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Island Biogeography Theory Applied to Parking Lot Islands

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The Assignment: Island Biogeography theory has application to wildlife conservation. The basics of the theory have relevance of the distance and size of an island to rates of species immigration to the island and extinction of species on the island. You are to explore the theory where the islands are planted areas within College parking lots and the "mainland" is to be decided and write a research paper.

Abstract

Island biogeography theory has often been applied to the study of land habitats to predict species diversity and number. The objective of this study was to determine whether MacArthur and Wilson's island biogeography theory applies to islands of land in a parking lot area. Several areas were measured and the bordering ones designated 'mainlands' and smaller ones within the parking lot 'islands'. Invertebrates were selected as the species to study and samples were collected from above ground and the soil. Measurements of soil moisture and light were collected at the same time.

A chi-square analysis was done to compare species richness and number between the study sites. The results suggest that the theory of island biogeography was not supported in this case; the island size-species diversity and distance-species diversity ratios did not hold true for the sites studied. However, correlation was found between species richness and soil moisture and species diversity and soil temperature. The only area that showed significant variation in species index was a naturalized prairie area, suggesting that anthropogenic changes to the landscape, such as cultivating large areas of a single plant species and mowing such planted areas down, need to be accounted for.

Introduction

The equilibrium theory of island biogeography as proposed by MacArthur and Wilson, predicts low species diversity on islands (Krohne 1998). According to this theory, islands that are smaller or farther from the mainland will be lower in species number and diversity (Odum 1993). The species population on an island will not be as stable as on the mainland because colonization and extinction determine the population of an island (Krohne 1998). Islands are populated by species from the mainland and other islands, but because of their small size can only support a limited number of species, so many of the species that do reach them will die out. When the rate of extinction is exactly balanced with the rate of immigration, the island's population should reach equilibrium. Two islands of the same size should have similar rates of extinction, but if one is farther away, its population will be less diverse because it is more difficult to emigrate to.

A key point of this theory is that isolation causes lack of diversity (Cotgreave and Forseth 2002). Thus it can be used to predict species composition not only on islands in the ocean, but also on any other kind of habitat that is small and isolated from a larger, more diverse area (Townsend and Begon 2003). From the time of its development in 1963, island biogeography theory has been applied to the study of fragmented habitats disrupted by human development (Wu and Vankat 1995). It has been widely used to develop design theories for nature preserves in areas already developed, and thus has had an important impact on conservation efforts (Dodson et. al. 1998). Using the model of species migration and extinction provided by island biogeography theory, conservationists came to the conclusion that to be effective, nature reserves needed to be large and that multiple reserves should be connected by corridors to facilitate

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migration (Wu and Vankat 1995). In addition, it became accepted that fragmentation of habitat led to species extinction (Jules 1998).

The applicability of island biogeography theory to fragmented habitats has been disputed by many studies, but no conclusive studies have been able to completely discount its reliability as a predictor of population diversity (Farina 1998). One of the major factors that needs to be researched is the population of the ocean of the surrounding landscape, which in many cases, can still support at least a limited number of species (Cook 2002).

It has been suggested that with modifications the theory can still reliably predict species diversity in fragmented natural areas (Cook 2002). For example, the theory is well suited to the study of natural areas in urban landscapes because these areas may be very isolated from each other and developed land such as parking lots or buildings cannot usually support more than a few species (Melles 2003, Cook 2002). However, although the parking lot area is inhospitable, it may not be as much of a barrier to animals as water is (Cook 2002). It is likely that species can migrate across it and perhaps even live on it (Melles 2003).

Using the landscaped areas in a parking lot, this paper focuses on island biogeography theory as applied to habitat fragmentation. The populations of macroinvertebrates on different islands and mainlands were compared to determine whether the distance and species-area relationships found on islands are applicable to the study of land islands. Macroinvertebrates were selected as the subject to study because they are likely to be found on the small habitat niche provided by the islands, which probably cannot support many larger animals (Gullan and Cranston 1994). Macroinvertebrates play an important role in decomposition, nutrient recycling, and soil mixing. They also provide food for other animals such as birds, and help support plants as pollinators.

Methods

The study site was located on the southwestern side of the main campus buildings of College of DuPage, which serves some 34,000 students in Northeastern Illinois. A naturalized tallgrass prairie and two lawns designated South mainland and West mainland, which bordered the parking lot, were considered the mainlands. The prairie is the result of a 20-year re-creation effort to preserve the native plants of Illinois in their natural habitat. The two lawn mainlands are mostly planted with grass. The islands are four smaller planted areas within the parking lot and surrounded by the three mainlands.

The area of each of the islands and mainlands was measured in square meters to test the island size-species diversity ratio. The distances between the different areas were also measured. The narrow west edges of North, Central and South Islands are 7.4 m from the West Lawn, which is the strip of mowed lawn around the edge of the prairie. The long edge of South Island is 10 m from the South Lawn, which was a mowed area. The L-shaped East Island has a southern length (70 m) that is 10 m from the South Lawn. The remainder of East Island faces South and Central Islands (8 m distance). Eight meters separate North Island from Central Island, and Central Island from South Island.

Above-ground samples of invertebrates were taken in late September, 2003. At the same time, the quantity of light reaching the soil and soil temperature were measured at 3cm depth using a DataMeter 1000 (DCP Microdevelopments Limited, Norfolk, UK). During early October 2003, 1-liter soil samples were taken from each of the study sites for analysis of soil invertebrates. The invertebrates were extracted using a Tullgren funnel. A portion of the soil was weighed and dried in an oven set at 60° C. Weight loss was used to determine the fraction of moisture content.

Species richness was equated to the number of species found above ground per sample site. The species diversity of the soil fauna was computed using the Shannon formula to compare species richness of the areas studied. Chi-square goodness of fit tests were used in pair-wise comparisons of species richness between sample sites. Linear correlation analysis was used to test for associations between diversity and physical measurements. It was predicted that the central island, which borders the prairie and three other islands would have the greatest species number and diversity, potentially followed by South Island and East Island. North Island was predicted to have the lowest species diversity, because it is near the SRC building of the college campus.

Results

An analysis of the data showed that the variety of species present on the prairie far outnumbered that of any of the other sites studied (Table 1). The prairie contained almost every species found on any of the other sites. The abundance of soil macro-invertebrates on the sample sites demonstrates that the prairie had the most varied number of species as well (Table 2). For example, the prairie had 1 to 3 invertebrates from each of 7 species, whereas the East Island had a total of 18 invertebrates from 3 species, with one species heavily represented.

Macroinvertebrate diversity and selected physical measurements are provided in Table 3. The data indicates that the species-island size ratio predicted by island biogeography theory does not hold true for this study. For example, less than half as many species were found on the South lawn as on the prairie, which is far smaller. The diversity of the prairie was also much greater than that of the South lawn. Of the other sites studied, not only was the variation of species between islands found to be non-significant, but those of the two lawn mainlands were not significantly greater than the species diversity of the islands either even though one (the South lawn) was much larger than any of the islands (Table 3).

A comparison of species richness show that the prairie's species richness was significantly greater than that of any other site studied (Table 4). No other site showed a significant difference in species richness. Comparison between diversity measurements and physical measurements taken from study sites revealed that two physical factors, soil moisture and temperature, can be linked to the species population of the islands (Table 5). The number of species increased with fractional soil moisture (which was greatest on the prairie) and the variety of species decreased with the increase of temperature on the sites studied (which was highest on the lawn mainlands and North Island). No other significant correlations were found between sample site comparisons.

Discussion

This study applied island biogeography theory to parking lot islands to determine whether it could be used to predict their species number and richness. The overall conclusion is that there was no significant evidence that supported island biogeography theory. There was very little variation of species populations among sites examined, not only of the islands, but of two of the mainlands as well. The only exception to this was the prairie mainland. However, it may be that other factors influenced the results.

One of these factors might be the plant varieties present on the areas studied. The species richness and number of invertebrate populations have been closely linked to the number and variety of plant species in the same area (Gullan and Cranston 1994). The re-created prairie is the only area studied that appeared to have a relatively varied and natural plant population. Its high species diversity and richness in relation to the other sites suggest that the prairie was the actual source of invertebrates now present on the lawn mainlands as well as that of the islands. If this were true, the same could not be said for the plant population. The plants were selected by humans and might not be native to the area. The introduction of exotic plant species may have affected the native invertebrate population.

Another possible explanation is that in the South and West mainlands the homogenous plant populations (mowed grass) affected the invertebrate population. The islands, while consisting for the most part of mowed grass, did have some trees, shrubs, and a few perennials on them (perhaps lowering soil surface temperature). This may have nullified the differences in invertebrate populations that could otherwise have existed between the islands and the lawn mainlands.

Island biogeography theory proposes that the farther an island is from the mainland, the lower its diversity (Krohne 1998). North, Central, and South Islands were spaced out approximately the same distance from each other and the prairie. North Island was thought to be the most isolated because it was closest to a building. However, if the prairie was the source of the migrant invertebrate population, this might not be significant. Because there was not much difference between distances from the prairie to the other sites, perhaps island biogeography theory is actually supported.

One significant correlation was found between soil moisture and species richness and another between soil temperature and species diversity. Species richness increased with fractional soil moisture and species diversity decreased with soil temperature. Soil moisture and soil temperature appeared to be the main determiners of species number and diversity on the areas studied. The plant population of the islands and mainlands was not recorded in this study, but it could be an important determining factor of species population, and island biogeography theory could be further explored by investigating this.

The results of the study suggest that there are many factors that can be considered in future studies. Research could focus on the effects of soil temperature and moisture on species richness and diversity. Future studies on island biogeography theory as applied to land habitats might need to investigate the effect of the plant population on the invertebrate population and the effect of non-native plant species on indigenous invertebrates. This could further the development of the application of island biogeography theory to urban and landscaped areas.

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Table 1. Macroinvertebrate species found above ground at each site studied. Symbols: P=re-created tallgrass prairie; WL=west lawn; SL=south lawn; N=north island; C=central island; S=south island; and E=east island; x=presence of species on site studied.

Taxon	Mainlands			Islands			
	P	WL	SL	N	C	S	E
Gastropod slug					x		
Lumbricus	x	x	x	x		x	
Oribatid mite (O. Acari)	x			x	x		x
Red mite (O. Acari)	x						x
Spider mite (O. Acari)	x	x				x	x
Opiliones (O. Acari)	x	x	x	x			
Lycosidae (O. Aranea)	x				x		
Oniscus (O. Isopoda)	x	x	x	x	x	x	x
O. Spirobolida (Milliped)	x			x	x	x	x
O. Lithobiomorpha (Centipede)	x					x	
O. Protura (Proturan)		x				x	
Entomobryidae (Springtail)	x				x	x	
Onychiuridae (Springtail)	x		x	x	x		
Cicadidae (Cicada)						x	
Acridinae	x	x				x	x
Melanoplus femurrubrum (Grasshopper)	x	x		x	x	x	x
Attonemobius (Field cricket)	x	x					x
Gryllus pennsylvanicus (Field cricket)	x	x					
Coenagrionidae (Damselfly)	x						
Dermaptera (Earwig)			x				
Aphidae (Aphid)			x		x		
Incompletes fasciatus (Large milkweed bug)	x						
Cicadellidae (tree hopper)	x						
Thripidae (Thrip)			x				
Noctuidae (Noctuid moth)	x		x			x	
Vanessa atalanta (Red Admiral)	x						
Pieridae (Cabbage butterfly)	x						
Carabidae (Ground beetle)	x						
Coccinellidae (Ladybug)	x	x	x	x	x		
Cucujidae (Flat bark beetle)	x						
Apion rostrum (Weevil)	x						
Elateridae (Click beetle)				x			
Histeridae (Hister beetle)	x						
Mycetophilidae (Fungus gnat)	x		x				
Cecidiomyiidae (Goldenrod midge)	x						
Tipulidae (Crane fly)	x					x	
Syrphidae (Flower fly)	x						
Stratiomyiidae (Soldier fly)	x						
Tephritidae (Goldenrod fly)	x						
Muscidae (House fly)	x		x				
Tachnidae (Tachnid fly)	x		x				
Vespula (Yellowjacket)	x	x					
Bombus	x						
Halictus (Halictid bee)	x	x					
Chalicidae	x						
Formica (Red ant)	x	x	x			x	x
Formica (Black ant)	x	x	x	x	x		
Lasius claviger (Field ant)	x	x					

Ponera (Ant)	x					x	
Taxon	Mainlands				Islands		
	P	WL	SL	N	C	S	E
Solenopsis molesta (Thief ant)	x	x	x	x			
Tetramorium caepitatum (ant)	x	x	x		x		

Table 2. Abundance of macroinvertebrates according to taxon collected from soil samples from the study sites. Symbols: P=re-created tallgrass prairie; WL=west lawn; SL=south lawn; N=north island; C=central island; S=south island; and E=east island.

Taxon	Abundance						
	Mainlands				Islands		
	P	WL	SL	N	C	S	E
Oribatid mite (O. Acari)	3			14	1		10
Spider mite (O. Acari)	1	1				2	6
Red mite (O. Acari)							2
Lycosidae (O. Aranea)					1		
O. Spirobolida (Millipede)				1			
O. Protura (Proturan)		1				1	
Entomobryidae (Springtail)	2				1	1	
Onychiuridae (Springtail)	3		1	7	2		
Aphidae (Aphid)			3		1		
Thripidae (Thrip)			3				
Cucujidae (Flat bark beetle)	1						
Elateridae (Click beetle)				1			
Chalicidae	3						
Ponera (Ant)						1	
Solenopsis molesta (Thief ant)	2	31	2	1			

Table 3. Comparison of island and mainland size; species number and diversity; soil moisture, soil temperature, and light penetration at 3 cm.

Study Sites	Area m2	Species richness	Shannon diversity	Fraction soil moisture	Surface soil temperature C°	Light
Mainlands						
Prairie	12000	44	1.864	0.228	15.05	88
West Lawn	900	17	0.271	0.0971	19.2	91
South Lawn	20000	16	1.31	0.148	18.7	87.5
Islands						
North	567	11	1.071	0.1728	17	87
Central	980	12	1.56	0.1024	16.1	87
West	1253	14	1.333	0.1383	16.65	91
East	2520	9	0.937	0.0972	19.9	91

Table 4. Chi-square statistics of goodness of fit tests comparing species richness between sample sites. *denotes significance at p<0.05. All df=1. Symbols: P=re-created tallgrass prairie; WL=west lawn; SL=south lawn; N=north island; C=central island; S=south island; and E=east island.

	WL	SL	N	C	S	E
P	*12.0	*13.1	*24.8	*23.3	*20.5	*27.8
WL		<0.01	2.1	1.5	0.5	3.8
SL			1.5	1.0	0.3	3.1
N				<0.01	0.4	0.2
C					0.2	0.4
S						1.1

Table 5. Correlation coefficients (r) from linear correlation analysis between diversity measurements and physical measurements taken from the study sites. *denotes significance at p<0.05. All df=5

Physical variable	Shannon Diversity	Species richness
Soil moisture	0.63	*0.78
Area of site	0.41	0.46
Soil surface temperature	*-0.78	-0.58
Surface light reception	-0.57	-0.18