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LUPINUS ARBOREUS AS AN ISLAND

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Abstract

Four areas of Lupinus arboreus, one in Marin County, and three in San Francisco, were sampled, and the arthropod populations residing on them were counted. The data were analyzed and discussed according to the theory of island biogeography (MacArthur and Wilson, 1967). The data were arranged to show that the four areas of lupine represented islands to their respective faunas of herbivores and predators. Species and Individuals Curves were graphed, although several assumptions were made to permit this. The species/area relationship ($S = CA^2$) failed to describe the relative numbers of species found in the samples. The analysis of plant species as islands is discussed, and some problems considered.

Introduction

There are many ways to explain the distribution and abundance of species in an environment. The theory of island biogeography (MacArthur and Wilson, 1967) examined this problem from the perspective of islands. Their theory states that an island reaches an equilibrium number of species through a balance of immigration and extinction, and that the equilibrium number of species is a function of the area (diversity) of the island.

This theory has suggested applications to mainland "islands", in which physical factors can produce isolation of an area similar to the way in which water isolates islands. The theory has also been suggested to apply to specific plants and their resident insect and

arachnid communities (Janzen, 1968 and 1973). As in islands, immigration rates and extinction rates determine the equilibrium number of species. For example, a factor determining the immigration rate can be a plant's taxonomic distance from adjacent plants; and a factor determining the extinction rate can be the number of species already present on the host plant. Although Janzen modified his argument in his later article, he still suggests that if plants and herbivores are species-specifically related, a "mainland island" might be observed.

Opler (1974) provides an example of how host specificity could be used in the analysis of oaks as islands for leaf-mining insects. The extreme host specificity of the leaf-miners leads to distinct patterns in their distributions, which can be shown to be dependent on the abundance and distribution of the host oak.

In the present study, Lupinus arboreus was selected to examine the possibility that it represents an island to those species of herbivores which have been able to penetrate its defenses, and can utilize the plant as a resource. The herbivores would be preyed upon by other insects and arachnids, and the whole community could be regarded as an island, with the number of species present depending on the size of the lupine population. Since it is not literally true that the lupine is an island, many assumptions have been made in order to apply the analysis presented by MacArthur and Wilson to the data obtained in this study.

Materials and Methods

Lupinus arboreus is a member of the pea family (Leguminosae), and is a native California plant. A perennial plant, it is usually found in sandy, poor soil. It is very common in some areas of Point Reyes,

and can be found in San Francisco in some of the few remaining dune areas, or in vacant lots.

Sampling was performed at four locations: one in Marin County in Point Reyes National Seashore; and three locations in San Francisco. The areas are illustrated in Figure 1. The land areas occupied by the lupine were estimated, though the patch on 7th Avenue could be paced-off and measured. A permit from the U. S. Park Service was obtained to allow sampling in Point Reyes. The lupine of these four areas were considered to be islands for the arthropod fauna found on them.

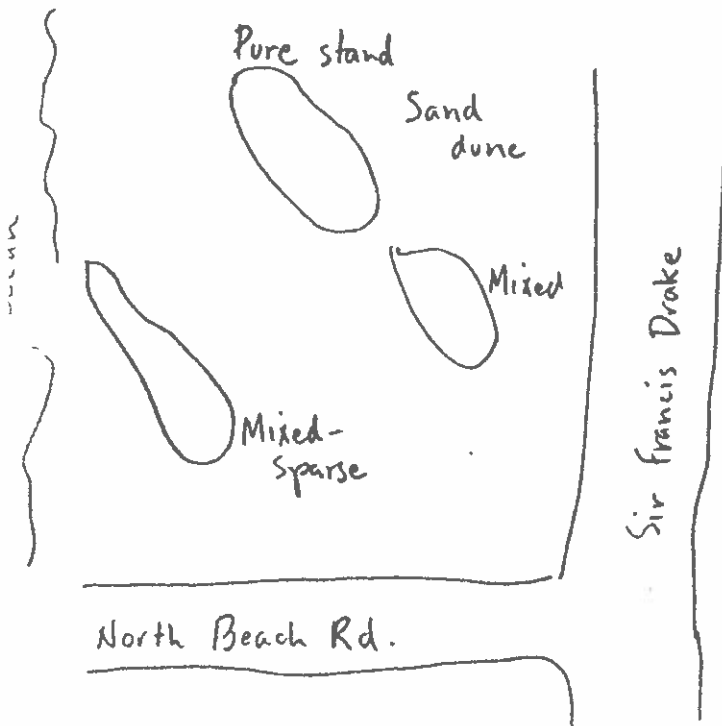
Sampling was performed on different dates for the four areas: Point Reyes was sampled on November 9 and 25; 7th Avenue and Winston were sampled on December 8; and 15th and Aloha was sampled on December 10, 1979.

Insects and arachnids were collected from the lupine in the following manner: a sweep net was held beneath the lupine foliage, and the plant was rapped firmly with a stick to dislodge the animals clinging to the plant. Care was taken not to damage the plants during the collection process. The animals collected were later killed and counted in the laboratory. They were sorted to Order, and subsequently divided to "species" on a visual basis, and given a number as identification. No attempt was made to determine if the species found in one sample site were identical to those found at other sites, though several species seemed to be present in all of the samples. There was also no attempt to identify the animals taxonomically. Various methods were used to kill the insects: immersion in alcohol,

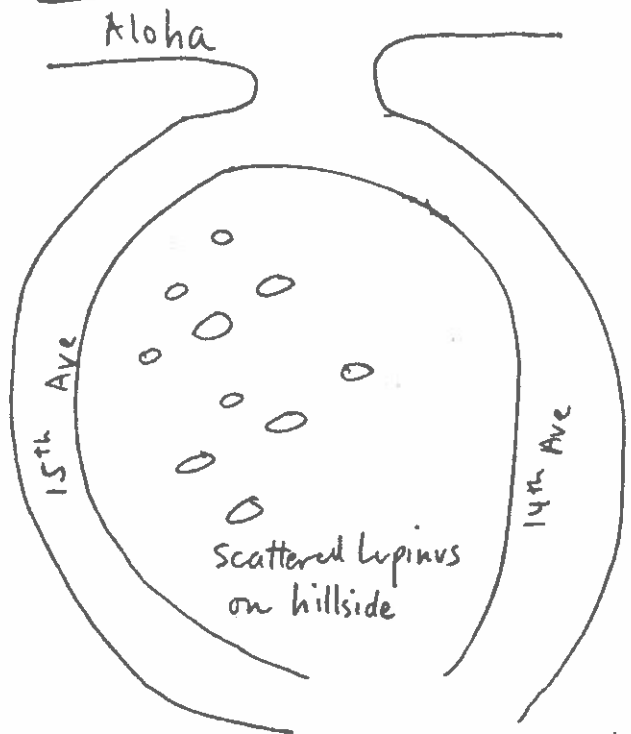
FIGURE 1

SCHEMATIC MAPS OF THE FOUR AREAS CONTAINING LUPINUS ARBORE

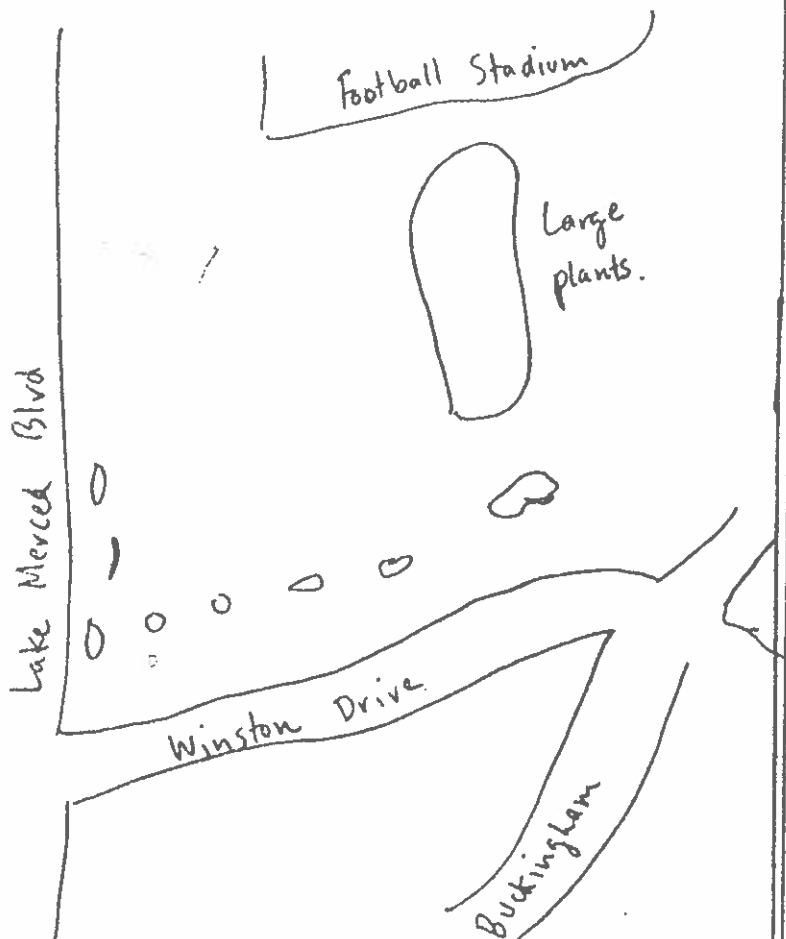
Point Reyes, Marin County



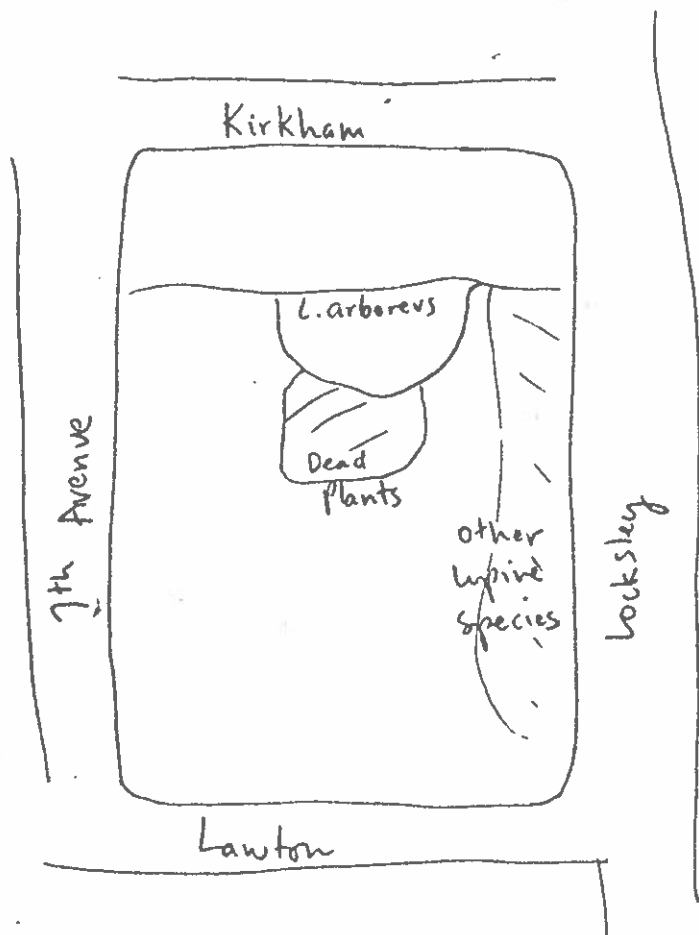
15th Avenue + Aloha, San Francisco



Winston Drive, San Francisco



7th Avenue, San Francisco

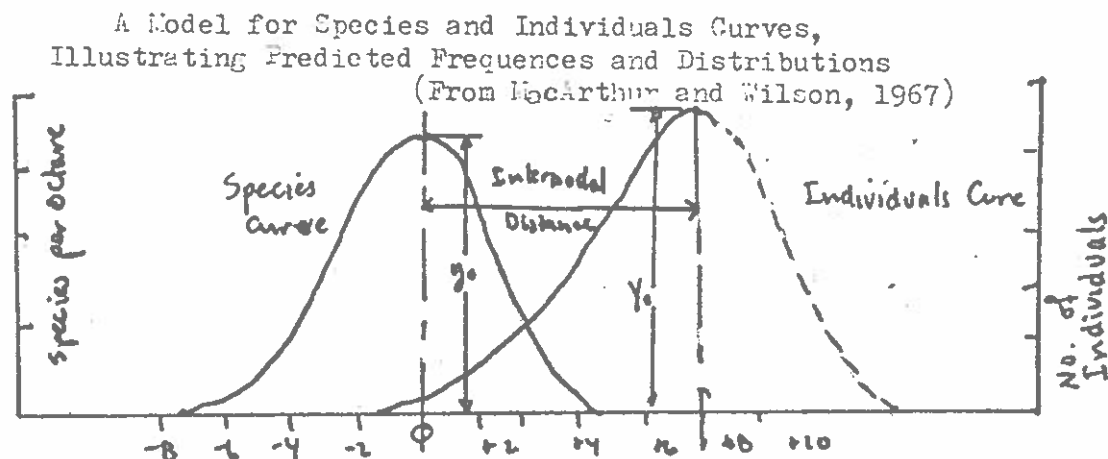


freezing, and placement in an ethyl acetate killing jar. The last method was preferred, although the subsequent sorting process in all cases was lengthy. A flotation technique should be used in order to shorten the time involved in separation the organisms from the lupine vegetation.

Results

The list of species and their frequencies, by sample site, are provided in Tables 1 and 2 respectively.

Species and Individuals Curves were constructed, as outlined by MacArthur and Wilson (1967). (Figure 2). The basis for Figure 2 is the following graph:



The figure above expresses certain relationships of expected frequencies of species on islands, and may apply to any natural community. Both the distribution of species and of individuals is "log-normal" when plotted against the log of the number of individuals. The two normal curves are separated by an intermodal distance, which is determined by the parameters of the population.

In the graphs presented in Figure 2, the number of individuals per species was transformed to their log base 2 values, and plotted

Table 1
Numbers of Species Captured, by Area

Arthropod Order and Species Number		Point Reyes	15th and Aloha	Winston	7th Avenue
Araneida	1	35	12	10	
	2	11	5	2	
	3	2	1		
	4	2	1		
	5	2			
	6	1			
	7	1			
	8	1			
Acari	1	7	24	42	7
	2	3			
	3	2			
Collembola	1	19			
	2	2			
Colleoptera	1	16	5	46	5
	2	12	5	8	2
	3	2			
	4	1			
	5	1			
Diptera	1	14	5	2	
	2	11	1	1	
	3	3	1	1	
	4	2	1	1	
	5	2		1	
	6	1			
Hemiptera	1	18	33	1	2
	2	15	7		1
	3	1	7		
	4		3		
	5		2		
	6		1		
	7		1		
Homoptera	1	201	15	7	22
	2	17			
	3	7			
	4	4			
	5	1			
Hymenoptera	1	76	6	4	6
	2	40	6	3	1
	3	25	2	1	1
	4	6	1		1
	5	5	1		
	6	4			1
	7	4			

Table 1 Page 2

Arthropod Order		Point Reyes	15th and Aloha	Winston	7th Avenue
Psocoptera	1	46	2		3
	2	4			
Thysanoptera	1	154	84	2	22
	2	74	4		
Tricoptera	1		1		
Larvae (Unidentified)	1	6	7	1	1
	2	1	2		
	3	1	2		
	4	1	1		
Number of species		47	32	18	14
Number of individuals		872	249	123	75

Table 2

Frequencies, Number of Individuals, and Log base 2 of Species

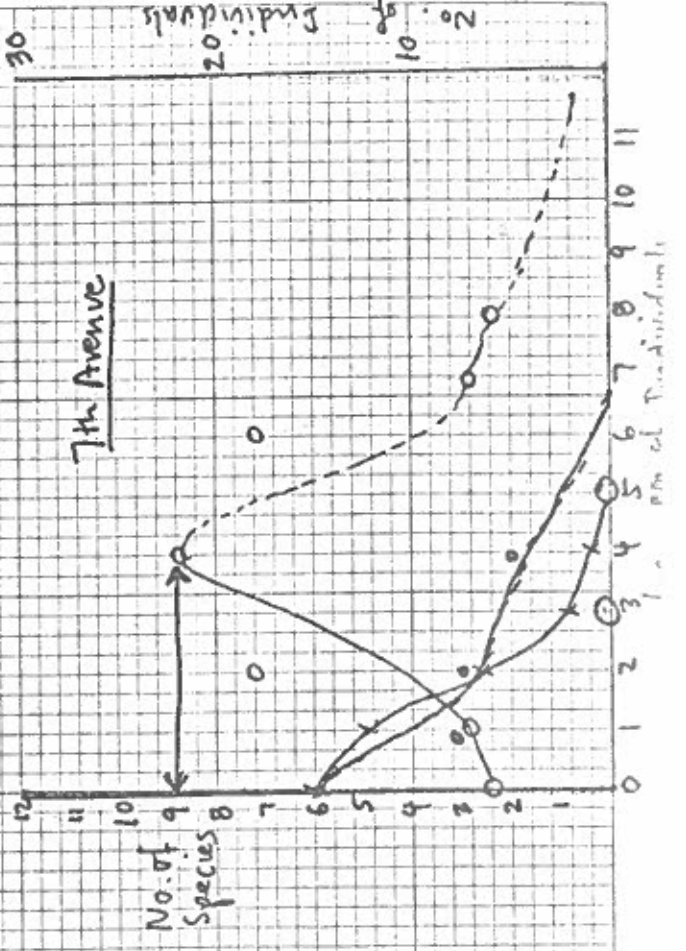
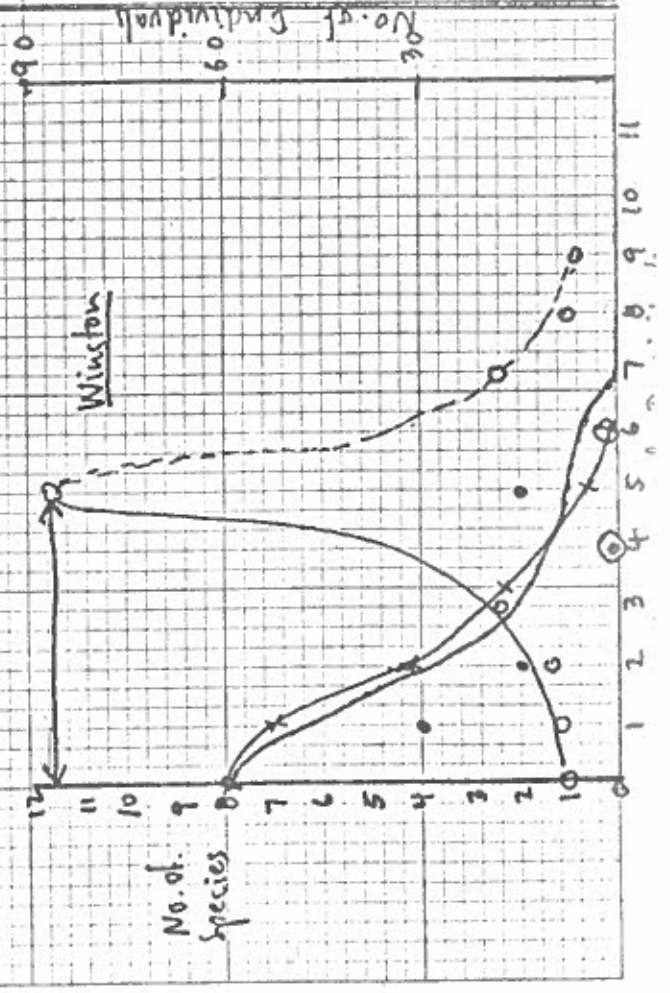
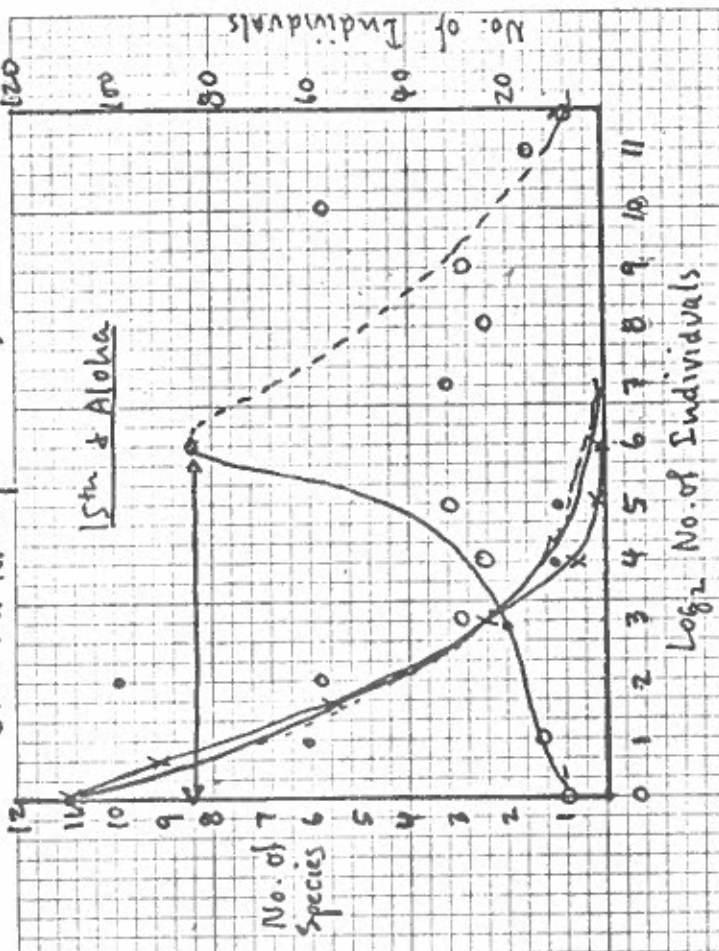
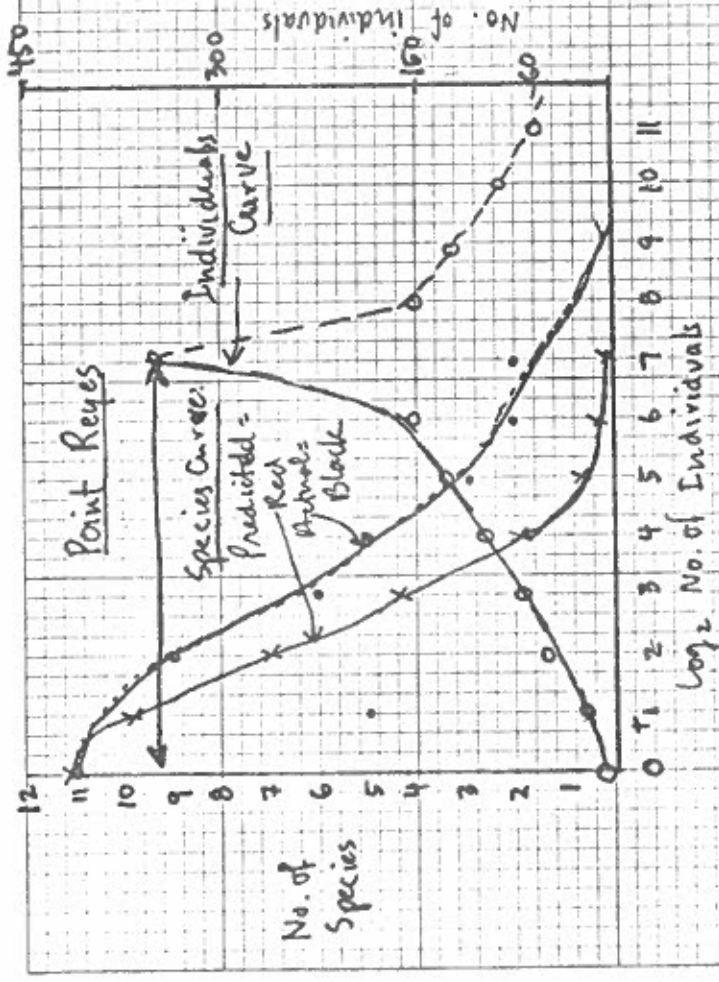
Point Reyes			15th and Aloha			Winston			7th Avenue		
Freq.	No. of Indiv.	Log ₂	Freq.	No. of Indiv.	Log ₂	Freq.	No. of Indiv.	Log ₂	Freq.	No. of Indiv.	Log ₂
1	201	7.65	1	84	6.39	1	46	5.52	2	22	4.96
1	154	7.27	1	33	5.05	1	42	5.39	1	7	2.81
1	76	6.25	1	24	4.50	1	10	3.32	1	6	2.58
1	74	6.21	1	15	3.91	1	8	3.0	1	5	2.31
1	46	5.52	1	12	3.58	1	7	2.81	1	3	1.58
1	40	5.32	3	7	2.81	1	4	2.0	1	2	1.0
1	35	5.13	2	6	2.58	1	3	1.58	6	1	0.0
1	25	4.64	4	5	2.32	3	2	1.0			
1	19	4.25	1	4	2.0	8	1	0.0			
1	18	4.17	1	3	1.58						
1	17	4.08	5	2	1.0						
1	16	4.0	11	1	0.0						
1	15	3.91									
1	14	3.81									
1	12	3.58									
2	11	3.45									
1	10	3.32									
2	7	2.81									
2	6	2.58									
1	5	2.32									
4	4	2.0									
2	3	1.58									
7	2	1.0									
11	1	0.0									
Σ	47		32			18			14		
$\bar{X}$	18.55	2.50		7.78	1.70		7.44	1.47		5.36	1.45
S^2	1461	4.6		242.8	2.99		184.7	3.38		53.78	2.73
S	38.2	2.14		15.58	1.73		13.59	1.84		7.33	1.65
σ		.33			.409			.384			.428

Table 3

Data for Species and Individuals Curves
 (Actual and Predicted Number of Species by Octave Distance from Mode)
 (Number of Individuals per Octave Interval)

Octaves	Point Reyes			15th and Aloha			Winston			7th Avenue	
	Act.	Pred.	No. of Indiv.	Act.	Pred.	No. of Indiv.	Act.	Pred.	No. of Indiv.	Act. Act	Pred.
$y_0(0-1)$	11		11	11		11	8		8	6	
1-2	5	9.82	20	6	9.3	13	4	6.9	9	3	4.99
2-3	9	7.11	47	10	5.6	57	2	4.43	11	3	2.88
3-4	6	4.12	73	2	2.45	27	2	2.12	18	0	1.15
4-5	5	1.93	94	1	.76	24	0	.752	0	2	.42
5-6	3	.73	121	1	.165	33	2	.2	88		
6-7	2	.22	150	1	.022	84					
7-8	2	.05	355								

FIGURE 2
GRAPHS OF SPECIES AND INDIVIDUALS CURVES, AFTER MACARTHUR & WILSON (1967)
(See text for explanation).



against the number of species (Species Curve) and the number of individuals (Individuals Curve).

Several assumptions were made in order to graph the data:

1. It was assumed that the modal point on the curve was the most common frequency of species obtained. For all samples, the modal point (y_0) is equal to one. This corresponds to an additional assumption that only one-half of the resident species population was actually captured.

2. The actual frequency of species versus the log number of individuals was compared to a predicted value. This frequency is shown on the graph in red, and the formula from MacArthur and Wilson is: $y = y_0 e^{-(aR)^2}$; where y_0 is the modal point (one, in all cases), R is the number of octaves distance from the modal point (by powers of 2), and the value of "a" is calculated from the data and the formula "a" = $\sqrt{\frac{1}{2}5^2}$.

No test of significance was applied to determine the degree of relationship between the observed and predicted values of the Species Curve.

3. The Individuals Curve is drawn with the assumption that the data is log-normally distributed. The validity of this assumption was not tested.

Area Relationship

In island situations, the number of species is related to the size of the island by the following relationship: $S = CA^z$; where S is the number of species, C is a constant, A is the area, and z is a constant which depends on the area being examined. The value of z is generally between .20 and .35 in island situations, but lower in mainland habitats due to the presence of many more "accidental"

species.

The most interesting use of the area/species relationship involves the calculation of the value of z , which is of biological significance: the value represents the degree of isolation of the community studied. In general, the higher the z value, the greater the degree of isolation.

The data obtained could not be analyzed to provide a z value of significance. The following chart shows what happens if z is assumed to be a certain value; a " z " value would fit the data if the resultant value of " C " is close to constant for the four sample areas.

Values of " C " Based on Assumed " z " Values of .25, .05, and .01:

Applied to the Relationship $C = \frac{S}{Az}$					
	Point Reyes	15th and Aloha	Winston	7th Avenue	
No. of Species (S)	47	32	18	14	
Estimated Area, in square miles (A)	10	5.79×10^{-5}	3.86×10^{-5}	1.54×10^{-5}	
Value of Az :					
1. $z=.25$	1.78	.087	.078	.062	
2. $z=.05$	1.12	.613	.602	.574	
3. $z=.01$	1.02	.9	.88	.89	
Values of C :					
1.	26.4	367.8	230.8	223.6	
2.	41.96	52.2	29.9	24.4	
3.	46.1	35.5	20.5	15.7	

The chart shows that the " C " values are widely divergent for " z " values in the range of .25, but can be narrowed if z values are taken as very small. This implies that the area affect is also very small, if the data collected are representative of the actual faunas inhabiting the different areas of lupine. The resulting C values however are much too high for the relationship to be of biological significance.

Discussion

The distribution of frequencies of individuals in a community may take on a lognormal distribution. In this study, a log-normal distribution of species was assumed, although perhaps only one-half of the distribution could be seen (Figure 2). The actual correspondence of the data to the log-normal distribution was not tested. It does appear from the collections made that one species tended to predominate over other "related" species in the same order: only rarely did two species in the same order appear in equal frequency. It is not easy to attach significance to this result. Although a log-normal distribution may be the result of niche partitioning (Price, 1975), the distribution found in the data do not correspond to any particular model. For example, we can consider the distribution frequency of spiders at Point Reyes, accepting that eight species are truly present, and applying MacArthur's "Broken-stick" model: $E \frac{N}{N} a = \frac{1}{S} \sum_{j=0}^{S-1} \frac{1}{S-j}$ (Pielou, 1975):

Frequencies of species predicted:	1	2	3	5	7	10	14	21
Frequencies of species counted:	1	1	1	2	2	10	11	35

Though the approach is suggestive, the existence of any log-normal distribution of species is uncertain.

The area/species relationship is probably the most significant relationship if an island situation actually exists for lupine and its herbivores, but the results indicate that the relationship probably does not exist. Many problems contribute to obscure any possible relationship. Three major problems in the present study can be cited:

1. Sampling. The method chosen certainly did not get all the species present on the lupine, and the sample sizes were very different

among the four sample areas. Samples were also taken at different times, which may have affected the results in unknown ways.

2. Species specificity. The species of insects inhabiting the lupine would have to be species-specific if the island analogy is to be demonstrated. Neighboring plants need to be sampled to determine their degree of similarity of herbivore populations.

3. Species distribution. The mode of the species distribution was assumed to be equal to one: this is the most common frequency in which species were found. Sampling must be much more intense if this problem is to be overcome. The "veil" of the log-normal distribution was simply assumed in order to graph the data.

Conclusions

An analysis of four samples of Lupinus arboreus did not show that the lupine acts as an island for a community of herbivores and predators. A suggestion of log-normal distribution of the data obtained could not be verified, due to the small sample size. The species-specificity of lupine and its herbivores should be examined to see if the island relationship can in fact exist.

Acknowledgements

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