AN ABSTRACT OF THE THESIS OF

Daniel Keith Edwards for the degree of Master of Science

in Wildlife Science presented on March 9, 1979

Title: AN ANALYSIS OF AVIAN COMMUNITIES ON A DREDGED MATERIAL ISLAND

Redacted for privacy

Abstract approved: ______________________

Dr. John A. Crawford

The effects of habitat differences and seasonal changes on the number of species, bird density (birds/ha), bird species diversity (BSD), equitability, standing crop biomass, and species composition of several avian communities on a dredged material island were studied for 14 months. Two multivariate statistical methods were used to identity avian community-plant community associations of four habitats. Tree-shrub, upland, and beach-marsh avian communities were significantly different ($P \leq 0.05$) from each other with regard to number of species, bird density, BSD, equitability, and standing crop biomass; no significant differences were detected between beach and marsh areas. A unique group of bird species was associated seasonally with tree-shrub, upland, and several beach-marsh areas; beach and marsh associations were not distinguishable from each other. Seasonal

differences with respect to the five avian community parameters were detected.

Vegetative and physical complexity of the habitat were primarily responsible for differences among avian communities associated with various habitats. Avian migrational patterns possibly accounted for the seasonal differences among bird communities on Miller Sands.

The approach of considering both community parameters and species composition of different habitats apparently was more useful for identification of bird community-plant community associations than were either of the approaches if used individually.

AN ANALYSIS OF AVIAN COMMUNITIES ON A DREDGED MATERIAL ISLAND

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed March 1979

Commencement June 1979

APPROVED:

Redacted for privacy

Professor of Wildlife Science
in charge of major

Redacted for privacy

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Date thesis is presented March 9, 1979

Typed by Christine Dewey for Daniel Keith Edwards

ACKNOWLEDGEMENTS

This research was supported by the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, under contract Number DACW57-76-C-0180.

I would like to thank my major professor, Dr. John A. Crawford, for his unfailing support and advice throughout my project.

I would like to extend my appreciation to Mr. David M. Greer, Mr. Mark Hinschberger, and Mr. Daniel Bynon for their assistance in data collection and analysis. I would also like to thank Ms. Suzanne D. Daniell for her aid in data analysis and her unyielding moral support throughout my project.

I am grateful to the many members of the Lower Columbia River Refuge staff who helped me on numerous occasions.

I would also like to thank Dr. C. David McIntire, Dr. Paula Kanarek, and Mr. Neil Poulsen for their advice on statistical procedures and to Ms. Christine Dewey for typing several drafts of the manuscript.

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INTRODUCTION

Historically, several approaches were used for investigating relationships between plant and avian communities. Early studies primarily involved identification of groups of species which were associated with habitats and the relative abundance of birds within these habitats. Adams (1908) identified associations of breeding birds which were related to various seral stages on Isle Royale. He concluded that the number of species and complexity of the avian community increased as plant succession progressed. However, the complexity of the avian community decreased as the vegetative community approached climax. Aldrich (1945) reported similar results from breeding bird communities associated with a hydrosere in northeastern Ohio. Quay (1947) concluded that four associations of wintering birds were related to eight seral stages of an upland plant community near Raleigh, North Carolina. He determined that early successional stages supported the highest bird densities but that the greatest number of species occurred in the forest stages.

More refined studies involved use of various statistical procedures to detect relationships between avian and vegetative parameters. Johnston and Odum (1956), Karr (1968), Hooper et al. (1973), and Shugart and James (1973) concluded that the density of breeding birds was related to the complexity of the plant community which usually increased with the age. Results of other studies revealed that relationships existed between breeding bird species diversity (BSD) and such vegetation parameters as foliage height diversity and total vegetative cover (MacArthur 1964, MacArthur et. al. 1966, Recher 1969, Willson 1974). Linear and curvilinear regression procedures were used to test for significant relationships. Kircher (1972, 1973, 1975) used univariate analysis of variance to investigate the relationships between avian and plant communities at times of the year other than the breeding season on the New Jersey Piedmont. His work supported the contention that BSD increased with the age of the plant community. Contrastingly Anderson (1972) concluded that BSD was highest in the earliest seral stage of a mixed hardwood-coniferous forest; this stage supported the most complex understory. Several studies concluded that the equitability (J') (a measure of apportionment of individuals among species) remained relatively stable and that species richness was responsible for most of the variation in breeding BSD among different seral stages of the plant community. However, Kricher (1972) concluded that equitability was quite variable and played an important role in determining BSD at times other than the breeding season. Karr (1968) noted that the standing crop biomass of breeding bird communities in Illinois increased with the complexity of the vegetation. However, he considered consuming biomass a more meaningful measurement because it was related to the energy available in the system.

Recently multivariate statistical procedures were used to detect relationships between the breeding birds of an area and habitat. James (1971), Anderson and Shugart (1974), and Whitmore (1975, 1977) used ordination procedures to arrange bird species along multidimensional continua which represented gradients in the structure of the vegetation. Anderson and Shugart (1974) concluded that the presence or absence of some species was related to specific vegetative factors; whereas, the presence or absence of other species was related weakly to several habitat variables.

The purpose of this study was to evaluate the usefulness of six avian community parameters (bird density, number of species, BSD, equitability, standing crop biomass, and species composition) for detecting bird community-plant community associations. It was hypothesized that a combination of previous methods would better aid in the understanding of these relationships than the singular application of the procedures. To test this hypothesis, a relatively simple ecosystem, associated with a dredged material island was selected.

STUDY AREA

The study site, Miller Sands, a dredged material island, was located approximately 19 km east of Astoria in the Columbia River, Clatsop County, Oregon. Miller Sands was formed by deposition of dredged material which was initiated in 1932 and resulted in an island-marsh complex of approximately 228 ha.

The climate of the area, characterized by wet winters and dry summers, was classified as Pacific Northwest Maritime (U.S. Army Engineer District, Portland 1975). Average maximum summer temperature was 24° C and average maximum winter temperature was 10° C. Mean annual precipitation for Astoria was 127.5 cm per year (U.S. Department of Commerce 1974).

The dredged material on Miller Sands was classified as clean fine sand with 10% of the particles finer than 0.1 mm in diameter (U.S. Army Engineer District, Portland 1975). Organic materials in the form of logs and other debris occurred on some areas.

The Miller Sands complex consisted of two land types: an island (approximately 175 ha) deposited during the 1930's and a sand spit (approximately 53 ha) most of which was deposited between 1948 and 1974. The vegetation was categorized into four habitats on a life-form basis (Figure 1): beach, with little or no vegetation; marsh, composed of aquatic grasses and forbs; upland, characterized by grasses, forbs,

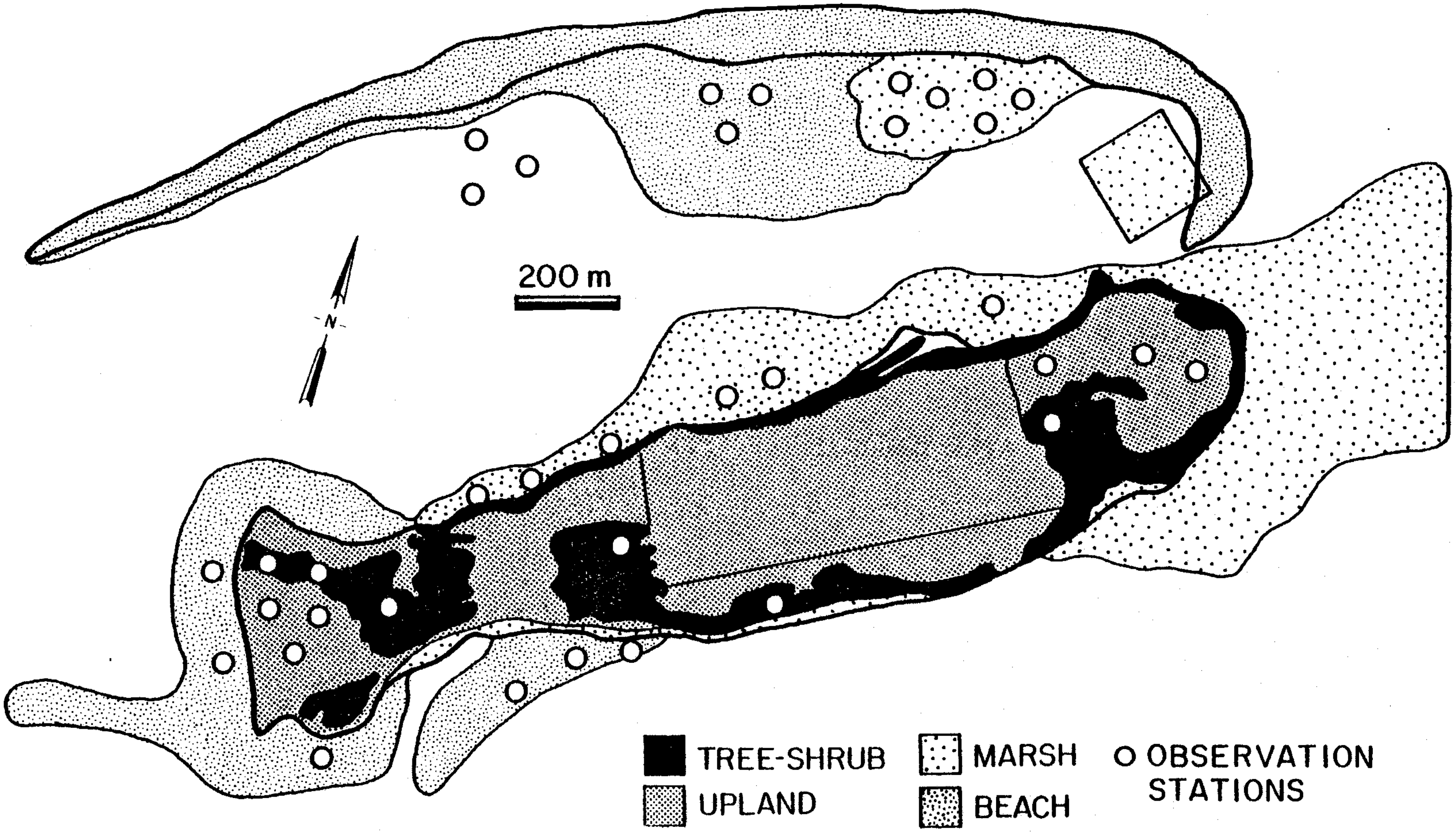

Figure 1. Location of habitat and observation stations on Miller Sands, Columbia River, Clatsop County, Oregon.

and mosses; and tree-shrub characterized by willow (Salix spp.), black cottonwood (Populus trichocarpa) and red alder (Alnus rubra). Beach, marsh, and upland areas were non-wooded. The island exhibited all four habitats; the spit consisted of marsh and beach.

The Coastal Zone Resources Corporation (1977) proposed a theoretical pattern of succession for Mott Island, located approximately 14.5 km southwest of Miller Sands. A sitka spruce (Picea sitchensis) forest was the theoretical climax for Mott Island. Soots and Parnell (1975) also proposed a general scheme for succession on dredged material. Vegetation usually developed first in the drift areas around the perimeter of newly deposited islands. Grasses and forbs were the pioneers; eventually these species covered the entire islands and tree-shrub species invaded the edges of the islands. Trees and shrubs usually covered entire islands after approximately 35 years in North Carolina (Soots and Parnell 1975). Similar patterns were noted on Miller Sands, however, the process may not proceed as rapidly in the Pacific Northwest, since Miller Sands was approximately 40 years old and much of its area was devoid of trees and shrubs.

The proposed pattern of plant succession for Miller Sands began with deposition of dredged material which resulted in a beach or upland habitats devoid of vegetation. Marsh replaced beach as silt raised the elevation of an area and marsh areas in some instances probably succeeded directly to tree-shrub sites. In areas above the high tide level, bare dredged material succeeded to an upland situation covered by grasses and forbs. The theory that upland sites progressed directly to tree-shrub areas was supported by the invasion of several upland sites by willow, black cottonwood, sitka spruce, Douglas fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) saplings. Beach and marsh areas varied more with respect to physical complexity than did upland and tree-shrub sites because of tidal inundation. The physical characteristics of beach and marsh sites varied from mud flats and marshes to open water.

METHODS

Twelve study areas were established in four habitats. Two study areas were located in each of the upland and tree-shrub areas; the marsh and beach habitats contained four study areas each (Figure 1). Three stations were established in each study area. Avian species composition and density were collected from each station between sunrise and 2.5 hr after sunrise twice monthly from July 1976 through August 1977. Birds which flew into an area from a different habitat were included in analyses only if their altitude was 40 m or less. The area from 0-40 m was considered the approximate distance between the lowest point at low tide and the top of the tallest tree on Miller Sands. All birds observed within the 0-40 m distance were considered using the habitat; birds flying higher than 40 m were not included unless they demonstrated use of the area (e.g. circling, foraging).

Bird populations were sampled by the "variable circular plot" technique developed by Reynolds et. al. (in press). This method involved recording the species, number of individuals, and distance from the observer of all birds observed. These data were used to generate density values for each species within each habitat. The "Shannon-Weaver Diversity Index" (Shannon and Weaver 1949) was used to calculate BSD. H' was selected as the diversity index because of its use in several other ecological studies (MacArthur and

MacArthur 1961 and Lloyd and Ghelardi 1964) and because it was deemed asymptotically normal (Hutcheson 1970). Density rather than the actual number of individuals observed was used to calculate P_i. Species richness (S) and equitability (J'), components of the Shannon-Weaver Index were analyzed for differences among the avian communities associated with habitats.

Standing crop biomass (g/ha) was obtained from the product of the density of a species and the approximate mean weight of individuals. Bird weights were obtained from the literature (Baldwin and Kendeigh 1938, Kilgore 1971). This procedure was not extremely accurate because of the effects of season and geographic location on bird weights. For analysis, data were apportioned into five periods. The first was July and August 1976; the other periods were three months each from September 1976 through August 1977.

A multivariate analysis of variance (MANOVA) (Morrison 1976; 179-192) was used to test for differences among the four habitats with respect to the five avian community parameters (density, number of species, BSD, J', and standing crop biomass). Multivariate analyses of variance procedures were also used to test for seasonal differences in the Miller Sands avifauna with respect to the same five parameters; differences among seasons within a habitat type were also tested with a MANOVA. Wilk's Lambda (Λ) was the statistic used to detect significant differences with the MANOVA. If a significant Λ was obtained, Bonferroni's multiple comparison technique was used to determine where differences occurred (Neter and Wasserman 1974). If a significant Λ was found a test for "additional information" was performed. The most significant response variable, given the full model, and when response variables were considered individually, and the most significant subset of response variables were determined from this analysis.

The CLUS B computer program (Oregon State University, Computer Center Library) was used to determine groups (clusters) of bird species which co-occurred. The program was developed by George Diehr, School of Business Administration, University of Washington (Seattle). The program determined the minimum variance partition of a set of n observations in p dimensions into a specified number of clusters; for further information see McIntire (1973). Clustering was performed on a seasonal basis; density of each species for each month of a three-month period was used to detect groups of species which co-occurred with regard to the twelve study areas (habitat variables). If a species was not observed in more than 10% of the samples it was excluded from this analysis to prevent rare species from clustering individually. Data were proportionalized to 1000 (which prevented uncommon species from clustering together regardless of where they were observed) before they were analyzed with the CLUS B program. Once arranged into clusters these data were analyzed with a "Stepwise Discrimant Analysis" (BMD 07 M) (Dixon 1974). Thus, a plot of the clusters in two-dimensional cannonical space was obtained. This plot was viewed subjectively to determine if clusters were different. If a cluster was separate from other clusters and did not overlap with other clusters, it was considered distinct. If two clusters exhibited overlap they were treated as the same rather than separate clusters. A distinct cluster of species comprised an avian community or association. The x and y coordinants of the cannonical points were back-correlated to the 12 original habitat variables in an attempt to relate the clusters with the four habitats. The cluster analysis also was used to identify groups of sites which co-occurred in relationship to the bird species observed during a season. Groups of species which were identified by the cluster analysis were named with regard to habitat and/or land-form (e.g. island or spit beach-marsh, non-wooded, upland, general beach-marsh, or tree-shrub).

Vegetation was sampled by a modification of the DuRietz life-form technique (Crawford 1974). Vegetation on each area was recorded into 13 habitat categories; tall and short trees; tall and short shrubs; tall, mid, and short grasses and grass-like species; tall, mid, and short forbs; others; litter; and bare ground. Thirty 1-m^2 plots were sampled along a transect in each study area to determine the percent cover in the grass, forb, others, litter, and bare ground categories. The percent canopy cover was estimated with a forest densiometer; readings were taken at 30 stations along each transect. Shrub cover was estimated by the line-intercept technique; 12 25-m transects were sampled on each study area. The percent cover in each category was averaged among the study areas to determine a mean value for each category for each habitat.

Fudicial limits for statistical analyses were set at the $P \leq 0.05$ level unless otherwise specified.

RESULTS

Habitat Differences

Means for each of the five avian community parameters differed within each of the four habitats (Table 1). Significant differences among habitats were detected after seasonal and replication variances were taken into account by the MANOVA procedure. Bonferroni's multiple comparison test indicated that both the upland and tree-shrub habitats were significantly different from each other and from the beach and marsh habitats with respect to the characteristics of the avian communities. However, beach and marsh bird communities were not significantly different from each other (Table 1). The tests for "additional information" indicated that when all five response variables were in the model, density accounted for the greatest amount of variation; number of species accounted for the most variation when the response variables were included individually in the model. A second test for "additional information" was performed in an attempt to determine if all of the response variables added significantly to the model and if not which subset of variables accounted for the variation. Results indicated that number of species, density, and J' accounted for the significant variation and that biomass and BSD were not necessary in the statistical model.

Table 1. Mean number of species, density, BSD, J', and standing crop biomass in each habitat on Miller Sands, Columbia River, Oregon, July 1976 and August 1977.

	Number of species	Diversity (BSD)	Density (birds/ha)	Standing crop biomass (g/ha)	J'
Upland	6.68	1.19	2.84	509	0.66
Tree-Shrub	7.46	1.56	12.10	999	0.79
Marsh[a]	10.29	1.17	10.36	1277	0.51
Beach	10.21	1.23	7.86	1088	0.53

[a]Habitats connected by a vertical line were not significantly different from each other with respect to the five avian community parameters

Seasonal Differences

A MANOVA test was conducted to detect differences among seasonal means (Table 2) in the entire Miller Sands avifauna after habitat and replication variation were accounted for by the statistical model; a significant Λ was obtained. Results of the multiple comparisons test indicated that: spring 1977 was significantly different from summer 1976, fall 1976, and winter 1976-77 and that summer 1977 differed significantly from fall 1976 and winter 1976-77 (Table 2). Tests for "additional information" indicated that density accounted for the most variation in the full model and number of species was responsible for the greatest amount of variation when the response variables were individually placed in the model. Number of species, BSD, and density comprised the subset of variables which best accounted for the variation in the model above which standing crop biomass and J' did not add significantly.

Seasonal Differences Within Habitat

Results of MANOVA tests used to detect seasonal differences within each habitat were significant, which indicated that seasonal differences occurred. However, the multiple comparisons test, in which all possible combinations of seasons within each habitat are contrasted, revealed only two significant differences. Fall 1976 was significantly different from spring 1977 in the tree-shrub habitat and summer 1976

Table 2. Mean numbers of species, density, BSD, J', and standing crop biomass by period on Miller Sands, Columbia River, Oregon between July 1976 and August 1977.

	Number of species	Diversity (BSD)	Density (birds/ha)	Standing crop biomass (g/ha)	J'
Fall 1976[a]	9.0	1.26	5.78	555	0.59
Winter 1976-77	8.1	1.12	5.88	1007	0.56
Summer 1976	8.3	1.23	7.72	1296	0.58
Summer 1977	9.6	1.38	13.03	1214	0.63
Spring 1977	10.6	1.29	10.26	1244	0.56

[a] Habitats connected by a vertical line were not significantly different from each other with respect to the five avian community parameters

differed significantly from summer 1977 in the beach habitat.

Avian Community - Plant Community Associations

Summer 1976

Cluster analysis indicated that the number and species composition of avian communities which are associated with habitats on Miller Sands varied seasonally. The cluster analysis for summer 1976 indicated that four distinct bird communities were present: upland, tree-shrub, general beach-marsh and island beach-marsh (Table 3). The cannonical plot indicated that the four communities were separate clusters; each point on the plot represented an avian species (Figure 2). The back-correlation technique indicated that the separation along the x-axis was positively correlated (0.95 and 0.93) with the two tree-shrub study sites. The separation along the y-axis was positive and correlated (0.82) with one of the upland sites. The cluster analysis which detected sites which co-occurred with regard to species during summer 1976 indicated five habitat clusters: upland, tree-shrub, island marsh and spit marsh, spit beach and one island beach, and one island beach site which clustered individually.

Fall 1976

The cluster analysis for fall 1976 revealed four avian communities: tree-shrub, beach-marsh, spit beach-marsh, and non-wooded (Table 4).

Table 3. Species composition of avian communities on Miller Sands, Oregon, summer 1976.

Tree-Shrub	Beach-Marsh	Upland	Island Beach-Marsh
Downy Woodpecker (*Picoides pubescens*)	Mallard (*Anas platyrhynchos*)	Starling (*Sturnus vulgaris*)	Western Gull (*Larus occidentalis*)
Willow Flycatcher (*Empidonax traillii*)	Great Blue Heron (*Ardea herodias*)	Brown-headed Cowbird (*Molothrus ater*)	Ring-billed Gull (*Larus delawarensis*)
Common Crow (*Corvus brachyrhynchos*)	Killdeer (*Charadrius vociferus*)	Savannah Sparrow (*Passerculus sandwichensis*)	Caspian Tern (*Sterna caspia*)
Black-capped Chickadee (*Parus atricappillus*)	Western Sandpiper (*Calidris mauri*)		American Goldfinch (*Carduelis tristis*)
Bewick's Wren (*Thryomones bewickii*)	Glaucous-winged Gull (*Larus glaucescens*)		
American Robin (*Turdus migratorius*)	California Gull (*Larus californicus*)		
Swainson's Thrush (*Catharus ustulatus*)	Barn Swallow (*Hirundo rustica*)		
Song Sparrow (*Melospiza melodia*)	Cliff Swallow (*Petrochelidou pyrrhonota*)		
	Tree Swallow (*Iridoprocene bicolor*)		

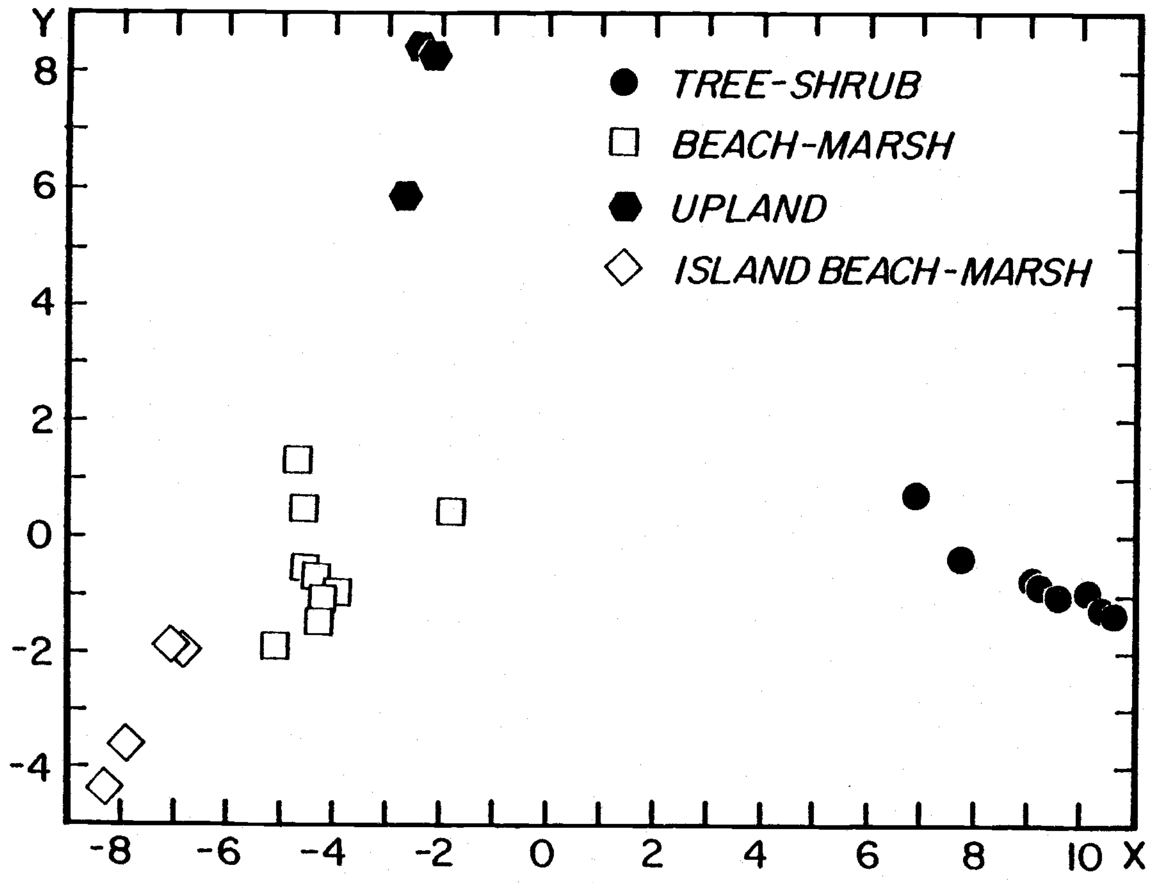

Figure 2. Location of avian communities in two dimensional cannoncial space, summer 1976.

When the data were further analyzed with the BMD 07 M program, the cannonical plot indicated that the beach-marsh and non-wooded groups displayed considerable overlap (Figure 3). Thus, the two groups were combined to form the beach-marsh-nonwooded avian community. Back-correlation procedures indicated that separation of the groups along the x-axis was negatively correlated (-0.82 and -0.79) with the tree-shrub areas. Separation along the y-axis was negatively correlated (-0.84) with one of the spit marsh sites.

Not only were the avian communities which occurred on Miller Sands different between summer and fall 1976, but the species composition of the communities also changed. The upland bird association disappeared during fall; two species, Starling (Sturnus vulgaris) and Savannah Sparrow (Passerculus sandwichensis), became components of the general group and the Brown-headed Cowbird (Molothrus ater) disappeared from the area during fall (Table 4). The tree-shrub association remained during fall; however, the species composition was somewhat different. Common Crows (Corvus brachyrhynchos), Black-capped Chickadees (Parus atricappillus), Bewick's Wrens (Thryomanes bewickii), and Song Sparrows (Melospiza melodia) were species common to the tree-shrub area during summer and fall. Certain other species left the tree-shrub area and several new species arrived during the transition from summer to fall (Tables 3 and 4). Numerous species which occurred in the beach-marsh and island beach-marsh associations during summer became members of the general and spit beach-marsh associations in fall (Tables 3 and 4).

Table 4. Species composition of avian communities on Miller Sands, Oregon, fall 1976.

Tree-Shrub	Beach-Marsh[a]	Spit Beach-Marsh	Non-wooded[a]
Common Flicker (*Colaptes auratus*)	Dunlin (*Calidris alpina*)	American-Wigeon (*Anas americana*)	Mallard (*Anas platyrhynchos*)
Common Crow (*Corvus brachyrhynchos*)	Least Sandpiper (*Calidris minutilla*)	Common Merganser (*Mergus merganser*)	Pintail (*Anas acuta*)
Black-capped Chickadee (*Parus atricappillus*)	Ring-billed Gull (*Larus delawarensis*)	Great Blue Heron (*Ardea herodias*)	Semipalmated Plover (*Charadrius semipalmatus*)
Winter Wren (*Troglodytes troglodytes*)	Bonaparte's Gull (*Larus philadelphia*)	Killdeer (*Charadrius vociferus*)	Sanderling (*Calidris alba*)
Bewick's Wren (*Thryomanes bewickii*)	Barn Swallow (*Hirundo rustica*)	Western Gull (*Larus occidentalis*)	Western Sandpiper (*Caladris mauri*)
House Finch (*Carpodacus mexicanus*)		Herring Gull (*Larus argentatus*)	Common Snipe (*Capella gallinago*)
Song Sparrow (*Melospiza melodia*)		California Gull (*Larus californicus*)	Glaucous-winged Gull (*Larus glaucescens*)
		Caspian Tern (*Sterna caspia*)	Water Pipit (*Anthus spinoletta*)
		American Goldfinch (*Carduelis tristis*)	Starling (*Sturnus vulgaris*)
			Savannah Sparrow (*Passerculus sandwichesis*)

[a] The two communities were combined because of overlap indicated by the cannonical plot

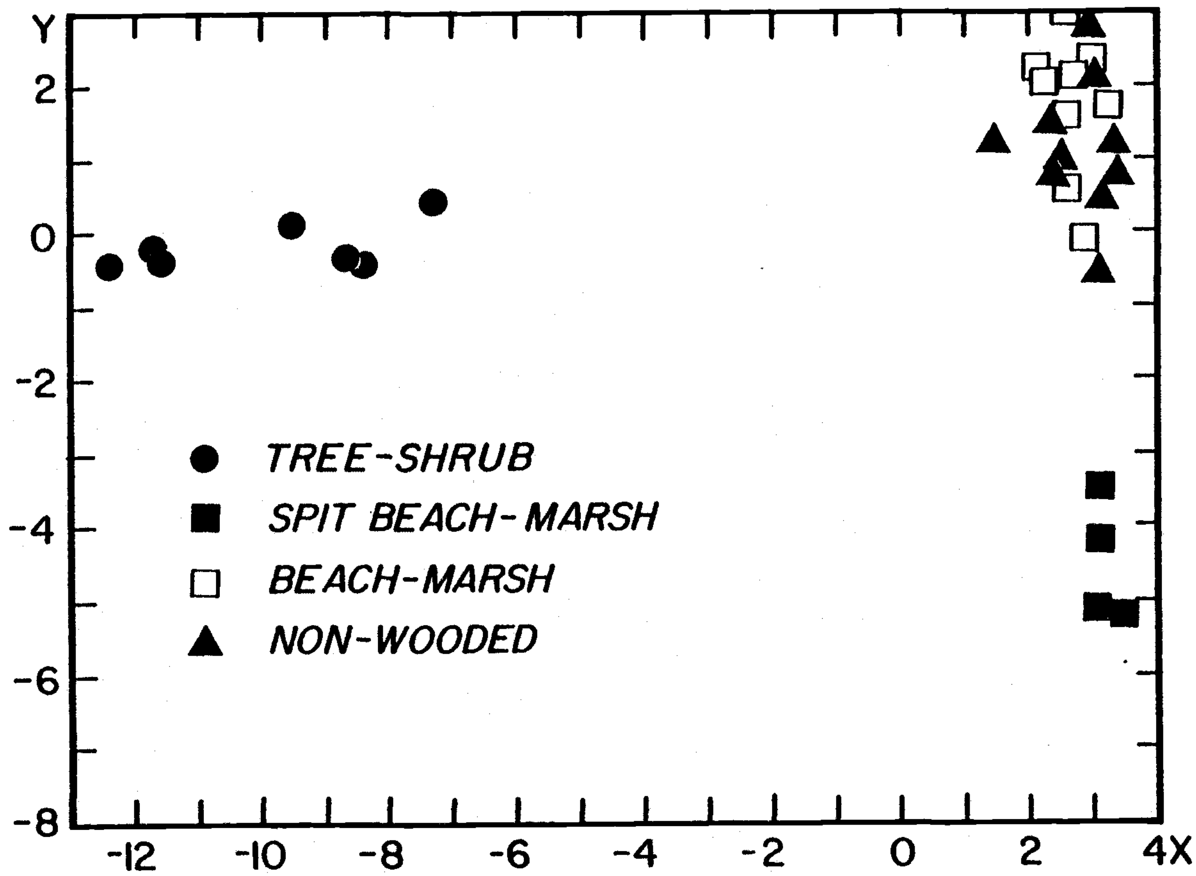

Figure 3. Location of avian communities in two dimensional cannonical space, fall 1976

Clusters of sites which co-occurred in relationship to the avian community indicated that the spit beach and marsh sites and one of the island beach areas clustered together. Tree-shrub, island marsh, and upland sites clustered into three distinct groups and one island beach site clustered individually.

Winter 1976-77

Clusters of species which co-occurred in regard to habitat indicated four avian communities tree-shrub, beach-marsh, non-wooded, and island beach-marsh, during winter 1976-77 (Table 5). However, the cannonical analysis indicated that beach-marsh and island beach-marsh bird associations were not separate groups, therefore, they were combined to form a general beach-marsh group (Figure 4). Back-correlation indicated that separation along the x-axis was negative and correlated (-0.77 and -0.74) to the tree-shrub sites. Separation along the y-axis was not correlated with any of the habitats, however, all but one of the beach and marsh sites displayed negative correlations with the y coordinates and the upland and tree-shrub had positive correlations.

The tree-shrub bird association was maintained from fall to winter 1976-77; Common Crow, Black-capped Chickadee, Winter Wren, and Song Sparrow were species common to the area during both seasons. Ruby-crowned Kinglets (Regulus calendula) appeared during winter and the Common Flicker (Colaptes auratus) and House Finch (Carpodacus)

Table 5. Species composition of avian communities on Miller Sands, Oregon, winter 1976-77.

Tree-Shrub	Beach-Marsh[a]	Non-wooded	Island Beach-Marsh[a]
Mallard (*Anas platyrhynchos*)	Double-crested Cormorant (*Phalacrocorax auritus*)	Pintail (*Anas acuta*)	American Wigeon (*Anas americana*)
Common Snipe (*Capella gallinago*)	American Green-winged Teal (*Anas crecca*)	Glaucous-winged Gull (*Larus glaucenscens*)	Bufflehead (*Bucephala albeola*)
Common Crow (*Corvus brachyrhynchos*)	Great Blue Heron (*Ardea herodias*)	Western Gull (*Larus occidentalis*)	Common Merganser (*Mergus merganser*)
Black-capped Chickadee (*Parus atricappilius*)	Dunlin (*Calidris alpina*)	Herring Gull (*Larus argentatus*)	Killdeer (*Charadrius vociferus*)
Winter Wren (*Troglodytes troglodytes*)	Sanderling (*Calidris alba*)	California Gull (*Larus californicus*)	
Bewick's Wren (*Thryomanes bewickii*)	Ring-billed Gull (*Larus delawarensis*)	Starling (*Sturnus vulgaris*)	
Ruby-crowned Kinglet (*Regulus calendula*)	Mew Gull (*Larus canus*)		
Song Sparrow (*Melospiza melodia*)			

[a]The two communities were combined because of overlap indicated by the cannonical plot

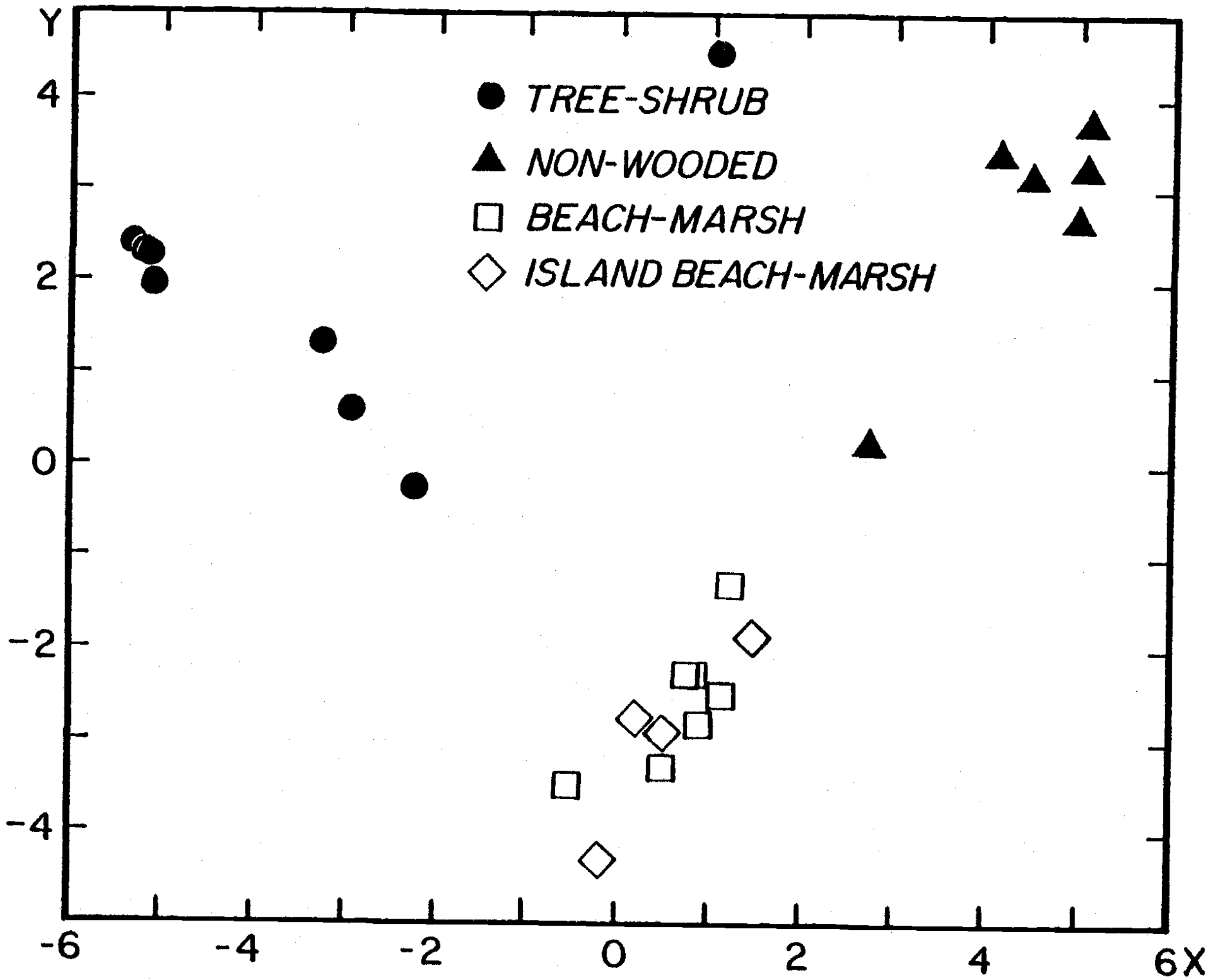

Figure 4. Location of avian communities in two dimensional cannonical space, winter 1976-77.

mexicanus) disappeared between fall and winter. Mallards (*Anas platyrhynchos*) and Common Snipe (*Capella gallinago*) became part of the tree-shrub association during winter. Numerous species associated with the beach-marsh sites remained on the area (Tables 4 and 5). Eleven species present during the fall were absent from the beach-marsh areas during winter and five new species moved onto the area (Tables 4 and 5). Clusters of sites which co-occurred with respect to species indicated that upland sites were separate, tree-shrub areas grouped together, and beach-marsh sites grouped together, except for one beach site. The two upland clusters separated from each other and all of the other groups which indicated that the upland was utilized differentially by the avifauna. However, none of the species was associated exclusively with upland sites.

Spring 1977

The cluster analysis of species which co-occurred with respect to sites for spring 1977 indicated that three (upland, tree-shrub, and beach-marsh) bird associations occurred on Miller Sands (Table 6). Results of the cannonical analysis indicated that the associations were distinct in two dimensional cannonical space (Figure 5).

The Common Snipe was the only species present in the tree-shrub association during winter which was not present in the tree-shrub group during spring 1977. Two species which were previously

Table 6. Species composition of avian communities on Miller Sands, Oregon, spring 1977.

Tree-Shrub	Upland	Beach-Marsh	Beach-Marsh (continued)
Mallard (*Anas platyrhynchos*)	Starling (*Sturnus vulgaris*)	Common Loon (*Gavia immer*)	Least Sandpiper (*Calidris minutilla*)
Downy Woodpecker (*Picoides pubescens*)	Savannah Sparrow (*Passerculus sandwichensis*)	Canada Goose (*Branta canadensis*)	Western Sandpiper (*Calidris mauri*)
Tree Swallow (*Iridoprocene bicolor*)		Cinnamon Teal (*Anas cyanoptera*)	Glaucous-winged Gull (*Larus glaucescens*)
Common Crow (*Corvus brachyrhynchos*)		American Green-winged Teal (*Anas crecca*)	Western Gull (*Larus occidentalis*)
Black-capped Chickadee (*Parus atricappillus*)		Greater Scaup (*Aythya marila*)	Herring Gull (*Larus argentatus*)
Winter Wren (*Troglodytes troglodytes*)		Common Merganser (*Mergus merganser*)	California Gull (*Larus californicus*)
Bewick's Wren (*Thryomanes bewickii*)		Red-breasted Merganser (*Mergus serrator*)	Mew Gull (*Larus canus*)
American Robin (*Turdus migratorius*)		Black-bellied Plover (*Pluvialis squatarola*)	
Ruby-crowned Kinglet (*Regulus calendula*)		Semipalmated Plover (*Charadrius semipalmatus*)	
Brown-headed Cowbird (*Molothrus ater*)		Killdeer (*Charadrius vociferus*)	
Song Sparrow (*Melospiza melodia*)		Dunlin (*Calidris alpina*)	

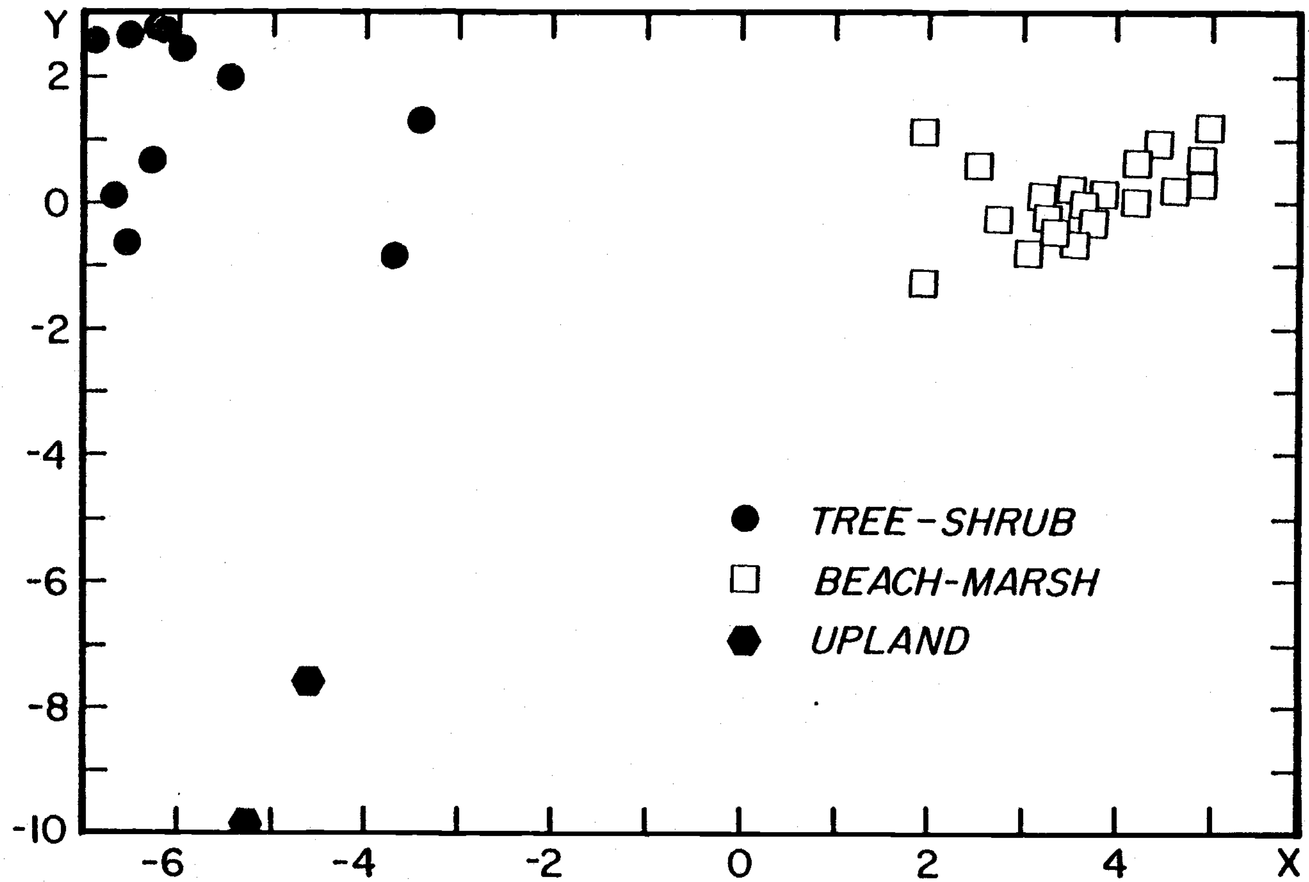

Figure 5. Location of avian communites in two dimensional cannonical space, spring 1977.

unrecorded in tree-shrub areas, Tree Swallow (Iredoprocene bicolor) and Brown-headed Cowbird, were recorded. American Robins (Turdus migratorius) returned to the tree-shrub habitat. The upland bird association also reappeared during spring 1977 and was composed of Savannah Sparrows and Starlings. These species were two of the three species which occurred in the upland bird community during summer 1976. Ten species from the winter beach-marsh and non-wooded associations were components of the beach-marsh association during spring; seven other species from the winter association were not recorded on beach-marsh sites during spring (Tables 5 and 6). Ten additional species were either observed for the first time on the study area or returned after an absence of one or more seasons (Table 6). Cluster analysis of sites which co-occurred in relationship to species indicated that the beach, marsh, and one upland site clustered together, the two tree-shrub sites grouped together, and one upland site occurred separately. Large numbers of Dunlins (Calidris alpina) and Western Sandpipers were recorded flying over the upland site which clustered with the beach-marsh sites during one of the spring sample periods.

The cluster analysis for summer 1977 indicated that four bird communities: tree-shrub, upland, spit beach-marsh, and beach-marsh were present (Table 7). Cannonical analysis of the data indicated that all four associations were distinct (Figure 6); thus, four avian communities were considered during summer 1977. Back-correlation indicated

Table 7. Species composition of avian communities on Miller Sands, Oregon, Summer 1977.

Tree-Shrub	Upland	Spit Beach-Marsh	Beach-Marsh
Willow Flycatcher	American Goldfinch	Western Sandpiper	Mallard
(*Empidonax traillii*)	(*Carduelis tristis*)	(*Calidris mauri*)	(*Anas platyrhynchos*)
Common Crow	Savannah Sparrow	Glaucous-winged Gull	Killdeer
(*Corvus brachyrhynchos*)	(*Passerculus sandwichensis*)	(*Larus glaucescens*)	(*Charadrius vociferus*)
Black-capped Chickadee	White-crowned Sparrow	Bonaparte's Gull	Western Gull
(*Parus atricappillus*)	(*Zonotrichia leucophrys*)	(*Larus philadelphia*)	(*Larus accidentalis*)
Bewick's Wren		Barn Swallow	Herring Gull
(*Thryomanes bewickii*)		(*Hirundo rustica*)	(*Larus argentatus*)
Swainson's Thrush		Cliff Swallow	California Gull
(*Cotharus ustulatus*)		(*Petrochelidon pyrrhonota*)	(*Larus californicus*)
Brown-headed Cowbird		Tree Swallow	Ring-billed Gull
(*Molothrus ater*)		(*Iridoprocene bicolor*)	(*Larus delawarensis*)
Song Sparrow			Caspian Tern
(*Melospiza melodia*)			(*Sterna caspia*)

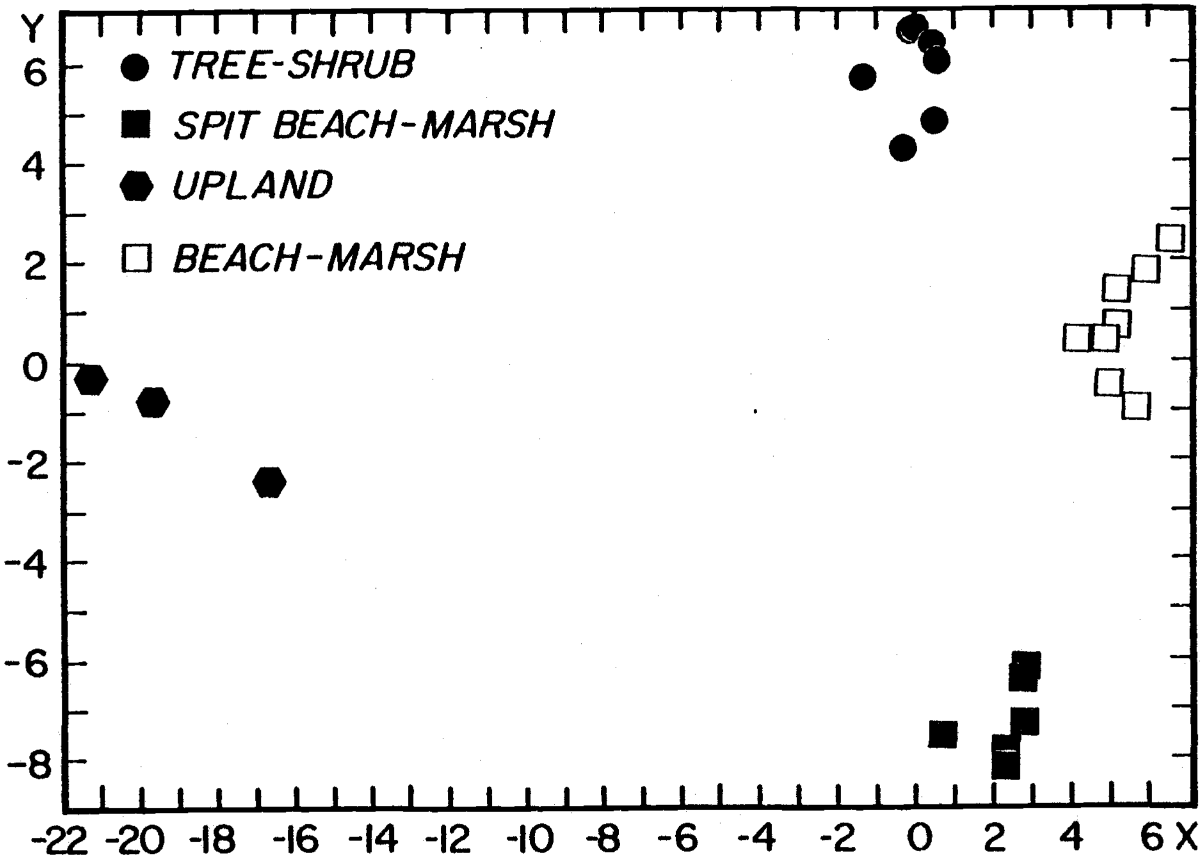

Figure 6. Location of avian communities in two dimensional cannonical space, summer 1977.

a negative correlation (-0.88 and -0.87) between the x-coordinates and the upland sites. The y-coordinates revealed a high positive correlation (0.73 and 0.72) with the tree-shrub sites and a high negative correlation (-0.70 and -0.67) with the spit marsh sites.

The American Goldfinch (Carduelis tristis) and the White-crowned Sparrow (Zonotrichia leucophyrs) became components of the upland association during summer 1977 and the Starling was not recorded on the area during summer (Table 7). The tree-shrub associations between spring and summer had five common species: Common Crow, Black-capped Chickadee, Bewick's Wren, Brown-headed Cowbird, and Song Sparrow. Willow Flycatchers and Swainson's Thrushes (Catharus ustuluta), not recorded on any sites during fall, winter, or spring, returned during summer. The Mallard again became associated with beach-marsh sites and the Tree Swallow became a component of the spit beach-marsh community during summer 1977. Four species which were components of the tree-shrub association during spring were not recorded on Miller Sands during summer 1977 (Table 7). Eight species from the spring beach-marsh association remained during the summer; five of the eight remained in the beach-marsh association and three became associated with the spit beach-marsh association and three became associated with the spit beach-marsh community (Tables 6 and 7). Three species which were not recorded during spring were observed in the beach-marsh association during summer and twelve spring inhabitants left the study area in the transition from spring to summer (Tables 6 and 7).

Vegetation

Vegetation analysis indicated that the tree-shrub habitat contained vegetation in each of the thirteen life-form categories (Table 8). Thus, the tree-shrub habitat was the most vertically stratified and complex vegetative community. Tall trees, short trees, and litter categories comprised the majority of the total cover. Major components of the tall tree category were red alder (31.5%) and black cottonwood (24.5%); willow (13.4%) and red alder (3.9%) were the most prominent species in the short tree category (Table 8). Red elderberry (Sambucus racemosa), nine bark (Physocarpus albus), and red-osier dogwood (Cornus stolonifera) were the most common species in the tall shrub category. Evergreen blackberry (Rubus spectabilis) and Himalayan blackberry (Rubus discolor) were the prominent species in the short shrub category. Slough sedge (Carex obnupta) and Reed canarygrass (Phalaris arundinacea) were the most common species of grass and grass-like plants in the tree-shrub sites. The forb categories contained numerous species of which touch-me-not (Impatiens capensis) was the most abundant. Mosses and horsetail (Equisetum spp.) were the primary components of the "others" category.

Upland sites had representative components in seven of the habitat

Table 8. Percent cover of vegetation, litter, and bare ground on Miller Sands, Oregon, June 1977.

	Tree-Shrub	Upland	Marsh	Beach
Tall trees	59.3	0	0	0
Short trees	20.4	0	0	0
Tall shrubs	7.5	0	0	0
Short shrubs	2.0	0	0	0
Tall grasses	1.9	0	6.7	0
Mid-grasses	4.5	1.9	14.3	0
Short grasses	0.5	4.5	3.4	0.4
Tall forbs	0.7	0	0	0
Mid-forbs	7.8	18.5	1.7	0
Short forbs	4.1	11.7	4.6	0
Litter	97.1	13.2	2.4	0.1
Others	15.4	58.7[a]	0.9[b]	15.7[b]
Bare Ground	2.3	1.2	75.1	83.9

[a]Mosses and lichens
[b]Algae

categories (Table 8). Mid-forb (18.5%), short-forb (11.7%), litter (13.2%) and others (58.7%) were the categories which accounted for most of the cover (Table 8). Stream lupine (Lupinus rivularis) and French hawksbeard (Crepis nicaeenis) were the dominant species in both the mid-forb and moss was the major component of the "others" category.

The marsh habitat contained information in eight of the categories. Tall-grass, mid-grass, short-grass, and bare ground were the major classifications (Table 8). Tufted hairgrass (Deschampsia caspitosa) and Lyngby's sedge (Carex lyngbei) were the dominant species in both the tall and short grass divisions. Mudwart (Limosella aquatica) and an unidentified forb were the most common species in the short-forb category.

Beach sites contained representatives in only four categories (Table 8). A filamentous algae was the primary vegetation on the beach sites; small patches of Common Spike Rush (Eleocharis palustris) occurred on some sites. Sandy beaches and mud flats composed the bare ground category which comprised most of the beach area (Table 8).

DISCUSSION

Habitats which were sampled on Miller Sands, probably represented four successional stages and possibly two seres. One sere progressed from beach to marsh to tree-shrub; the other progressed from bare sand to upland to tree-shrub. Since no part of Miller Sands was older than 40 years it was unlikely that the tree-shrub plant community was in the climax stage.

Significant differences were detected among the avian communities associated with the various stages of complexity in the plant community in regard to the five parameters of the avian community which were measured. The MANOVA procedure did not provide information as to which avian parameters differed among the habitats. Therefore, it was difficult to compare the results of our study with studies which only considered one of the parameters or several parameters but with univariate analyses, however, similarities were observed. The MANOVA procedure indicated that density, number of species, and equitability were the variables which accounted for the significant variation among the habitats.

Density of birds on Miller Sands, although not restricted to breeding birds, was greatest in the tree-shrub area (12.1 birds/ha), followed by marsh (10.4 birds/ha), beach (7.9 birds/ha), and upland (2.8 birds/ha) sites. Results of the MANOVA did not indicate whether or not density differed among the habitats, however, a trend developed which indicated increased density with increased complexity. Johnston and Odum (1956) determined that breeding bird densities increased with age and complexity of the vegetative community, from cultivated or abandoned fields to mature hardwood forests; complexity of the vegetation was more important than age of the plant community. Hopper et. al. (1973) reported a significant positive linear relationship between the amount of understory and breeding bird density on several study areas in the eastern United States. Shugart and James (1973) examined three successional stages of vegetation in northwestern Arkansas and concluded that breeding bird density increased as plant succession progressed from abandoned fields to forests. Karr (1968) also noted that bird density increased with the age of the vegetative community. The density of breeding birds was higher on the strip-mined areas in central Illinois than densities reported by others. Karr (1968) concluded that higher bird density was probably due to the rolling topography and the occurrence of numerous small ponds; he felt that these features added to the complexity of the strip-mined areas. Contrastingly, Anderson (1972) found that bird density was highest in the earliest of three seral stages which were studied in Oregon. However, the early stage supported a more complex understory than the two later stages; this finding supported the contention of Karr (1968) that complexity of the vegetation was more important than seral stage.

The number of species on Miller Sands was lowest on upland areas, intermediate in the tree-shrub area, and highest in the beach and marsh areas (Table 1). Thus, number of species did not increase with the complexity of the habitat. Johnston and Odum (1956) reported that the number of breeding species on the New Jersey Piedmont increased with the age of the vegetative community. Tramer (1969) concluded that the number of bird species was an accurate predicter of BSD which increased with vegetative complexity when breeding birds were considered. Cody (1966) concluded that the number of species which a habitat supported depended on the complexity of the habitat, which usually increased with age. The apparent discrepancy between my study and the others possibly was accounted for by the factor that all birds and not simply breeding birds were considered in the present study. Kricher (1972) concluded that when only breeding birds were considered on an area, BSD varied directly with the number of species. However, when birds other than breeding birds were also considered J' became an important factor in determining BSD, especially in unstable habitats such as early successional stages. Data from beach and marsh areas on Miller Sands supported this contention because these areas contained the greatest number of species but the lowest values of J' (Table 1). Beach and marsh areas were extremely unstable and variable due to the tidal influence. Upland and tree-shrub areas were more stable and displayed higher values of J' (Table 1).

Numerous studies indicated that BSD was influenced by the complexity of the habitat (MacArthur 1964; MacArthur et. al. 1966; Recher 1969; Anderson 1972; Willson 1974; Kricher 1972, 1973, 1975); yet BSD was not one of the three parameters which accounted for the significant variation among habitats in my study. BSD probably was not important because the variability which it accounted for was also accounted for by number of species and J' which were both components of BSD (Pielou 1966). Since the purpose of the MANOVA was to test for differences among habitats with respect to five related parameters and take their relationship into account, this result was not surprising.

Standing-crop biomass was not significant in revealing differences among the habitats on Miller Sands. Similar results were reported by Karr (1968); however, he noted that consuming biomass was a more biologically important factor.

Density, number of species, and BSD accounted for the significant variation among seasons with respect to the total avifauna on Miller Sands (Table 2). Most of the significant differences which were detected were probably accounted for by seasonal migrational patterns of the birds. However, the difference between summer 1976 and summer 1977 was possibly related to the absence of data for June 1976. BSD was more important in detecting seasonal differences in the Miller Sands avifauna than was J'. This situation indicated that J' was relatively stable from season to season and that BSD which varied with the number of species accounted for more variation than did J'. Anderson (1972) found that J' was relatively stable from season to season in Oregon white-oak (Quercus garryana), Douglas fir, and western hemlock forests in western Oregon. He also noted that BSD and number of species varied considerably among seasons within each habitat. MANOVA procedures revealed significant seasonal differences within each habitat, however, only two differences: fall 1976 to spring 1977 in the tree-shrub area and summer 1976 to summer 1977 in the beach areas were significant. The paucity of differences was possibly an artifact of the rigor of the multiple comparisons test. Anderson (1970 and 1972) reported seasonal differences with respect to number of species and BSD in mixed hardwood and coniferous forests in western Oregon.

A unique group of species was associated with the tree-shrub habitat during every season. Four species, Common Crow, Black-capped Chickadee, Bewick's Wren, and Song Sparrow were resident species in the tree-shrub area (Tables 3-7). Other species were present during one or more seasons of the year. The Common Snipe in winter and the Mallard in winter and spring were unexpected components of the tree-shrub bird community. The association of the Common Snipe with the tree-shrub habitat was probably due to its use of areas inundated by tide channels. Mallards used the tree-shrub areas more for nesting than they used any other habitat; nests in the tree-shrub area were not preyed on as heavily by Common Crows as were nests in other plant communities (Crawford and Edwards 1978). The presence of a distinct tree-shrub bird community was further supported by the event that the two tree-shrub sites clustered together during every season when sites were grouped with respect to species.

The upland sites supported a definitive avian community only during summer and spring periods (Tables 3, 6, 7 and Figures 2, 5, 6). Cluster analysis which grouped sites with respect to species indicated that upland sites either clustered together or individually except during spring 1977 when one upland site clustered with beach and marsh sites (large flocks of Dunlins and Western Sandpipers (Calidris mauri) were observed flying over the site during one of the spring sampling periods). Thus, upland sites supplied a distinct habitat used by the Miller Sands avifauna during each season; however, during fall and winter, none of the species was singularly related to upland. The Savannah Sparrow was always a component of the upland bird community when it was present and was the most common bird of the upland community (Crawford and Edwards 1978).

Clustering patterns were difficult to interpret for the beach-marsh sites. A general beach-marsh community was present during each season as indicated by the clusters of species which co-occurred in regard to sites (Tables 3 - 7). Island beach-marsh and spit beach-marsh groups were also identified periodically (Tables 3, 4, 5, 7). No factors were detected which explained this separation of island beach-marsh and spit beach-marsh associations; possibly they were artifacts of the sampling scheme. Beach and marsh areas were under considerable tidal influence which changed their physical characteristics greatly. If during a sampling period the degree of inundation was different between spit beach-marsh and island beach-marsh sites, one or the other of the areas possibly attracted a particular group of species. Some species were uncommon and were only recorded on one of the two areas because of coincidence or tidal influence. Thus, it was not clear whether several different beach-marsh communities were present due to biological reasons or whether some of the associations were artifacts of the sampling procedure. All beach-marsh areas were, however, distinct from upland and tree-shrub areas. Results of clustering sites which co-occurred in relationship to species generally supported some separation between groups of beach-marsh sites; again it was difficult to determine whether these groups were biologically distinct or if they were artifacts of the sampling and analytical schemes.

The results of this study indicated that seasonal changes, complexity of the vegetative, and physical characteristics of a habitat greatly affected the parameters of the avian community and species composition. The multivariate statistical approach provided a method for consideration of community parameters simultaneously, thus accounting for interrelationships. The most "important" parameters were identified for determining differences among the avian communities with respect to seasonal and habitat variation, both when they were considered individually and when all the parameters were included in the analysis. A subset of parameters which provided significant information in addition to that provided by the most significant parameter also was identified. The clustering procedure provided a partially objective format by which to associate bird species to habitats with respect to occurrence and density. Thus, the procedures outlined in this paper may provide a more precise technique for analyzing avian communities than other methods which have been used for the determination of bird community-plant community associations.

LITERATURE CITED

Adams, C. C. 1908. The ecological succession of birds. Auk 25: 109-153.

Aldrich, J. W. 1945. Birds of a deciduous forest aquatic succession. Wilson Bull. 57: 243-244.

Anderson, S. H. 1970. The avifaunal composition of Oregon White-oak stands. Condor 72: 417-423.

_________. 1972. Seasonal variations in forest birds of western Oregon. Northwest Sci. 46: 184-206.

_________, & H. H. Shugart Jr. 1974. Habitat selection of breeding girds in an east Tennessee deciduous forest. Ecology 55: 828-837.

Baldwin, S. P., & S. C. Kendeigh. 1938. Variations in weights of birds. Auk 55: 416-467.

Coastal Zone Resource Corporation. 1977. A comprehensive study of successional patterns of plants and animals at upland disposal areas. U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Cody, M. 1966. The consistency of intra- and inter-continental grassland bird species counts. Amer. Nat. 100: 371-376.

Crawford, J. A. 1974. The effects of land use on Lesser Prairie Chicken population in west Texas. Unpublished Ph. D. dissertation, Lubbock, Texas Tech. Univ.

________, & D. K. Edwards. 1978. Habitat development field investigation, Miller Sands marsh and upland development site Columbia River, Oregon. Appendix F: Postpropagation assessment of wildlife resources on dredged material. Tech. Report 0-78-38, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Dixon, W. J. 1974. Biomedical computer programs. Univ. Calif. Press, Los Angeles.

Hooper, R. G., H. S. Crawford, & R.F. Harlow. 1973. Bird density and diversity as related to vegetation in forest recreation areas. J. For. 71: 766-769.

Hutcheson, K. 1970. A test for comparing diversities based on the Shannon formula. J. Theoret. Biol. 29: 151-154.

James, F. C. 1971. Ordination of habitat relationships among breeding birds. Wilson Bull. 83: 215-226.

Johnston, D. W., & E. P. Odum. 1956. Breeding bird populations in relation to plant succession on the Piemont of Georgia. Ecology 37: 50-62.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. Condor 70: 348-357.

Kilgore, B. M. 1971. Response of breeding bird population to habitat changes in a giant sequoia forest. Amer. Midl. Natur. 85: 135-152.

Kricher, J. C. 1972. Bird species diversity: the effect of species richness and equitability on the diversity index. Ecology 53: 278-282.

________. 1973. Summer bird species diversity in relation to secondary succession on the New Jersey Piedmont. Amer. Midl. Nat. 89: 121-137.

________. 1975. Diversity in two wintering bird communities: possible weather effects. Auk 92: 766-777.

Lloyd, M., & R. J. Ghelardi. 1964. A table for calculating the equitability component of species diversity. J. Anim. Ecol. 33: 217-225.

MacArthur, R.H. 1964. Environmental factors affecting bird species diversity. Amer. Nat. 98: 387-397.

________, & J. W. MacArthur. 1961. On bird species diversity. Ecology 42: 574-598.

________, H. Recher, & M. Cody. 1966. On the relation between habitat selection and species diversity. Amer. Nat. 100: 319-325.

McIntire, C. D. 1973. Diatom associations in Yaquina Estuary, Oregon: a multivariate analysis. J. Phycology 9: 254-259.

Morrison, D. F. 1976. Multivariate statistical methods. 2nd Edition, McGraw Hill, Inc. New York.

Neter, J., & W. Wasserman. 1974. Applied linear statistical models. Richard D. Irwin, Inc. Homewood, Ill.

Pielou, E. C. 1966. Species-diversity and pattern-diversity in the study of ecological succession. J. Theoret. Biol. 10: 370-383.

Quay, T. L. 1947. Winter birds of upland plant communities. Auk 64: 382-388.

Recher, H. F. 1969. Bird species diversity and habitat diversity in Australia and North America. Amer. Nat. 103: 75-80.

Reynolds, R. T., J. M. Scott, & R. A. Nussbaum. in press. A variable circular-plot method for censusing birds. Condor.

Shannon, C., & W. Weaver. 1959. The mathematical theory of communication. Univ. Illinois Press, Chicago.

Shugart, H. J., Jr., & D. James. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. Auk 90: 62-77.

Soots, R. F., & J. F. Parnell. 1975. Ecological succession of breeding birds in relation to plant succession on dredge islands in North Carolina estuaries. N. C. Sea Grant Publ. UNC-SG-75-27, Raleigh N. C.

Tramer, E. J. 1969. Bird species diversity: components of Shannon's formula. Ecology 50: 927-929.

U. S. Army Engineer District, Portland, Oregon. 1975. Columbia and lower Willamette River environmental statement. U. S. Army Engineer District, Portland, Ore.

U. S. Dept. Commerce. 1974. Climatological data, Oregon. U. S. Dept. Commerce, Nat. Oceanic and Atmospheric Ad., Environ. Data Serv., No. 80.

Whitmore, R. C. 1975. Habitat ordination of passerine birds of the Virgin River Valley, southwestern Utah. Wilson Bull. 87: 65-74.

________. 1977. Habitat partitioning in a community of passerine birds. Wilson Bull. 89: 253-265.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55: 1017-1029.