been identified to lower taxonomic levels (e.g., species), the older dunes would show greater diversity.

These results suggest that plant richness and diversity may increase over the first 500 years of primary succession on sand dunes, while arthropod abundance may increase then decrease, and arthropod diversity may decrease within the same time period. Future studies could address the relationship of richness, abundance, and diversity of arthropods to that of vascular plants.

ACKNOWLEDGMENTS

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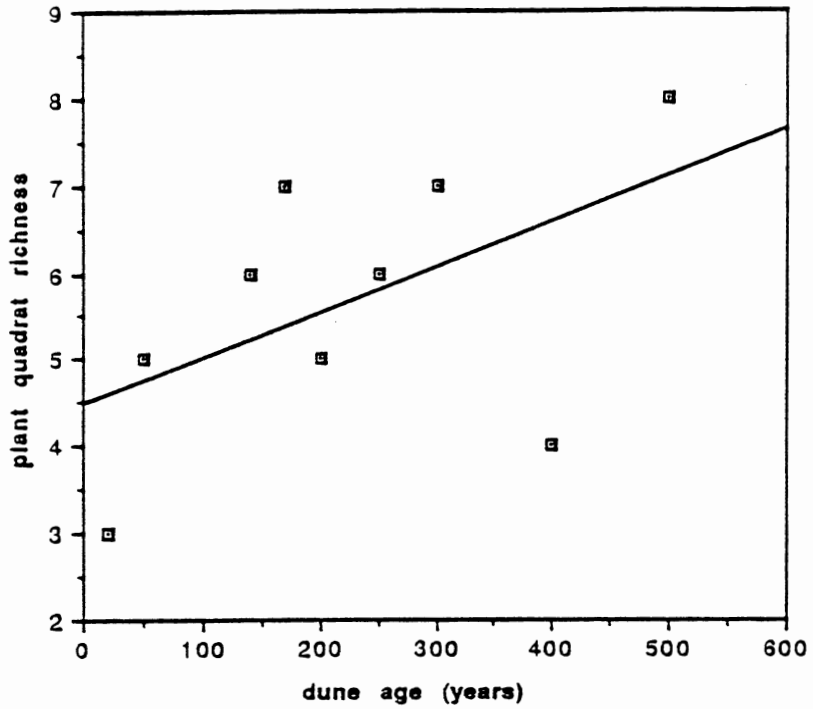


Figure 1. Species richness (number of species) of plants in quadrats from nine dated dune ridges at Sturgeon Bay, Wilderness State Park, Michigan, 1 June 1993. Richness of plants in quadrats is not significantly related to dune age ($p=0.148$, $r^2=0.274$).

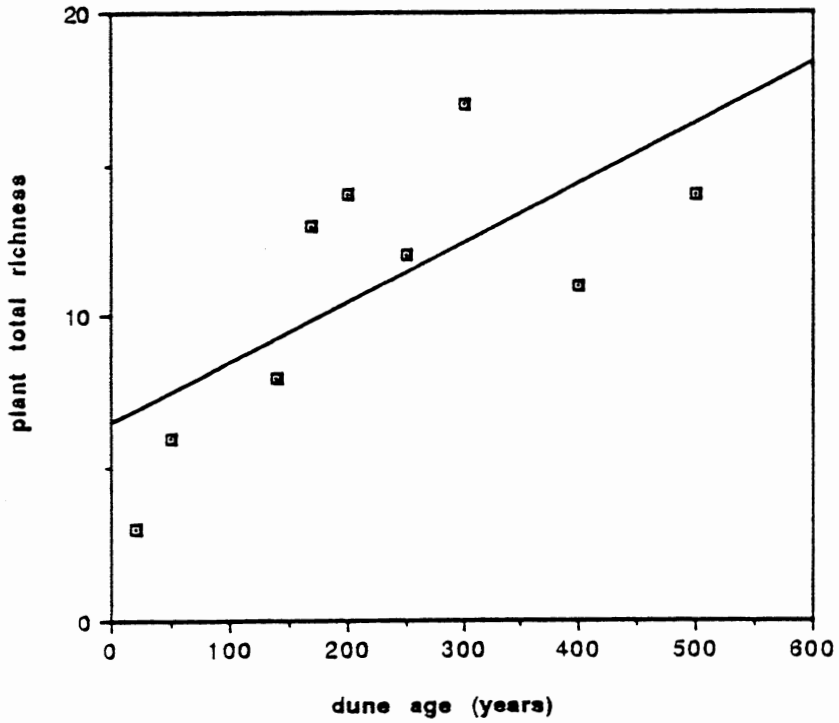


Figure 2. Species richness of all plants from nine dated dune ridges at Sturgeon Bay, Wilderness State Park, Michigan, 1 June 1993. Total plant richness is correlated to dune age ($p=0.036$, $r^2=0.491$).

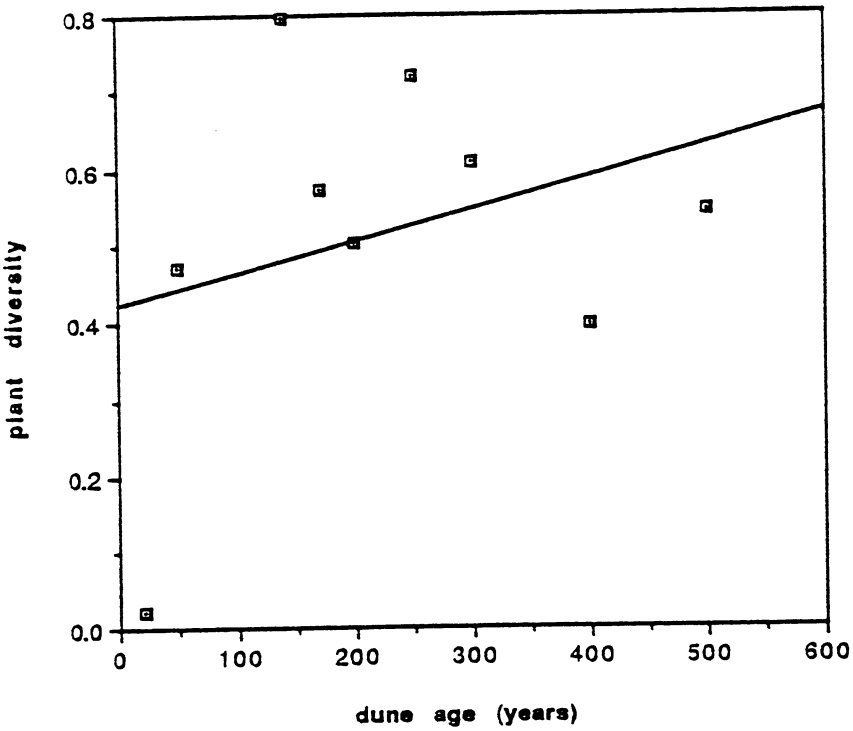
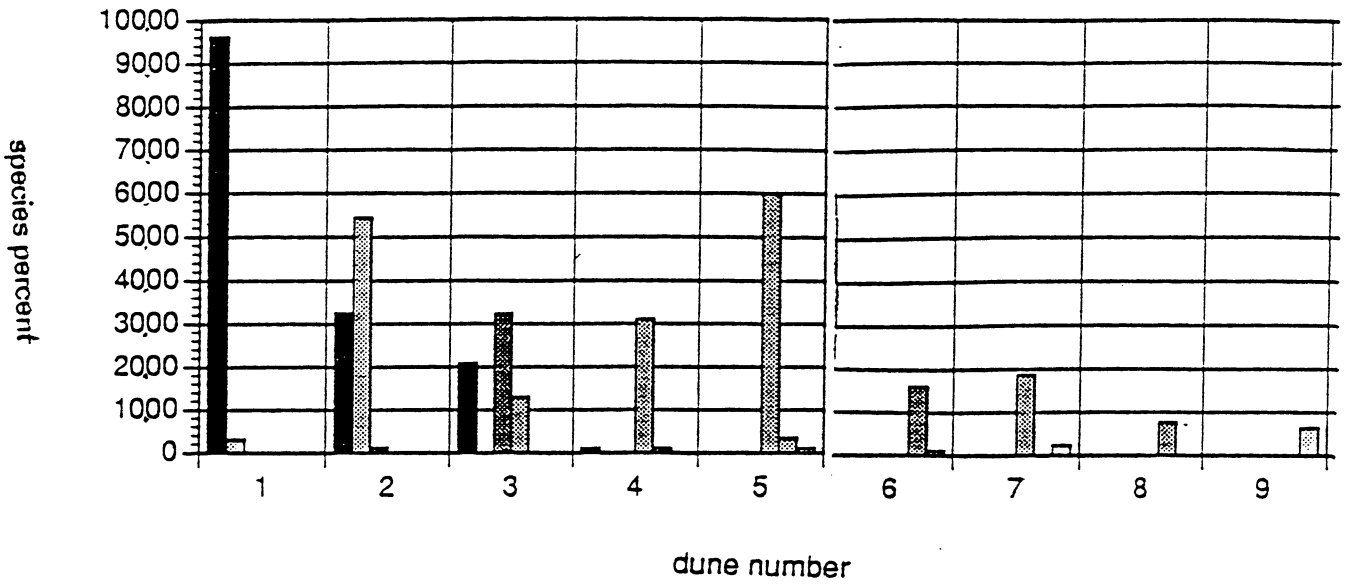


Figure 3. Shannon-Weiner diversity of plants from nine dated dune ridges at Sturgeon Bay, Wilderness State Park, Michigan, 1 June 1993. Plant diversity is not significantly related to dune age ($p=0.444$, $r^2=0.086$).



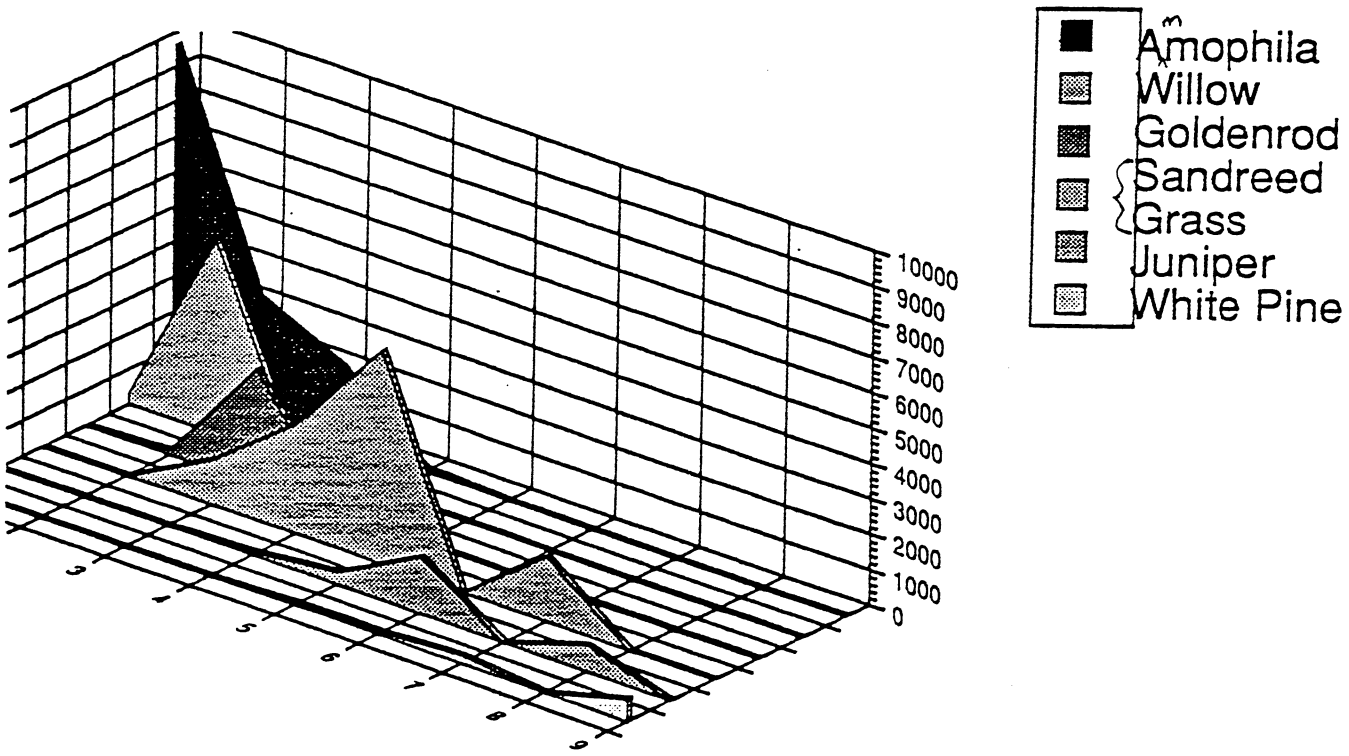


Figure 4. Differences in abundance of selected plant species on nine dated dune ridges at Sturgeon Bay, Wilderness State Park, Michigan, 1 June 1993.

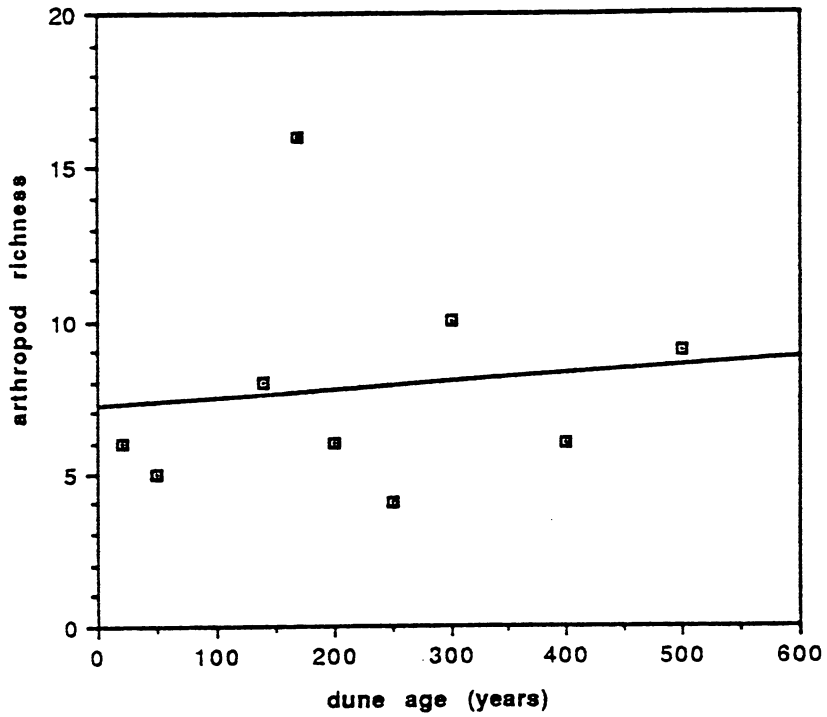


Figure 5. Richness (number of species) of arthropod taxa in leaf litter from nine dated dune ridges at Sturgeon Bay, Wilderness State Park, Michigan, 1 June 1993. Arthropod richness is not significantly related to dune age ($p=0.769$, $r^2=0.013$).

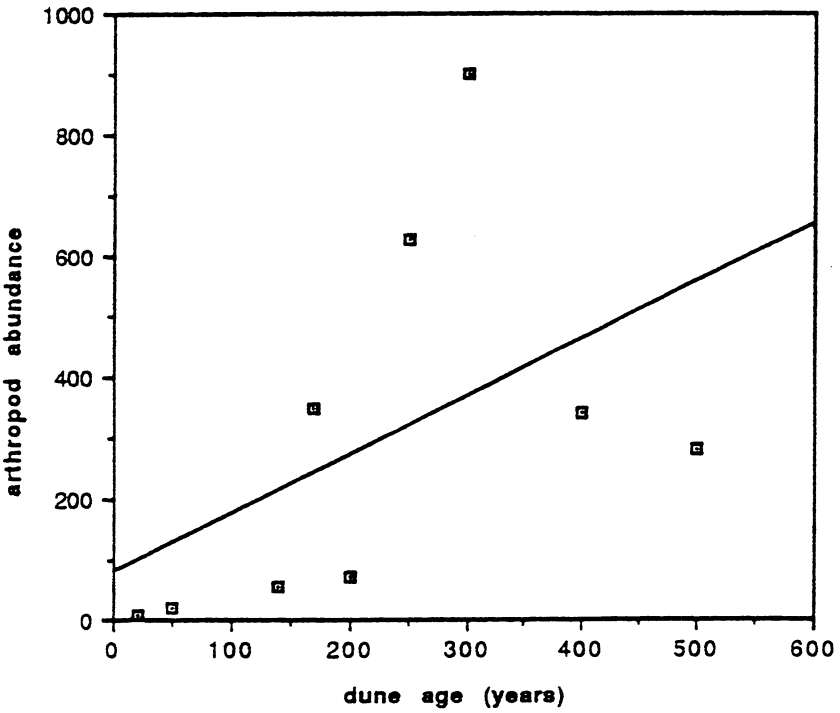


Figure 6. Abundance of arthropod taxa in leaf litter from nine dated dune ridges at Sturgeon Bay, Wilderness State Park, Michigan, 1 June 1993. Arthropod abundance is not significantly related to dune age ($p=0.183$, $r^2=0.183$).

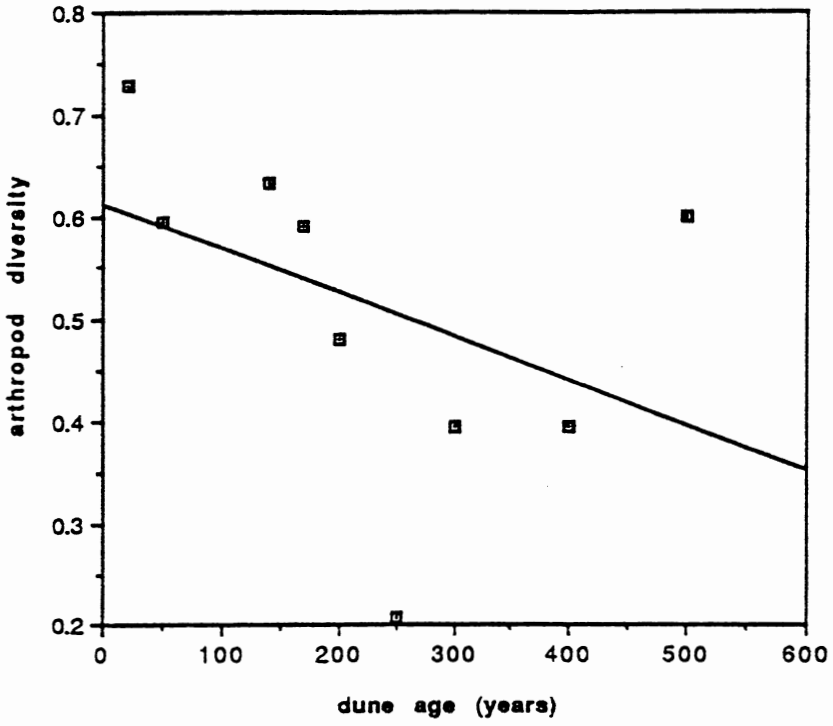


Figure 7. Diversity of arthropod taxa in leaf litter from nine dated dune ridges at Sturgeon Bay, Wilderness State Park, Michigan, 1 June 1993. Arthropod diversity is not significantly related to dune age ($p=0.252$, $r^2=0.182$).

Table 1. Plant species identified on nine aged dune ridges at Sturgeon Bay, Wilderness State Park, Michigan, 1 June 1993, by the General Ecology class from the University of Michigan Biological Station. Number of individuals found per quadrat (about 4.5 square meters), or X indicates presence on dune ridge, but not in quadrat. (After calculation of diversity and richness, data were lost for dunes 2, 4, 5, 7, 9, so are not presented).

	dune ridge								
dune ridge	1	2	3	4	5	6	7	8	9
age estimate (years)	20	50	140	170	200	250	300	400	500
species									
Ammophila breviligulata	221								
Salix sp.	X								
Calamovilfa longifolia	2		14						
Solidago hispida			45						
Brassicaceae sp.			20						
Equisetum laevigatum			17						
Larix sp.			X						
Arctostaphylos uva-ursi			18			X			
Smilacina stellata			10			X			
Thuja occidentalis			X			X			
Grass sp.			29					12	
Juniperus horizontalis			X					2	
Pinus resinosa			X					X	
Pinus strobus			X			X		X	
Trientalis borealis						45			
Linnaea borealis						35			
Cornus canadensis						24			
Juniperus communis						24			
Chimaphila umbellata						13			
Maianthemum canadense						8			
Aralia nudicaulis						X			
Cladina sp.						X		X	
Abies balsamea						X		X	
Pteridium aquilinum								2	
Quercus rubra								1	
Betula papyrifera								X	
Amelanchier sp.								X	
Richness in Quadrats	3	5	6	7	5	6	7	4	8
Richness total	3	6	8	13	14	12	17	11	14
Diversity	0.022	0.473	0.797	0.574	0.506	0.721	0.610	0.398	0.545

Table 2. Arthropod taxa from nine differently aged dune ridges at Sturgeon Bay, Wilderness State Park, Michigan, 1 June 1993. Taxa were extracted from leaf litter using Berlese funnels and identified by the General Ecology class from the University of Michigan Biological Station. Shown are number of individuals of each taxon from each dune ridge. Dune age estimates are shown in Table 1.

	dune ridge									
taxon	1	2	3	4	5	6	7	8	9	total
Isopod	1		4	3	2		3			13
Millipede			1						1	2
Centipede				1						1
Pauropod			4	1					1	6
Symphyla				2	1					3
Pseudoscorpion		1		4			2			7
Mite	3	7	31	205	43	79	547	189	119	1223
Spider	2	6	5	28	7	11	32	5	18	114
Proturan	1		2	5			3			11
Dipluran				2			2		22	26
Springtail	1	1		75	20	536	303	134	99	1169
Harvestman				3						3
Bristletail				3					1	4
Fly				8			3	7	9	27
Thrips				2						2
Beetle	1		1	3	1		1			7
Bug				2				3		5
Hymenoptera		6	8			1	5	2	8	30
Total Number	9	21	56	347	74	627	901	340	278	2653
Richness	6	5	8	16	6	4	10	6	9	
Diversity	0.728	0.596	0.634	0.591	0.480	0.207	0.395	0.394	0.601	