RELATION OF PARK SIZE AND VEGETATION TO URBAN BIRD POPULATIONS IN SEATTLE, WASHINGTON

CAROL A. GAVARESKI

Most research directed toward determining the habitat needs of various birds has centered on natural ecosystems, while urban ecosystems have been largely ignored. However, with the rapid expansion of urban and suburban development and the associated modification of habitat, the importance of understanding the relationship of birdlife to urban habitats is evident. Urban parks, especially, provide much potential avian habitat, and offer an opportunity to study the relationships of bird communities to human-induced changes in habitat such as extensive vegetation modification, reduction in size of suitable habitats, disturbance associated with proximity to human populations, presence of buildings, etc.

My purpose here is to examine some effects of changes in urban parks on bird populations in the Pacific northwest. The hypotheses to be tested are that 1) parks with large tracts of natural forest can support a diversity and abundance of birds comparable to those in natural forest areas, and that 2) modification of the forest and small size of parks are associated with reduced diversity and abundance of birds in urban parks.

METHODS

STUDY AREAS

Six urban parks and one natural control area outside the urban influence were used as study areas. The parks represented three types of vegetation: native forest with little or no altered vegetation; parkland where major expanses of forest undergrowth and trees were replaced with lawns, garden shrubbery and trees; and parkland where all subordinate vegetation was cleared, leaving only grass and trees. Two parks of each type were studied, one large (over 40 ha), and one small neighborhood park (less than 4 ha). The parks were all located within the city limits of Seattle, King County, Washington. Lee Forest, the 61 ha control area, was located about 35 km NE of Seattle, near Snohomish, Washington.

Lee Forest is maintained as a demonstration and experimental forest by the College of Forest Resources, University of Washington, although its present use by University personnel is low. It represents lowland coniferous forest typical of the Puget Sound basin and the Seattle area. It is a 40- to 70-year old Douglas-fir (*Pseudotsuga menziesii*) forest with extensive understory and ground cover vegetation as well as many fallen logs and dead stumps. The major plant species, and percent cover of each forest stratum, and average tree heights, are shown in table 1. The forest is surrounded by farms, homes on large lots, and other woodlots, and it receives only moderate human use. Although not isolated from human influence, it is well removed from urban areas.

Seward Park represents a large urban forest with little or no modified vegetation. About two-thirds of its 113 ha is native forest (used as the study area); the remainder is cleared recreation area. The park is located on a large peninsula which juts into a freshwater lake, and its only land connection is a residential area. It is a dense, second-growth Douglas-fir forest with a few scattered mature trees (table 1). Understory vegetation and stumps and logs are abundant. The only evidence of current vegetation modification was the removal of some fallen logs and some shrubs along the foot paths. The park receives heavy recreational use, primarily in the cleared areas.

Northacres Park represents a small park with native forest vegetation. About half of its 8 ha is second-growth Douglas-fir (30–40 year old) and red alder (*Alnus rubra*) forest (table 1). The remaining area is cleared for recreational areas and was not included in the study area. The park is completely surrounded by residential areas and it is heavily used by the neighborhood children. Although the park consists of mostly unmodified native forest, a little has been cleared. Fallen logs are plentiful, and low ground cover is dense.

The University of Washington Arboretum (69 ha) represents a park area in which native forest vegetation has been replaced by open lawns mixed with garden areas of planted trees and shrubs. There are also small patches of native forest vegetation. The surrounding area is residential. The Arboretum is very heavily used for walking and picnicking. Plant species found there are both native and introduced (table 1). In the study area, trees were relatively evenly spaced, but shrubs and ground cover were confined to definite garden areas.

Government Locks Park (3 ha) exemplifies a small park with a garden arrangement of vegetation, similar to the Arboretum. It is surrounded by residential and business areas and is subjected to very heavy use by visitors to the locks, which form one of the park's boundaries. Plant species are both native and introduced (table 1).

Woodland Park (77 ha) contains a few coniferous trees, but most of the trees are bigleaf maple (*Acer macrophyllum*) (table 1). Almost all understory vegetation has been cleared and is replaced by grass and some concrete. This park is located in a residential area and is heavily used by residents of the area for picnicking and other recreation.

Roanoke Park (2 ha, one city block) is located in a residential area and is heavily used. Nearly all subordinate vegetation has been cleared, leaving only open lawns and trees (Douglas-fir and a variety of introduced deciduous ornamentals) (table 1). Low vegetation is restricted to hedges found along the periphery of the park.

The Condor 78:375–382, 1976

TABLE 1. Description of vegetation in study areas.

Study area	Tree cover[1] (> 25′)	High shrub-low tree cover[2] (4–25′)	Low shrub cover[2] (1–4′)	Ground cover[2] (< 1′)
Lee Forest (native forest) (control area)	80% *Pseudotsuga menziesii* 55%; 100′ *Tsuga heterophylla* 21%; 90′ *Alnus rubra* 14%; 65′	29% *Sambucus* sp. *Cornus* sp. *T. heterophylla*	68% *Rubus* sp. *Gaultheria shallon* *Polystichum munitum*	24%
Seward (native forest)	83% *P. menziesii* 26%; 140′ *A. rubra* 16%; 40′ *Acer macrophyllum* 16%; 75′ *Thuja plicata* 13%; 89′ *Arbutus menziesii* 12%; 87′	53% *A. rubra*	82% *P. munitum* *G. shallon* *Berberis nervosa*	14%
Northacres (native forest)	89% *A. rubra* 59% *P. menziesii* 36% both 65′	21% *Sambucus* sp. *Prunus* sp.	54% *Rubus* sp. *G. shallon* var. grass sp.	43%
Arboretum (formal garden shrubs and trees)	45% *T. plicata* 18% *A. macrophyllum* 15% *Prunus* sp. 10% *Pinus* sp. 10% all 40–65′	37% *Rhododendron* sp. *Prunus* sp. *G. shallon*	34% var. grass sp. *Rhododendron* sp.	42%
Government Locks (formal garden shrubs and trees)	26% *Acer* sp. 32% *Pinus* sp. 24% *P. menziesii* 22% all 35–45′	27% *Rhododendron* sp. *Ilex* sp.	16% *Rhododendron* sp. *B. nervosa*	41%
Woodland Park (trees and grass)	73% *A. macrophyllum* 81%; 65′	8% *Prunus* sp. *Chamaecyparus nootkatensis*	1%	90%
Roanoke Park (trees and grass)	36% *Quercus* sp. 24% *Tilia* sp. 19% *P. menziesii* 18% *Carpinus* sp. 11% all 55–70′	2%	1%	100%

[1] Figures are % cover of vegetation in this stratum. Tree species listed are those which comprised at least 10% of the canopy cover. Each species is listed with the percent of total cover represented by that species and its average height.

[2] Figures are % cover of vegetation in each stratum. Also listed are the most abundant species of each stratum.

In all cases vegetation cover in each stratum was measured by the line-intercept method described by Phillips (1959).

POPULATION ESTIMATES

Bird populations were studied from 1 May through 2 July 1971, by a strip census method (Kendeigh 1944). Each park was censused eight times, and Lee Forest, four times beginning 30 May. In the large parks, the study transects were 762 m long; in the smaller ones, they varied with size of the park: Northeacres—305 m, Government Locks—229 m, and Roanoke Park—153 m. In all cases, the transect was approximately 46 m wide. Censusing consisted of slowly walking the transect, counting every bird that was seen or heard within its boundaries. All censuses were made between 06:00 and 09:30. Approximately one hour was spent on the larger study areas and a half hour on the smaller ones during each census.

This method of censusing introduces some sources of sampling error but it also has advantages for this type of study. One source of error is the differences in conspicuousness of various species and of the same species in habitats with different amounts of vegetation. This problem exists, however, with any censusing technique used when different habitats are compared. Some of this error can be corrected by applying various indices of conspicuousness to abundance values; however, derivation of these factors is time-consuming and also introduces other potential errors. In this study, the narrowness of the transect reduced some of the error by eliminating birds seen across open areas in cleared parks. The second major source of error is inherent in the shape of the study area. A long narrow strip has more

edge than a more compact plot, and hence there are more problems in determining which birds are actually inside the study area.

Nevertheless, the strip census method has a number of important advantages in this type of study over more accurate, but more time-consuming techniques, such as the singing male (spot-map) method (Anon. 1970). The strip census method is efficient and allows the researcher to cover more study areas more quickly. The results provide indices of species abundance which are useful when comparing different habitats. The long narrow study transect allows one to cover a larger, more diverse, cross-section of the study area than would a compact plot. Results include all birds, not just breeding pairs. In this study, I did not seek to measure species abundances exactly, but to obtain comparative indices. I wished also to evaluate the occurrence of all species, not just breeding pairs. Therefore, for these reasons, I chose the strip census technique.

The occurrence of each bird species was evaluated both by its abundance and its frequency of occurrence. Abundance was expressed as the mean number of individuals counted per census (762 m of transect). Frequency of occurrence was calculated as the percent of censuses in which a species was observed, and was used as an indicator of the long-term occurrence of a species in a certain area.

After evaluating the occurrence of each species, I measured the avifauna of each park in six ways:

1) The total number of species observed in an area.

2) Number of regularly occurring species—those species which occurred on at least three of the eight censuses (Lee Forest, two out of four), and which were not known to be spring migrants through the area.

3) Number of "non-urban" species—those which are not typically associated with humans and the urban landscape. The species which were to be included in the group of "typical urban" species were determined before analyzing the population data. This group consisted of foreign species introduced to the Pacific northwest by man, and wide-ranging native species which are generally more characteristic of urban areas than local forests. The foreign species are the California Quail (*Lophortyx californicus*). Rock Dove (*Columba livia*), Starling (*Sturnus vulgaris*), and House Sparrow (*Passer domesticus*). The second group includes the Violet-green Swallow (*Tachycineta thalassina*), Barn Swallow (*Hirundo rustica*), Common Crow (*Corvus brachyrhynchos*), American Robin (*Turdus migratorius*), Brown-headed Cowbird (*Molothrus ater*), and House Finch (*Carpodacus mexicanus*).

I separated these typical urban species from the total list in order to evaluate whether the effect of all parks on their presence is the same or different, possibly owing to differences in vegetation and in the size of the parks. The remaining number of non-urban birds indicates the contribution of that park to the presence of typical forest birds.

4) Number of regularly occurring non-urban species—combination of above two figures.

I calculated the preceding values first by combining the results of all censuses in an area to form one composite species number for each category, and second by computing the mean number of species observed per census for each category.

5) Bird species diversity—a measure which takes into account the evenness of abundance of the different species as well as the total number of species. Rare species contribute less to diversity than do more common ones. The following formula derived from information theory was used: Bird species diversity $= \mathrm{BSD} = H' = -\sum_{i=1}^{s} p_i \ln p_i$ (MacArthur and MacArthur 1961) where s equals the total number of species and p_i equals the proportion of the total number of individuals which belong to the i^{th} species. BSD was also calculated as a mean value per census, and as a composite value.

6) Abundance—the mean number of individuals observed per census regardless of the number of different species observed.

The mean values for the above measures for the six parks were compared statistically by analysis of variance with two-way classification (0.05 significance level). The F-values thus generated represented the vegetation factor, the park size factor, and the interaction between the two. Mean values for all measures for the control area and the large forest park were compared statistically by the t-test (0.05 significance level).

RESULTS

PARK AVIFAUNAS

Comparison of the composite species numbers and diversity for each study area (table 2A) shows that the large forest park, Seward Park, and the control area, Lee Forest, had similar values in every measure. However, an exact quantitative comparison could not be made since censusing began later in Lee Forest than in Seward Park and earlier-occurring species in Lee Forest may have been missed. All of the parks had similar numbers of species except for the two small parks with modified vegetation, where fewer species were seen. In all of the other measures, numbers and diversity of species declined as modification of vegetation increased and park size decreased. In each size group, species numbers differed mostly between the forest park and the two parks with modified vegetation. Within each vegetation type, the large park had more species in each measure than the small park. Comparison of the different measures (table 2A) shows that the typical urban species comprised an increasingly large proportion of all species seen and of regularly occurring species in the smaller and more modified parks.

Statistical comparison of the mean values for each study area (table 2B) generally supports the pattern seen with the composite values. Mean values did not differ significantly between the control area and the large forest park as seen from the t-values (table 3).

The analysis of variance (table 4) indicates that change in park vegetation and size both significantly affected all of the measures of

TABLE 2. Diversity and abundance of birds in each study area.

Measures	Lee Forest (Control)	Seward (large forest)	Arboretum (large garden)	Woodland (large cleared)	N. acres (small forest)	G. locks (small garden)	Roanoke (small cleared)
A. COMPOSITE NUMBER[1]							
All species	33	33	31	29	29	20	15
Regularly occurring spp.	22	24	17	16	14	9	8
Non-urban spp.	29	29	23	19	21	10	6
Regularly occ. non-urban spp.	19	20	11	7	9	2	1
Bird species diversity (H′)	2.93	2.95	2.56	2.63	2.73	2.34	2.01
Proportion of all spp. which are non-urban	.88	.88	.74	.66	.72	.50	.40
Proportion of reg. occurring spp. which are non-urban	.86	.83	.65	.44	.64	.22	.13
B. MEAN NUMBER[2]							
All species	20.5	20.3	14.4	13.5	11.1	8.8	6.4
Regularly occ. species	17.5	18.5	11.5	10.9	8.9	7.1	5.4
Non-urban spp.	17.8	17.0	9.9	6.4	6.9	2.9	1.3
Regularly occ. non-urban spp.	14.8	15.3	7.4	3.9	5.0	1.8	0.5
Bird species diversity (H′)	2.62	2.67	2.09	2.18	2.17	1.87	1.52
Abundance[3]	77.8	85.6	82.0	77.5	79.7	108.5	115.0

[1] Composite number of species for all censuses combined.
[2] Mean number of species observed per census.
[3] Mean number of individuals observed per census (762 m of transect).

species numbers and diversity. However, park vegetation had no significant effect on abundance of all birds and park size had an effect of only marginal significance. In order to see which specific vegetation changes were significant within the above analysis of all vegetation types, I separately analyzed variance for only the two forest and two garden parks, and for only the two garden and two cleared parks. The F-values thus obtained show significant differences in mean values for all measures of species numbers and diversity when comparing the forest and garden parks, but for only some measures when comparing the garden and cleared parks. In most cases, the effect of interaction between the vegetation and size factors was also significant. This indicates that although vegetation significantly affected both size groups together, there *may* have been no significant difference due to vegetation in each size group. Similarly, although all of the large parks were significantly different from all of the small parks, there *may* not have been a significant difference due to size in every vegetation category.

TABLE 3. Statistical comparison of means from Lee Forest (control area) and Seward Park (large forest park).

Category compared	t-value*
All species	0.186
Non-urban species	0.545
Regularly occurring species	0.651
Regularly occurring non-urban species	0.365
Bird species diversity (H′)	0.628
Abundance	0.485

* None are significant at 0.05 significance level.

OCCURRENCE OF INDIVIDUAL SPECIES

Important differences among the parks could also be seen by noting the occurrences of individual species of birds. Table 5 lists the species observed in each park and gives the mean number observed per census (762 m of transect). Also shown in the table are the regularly occurring species.

Certain birds were noticeably fewer and occurred less frequently as clearing and

TABLE 4. Analysis of variance tables (.05 significance level).

A. ALL SPECIES

Source	All parks D.F.	S.S.	M.S.	Forest-garden only D.F.	S.S.	M.S.	Garden-cleared only D.F.	S.S.	M.S.
Veg.	2	281.17	140.59	1	136.12	136.12	1	21.12	21.12
Size	1	638.02	638.02	1	435.12	435.12	1	325.12	325.12
Inter.	2	24.66	12.33	1	24.52	24.52	1	4.52	4.52
Error	42	239.63	5.71	28	143.74	5.13	28	149.24	5.33
Total	47	1183.48		31	739.50		31	500.00	
	$F_{veg(2,42)} = 24.62$ (signif)			$F_{veg(1,28)} = 26.53$ (signif)			$F_{veg(1,28)} = 3.96$ (not)		
	$F_{size(1,42)} = 111.74$ (signif)			$F_{size(1,28)} = 84.82$ (signif)			$F_{size(1,28)} = 61.00$ (signif)		
	$F_{int(2,42)} = 2.16$ (not)			$F_{int(1,28)} = 4.78$ (signif)			$F_{int(1,28)} = 0.85$ (not)		

B. NON-URBAN SPECIES

Source	D.F.	S.S.	M.S.	D.F.	S.S.	M.S.	D.F.	S.S.	M.S.
Veg.	2	552.12	276.06	1	247.53	247.53	1	52.53	52.53
Size	1	660.09	660.09	1	586.53	586.53	1	294.03	294.03
Inter.	2	49.04	24.52	1	19.55	19.55	1	7.05	7.05
Error	42	136.00	3.24	28	82.61	2.95	28	71.11	2.54
Total	47	1397.25		31	936.22		31	424.72	
	$F_{veg} = 85.20$ (signif)			$F_{veg} = 83.91$ (signif)			$F_{veg} = 20.68$ (signif)		
	$F_{size} = 203.73$ (signif)			$F_{size} = 198.82$ (signif)			$F_{size} = 115.76$ (signif)		
	$F_{int} = 7.57$ (signif)			$F_{int} = 6.63$ (signif)			$F_{int} = 2.78$ (not)		

C. REGULARLY-OCCURRING SPECIES

Source	D.F.	S.S.	M.S.	D.F.	S.S.	M.S.	D.F.	S.S.	M.S.
Veg.	2	274.62	137.31	1	153.12	153.12	1	11.28	11.28
Size	1	507.01	507.01	1	392.00	392.00	1	195.03	195.03
Inter.	2	61.14	30.57	1	55.14	55.14	1	2.55	2.55
Error	42	134.48	3.20	28	95.74	3.42	28	73.61	2.63
Total	47	977.25		31	696.00		31	282.47	
	$F_{veg} = 42.91$ (signif)			$F_{veg} = 44.77$ (signif)			$F_{veg} = 4.29$ (signif)		
	$F_{size} = 158.44$ (signif)			$F_{size} = 114.63$ (signif)			$F_{size} = 74.16$ (signif)		
	$F_{int} = 9.55$ (signif)			$F_{int} = 16.12$ (signif)			$F_{int} = 0.97$ (not)		

D. REGULARLY-OCCURRING NON-URBAN SPECIES

Source	D.F.	S.S.	M.S.	D.F.	S.S.	M.S.	D.F.	S.S.	M.S.
Veg.	2	531.12	265.56	1	247.53	247.53	1	45.12	45.12
Size	1	494.09	494.09	1	504.03	504.03	1	162.00	162.00
Inter.	2	98.30	49.15	1	42.79	42.79	1	10.14	10.14
Error	42	63.74	1.52	28	52.87	1.89	28	26.24	0.94
Total	47	1187.25		31	847.22		31	243.50	
	$F_{veg} = 174.71$ (signif)			$F_{veg} = 130.97$ (signif)			$F_{veg} = 48.00$ (signif)		
	$F_{size} = 325.06$ (signif)			$F_{size} = 266.68$ (signif)			$F_{size} = 172.34$ (signif)		
	$F_{int} = 32.34$ (signif)			$F_{int} = 22.64$ (signif)			$F_{int} = 10.79$ (signif)		

E. BIRD SPECIES DIVERSITY (H')

Source	D.F.	S.S.	M.S.	D.F.	S.S.	M.S.	D.F.	S.S.	M.S.
Veg.	2	2.83	1.42	1	1.54	1.54	1	0.14	0.14
Size	1	2.56	2.56	1	1.06	1.06	1	1.56	1.56
Inter.	2	0.40	0.20	1	0.15	0.15	1	0.39	0.39
Error	42	2.47	0.06	28	1.23	0.04	28	1.81	0.07
Total	47	8.26		31	3.98		31	3.90	
	$F_{veg} = 23.67$ (signif)			$F_{veg} = 35.00$ (signif)			$F_{veg} = 2.15$ (not)		
	$F_{size} = 42.67$ (signif)			$F_{size} = 24.09$ (signif)			$F_{size} = 24.00$ (signif)		
	$F_{int} = 3.33$ (signif)			$F_{int} = 3.41$ (not)			$F_{int} = 6.00$ (signif)		

F. ABUNDANCE

Source	D.F.	S.S.	M.S.
Veg.	2	1793.38	896.69
Size	1	4543.52	4543.52
Inter.	2	4017.05	2008.53
Error	42	40539.86	965.23
Total	47	50893.81	
	$F_{veg} = 0.929$ (not)		
	$F_{size} = 4.707$ (signif)		
	$F_{int} = 2.081$ (not)		

Forest-cleared only (H', cont.)

Source	D.F.	S.S.	M.S.
Veg.	1	2.57	2.57
Size	1	2.70	2.70
Inter.	1	0.06	0.06
Error	28	1.90	0.07
Total	31	7.23	
	$F_{veg} = 36.71$ (signif)		
	$F_{size} = 38.57$ (signif)		
	$F_{int} = 0.86$ (not)		

TABLE 5. Urban park species list. Figures are mean number of birds observed per census per 762 m of transect.

Species	Lee Forest	Seward	Arbor.	Woodl.	North-acres	Govt. Locks	Roanoke
[1]*Lophortyx californicus*		.88*	.38	.13	2.20*	.83	3.15*
Columba fasciata	1.75*	.88*	.75*	.50*	2.83*		4.40*
[1]*C. livia*				.50*		1.65	
Bubo virginianus		.63*					
Selasphorus rufus	.25				.33		
Colaptes auratus	.25	.75*	.13	.50*	.95*		
Dendrocopos spp.	2.00*	1.25*					
Empidonax traillii	1.00*				.63		
E. difficilis	4.50*	.38	.25	.25			
Contopus sordidulus		.63*	.50	.25	.63		
Nuttallornis borealis		1.75*	.75*	.38			
[1]*Tachycineta thalassina*			3.75*	13.63*	.63	9.90*	30.65*
[1]*Hirundo rustica*				1.50*	.33	3.73*	4.40*
Cyanocitta stelleri	.25	2.13*		.13			1.25
[1]*Corvus brachyrhynchos*	.75*	2.25*	1.63*	11.13*	9.38*	5.38*	.65
Parus atricapillus	2.25*	5.13*	4.63*	4.50*	8.45*	3.73	1.25
P. rufescens	6.00*	6.13*	.13	.38	.63		
Psaltriparus minimus	.50*	16.25*	7.00*	3.00*	.33		
Sitta canadensis	1.50*	2.00*	.88*	.38	1.25*		
Certhia familiaris	.50*	.38*					
Troglodytes troglodytes	11.75*	2.38*					
Thyromanes bewickii	.50	3.00*			.95		
[1]*Turdus migratorius*	6.25*	6.63*	24.00*	8.38*	11.25*	22.70*	28.15*
Catharus ustulatus	3.00*	1.63	.38		.63		
Regulus satrapa	12.50*	.38			.95		
R. calendula	.75					.43	
Bombycilla cedrorum	.50		6.50*			1.65	
[1]*Sturnus vulgaris*	.25		1.75*	10.25*	.33	20.63*	11.25*
Vireo gilvus		.50		1.25*	.63	.43	
Vermivora celata		.13	.25	.38		.43	.65
Dendroica coronata	.75	.25	.38				
D. nigrescens	1.50*	4.13*	.38*		.33		
D. townsendii				.25			
Wilsonia pusilla	2.25*	2.50*	.50	2.25*	.95*	6.20*	.65
[1]*Passer domesticus*			.38	4.88*	2.20*	17.33*	8.75*
[1]*Molothrus ater*	2.00*	2.38*	6.63*	4.63*	8.45*	5.38*	1.25
Piranga ludoviciana	1.75*	1.38*	.13	2.25*	2.20*		
Pheucticus melanocephalus	.50*	.50	.13	.13	.33		
Hesperiphona vespertina		.25	7.25	3.50	1.25		
Carpodacus purpureus	1.25*	1.50*	1.00*				
[1]*C. mexicanus*			1.38*	1.13*		.43	18.15*
Spinus tristis	.25		.88*			.43	
Loxia curvirostra	1.00	1.00					
Pipilo erythrophthalmus	.25	8.13*	5.25*		11.25*		
Junco hyemalis	6.00*			.63			
Zonotrichia leucophrys			.13		2.20*	.43	
Z. atricapilla						.83	
Melospiza melodia	3.25*	6.63*	4.00*	.50	7.50*	6.20*	.65

[1] Typical urban species.
* Regularly occurring species.

modification of vegetation increased and park size decreased. These included the Chestnut-backed Chickadee (*Parus rufescens*), Bushtit (*Psaltriparus minimus*), Red-breasted Nuthatch (*Sitta canadensis*), Winter Wren (*Troglodytes troglodytes*), Bewick's Wren (*Thryomanes bewickii*), Swainson's Thrush (*Catharus ustulatus*), Black-throated Gray Warbler (*Dendroica nigrescens*), Purple Finch (*Carpodacus purpureus*), Rufous-sided Towhee (*Pipilo erythrophthalmus*), and Song Sparrow (*Melospiza melodia*). All of these species were generally more abundant in Seward Park, Lee Forest, and Northacres, and were much less abundant or absent in the parks with extensively modified vegetation.

This pattern was particularly evident for the Winter and Bewick's wrens, species that were seen only in the parks with natural forest floor vegetation. The Winter Wren and Brown Creeper (*Certhia familiaris*), species usually found only in dense forests with well-

TABLE 4. Analysis of variance tables (.05 significance level).

A. ALL SPECIES

Source	All parks D.F.	S.S.	M.S.	Forest-garden only D.F.	S.S.	M.S.	Garden-cleared only D.F.	S.S.	M.S.
Veg.	2	281.17	140.59	1	136.12	136.12	1	21.12	21.12
Size	1	638.02	638.02	1	435.12	435.12	1	325.12	325.12
Inter.	2	24.66	12.33	1	24.52	24.52	1	4.52	4.52
Error	42	239.63	5.71	28	143.74	5.13	28	149.24	5.33
Total	47	1183.48		31	739.50		31	500.00	
	$F_{veg(2,42)} = 24.62$ (signif)			$F_{veg(1,28)} = 26.53$ (signif)			$F_{veg(1,28)} = 3.96$ (not)		
	$F_{size(1,42)} = 111.74$ (signif)			$F_{size(1,28)} = 84.82$ (signif)			$F_{size(1,28)} = 61.00$ (signif)		
	$F_{int(2,42)} = 2.16$ (not)			$F_{int(1,28)} = 4.78$ (signif)			$F_{int(1,28)} = 0.85$ (not)		

B. NON-URBAN SPECIES

Source	All parks D.F.	S.S.	M.S.	Forest-garden only D.F.	S.S.	M.S.	Garden-cleared only D.F.	S.S.	M.S.
Veg.	2	552.12	276.06	1	247.53	247.53	1	52.53	52.53
Size	1	660.09	660.09	1	586.53	586.53	1	294.03	294.03
Inter.	2	49.04	24.52	1	19.55	19.55	1	7.05	7.05
Error	42	136.00	3.24	28	82.61	2.95	28	71.11	2.54
Total	47	1397.25		31	936.22		31	424.72	
	$F_{veg} = 85.20$ (signif)			$F_{veg} = 83.91$ (signif)			$F_{veg} = 20.68$ (signif)		
	$F_{size} = 203.73$ (signif)			$F_{size} = 198.82$ (signif)			$F_{size} = 115.76$ (signif)		
	$F_{int} = 7.57$ (signif)			$F_{int} = 6.63$ (signif)			$F_{int} = 2.78$ (not)		

C. REGULARLY-OCCURRING SPECIES

Source	All parks D.F.	S.S.	M.S.	Forest-garden only D.F.	S.S.	M.S.	Garden-cleared only D.F.	S.S.	M.S.
Veg.	2	274.62	137.31	1	153.12	153.12	1	11.28	11.28
Size	1	507.01	507.01	1	392.00	392.00	1	195.03	195.03
Inter.	2	61.14	30.57	1	55.14	55.14	1	2.55	2.55
Error	42	134.48	3.20	28	95.74	3.42	28	73.61	2.63
Total	47	977.25		31	696.00		31	282.47	
	$F_{veg} = 42.91$ (signif)			$F_{veg} = 44.77$ (signif)			$F_{veg} = 4.29$ (signif)		
	$F_{size} = 158.44$ (signif)			$F_{size} = 114.63$ (signif)			$F_{size} = 74.16$ (signif)		
	$F_{int} = 9.55$ (signif)			$F_{int} = 16.12$ (signif)			$F_{int} = 0.97$ (not)		

D. REGULARLY-OCCURRING NON-URBAN SPECIES

Source	All parks D.F.	S.S.	M.S.	Forest-garden only D.F.	S.S.	M.S.	Garden-cleared only D.F.	S.S.	M.S.
Veg.	2	531.12	265.56	1	247.53	247.53	1	45.12	45.12
Size	1	494.09	494.09	1	504.03	504.03	1	162.00	162.00
Inter.	2	98.30	49.15	1	42.79	42.79	1	10.14	10.14
Error	42	63.74	1.52	28	52.87	1.89	28	26.24	0.94
Total	47	1187.25		31	847.22		31	243.50	
	$F_{veg} = 174.71$ (signif)			$F_{veg} = 130.97$ (signif)			$F_{veg} = 48.00$ (signif)		
	$F_{size} = 325.06$ (signif)			$F_{size} = 266.68$ (signif)			$F_{size} = 172.34$ (signif)		
	$F_{int} = 32.34$ (signif)			$F_{int} = 22.64$ (signif)			$F_{int} = 10.79$ (signif)		

E. BIRD SPECIES DIVERSITY (H')

Source	All parks D.F.	S.S.	M.S.	Forest-garden only D.F.	S.S.	M.S.	Garden-cleared only D.F.	S.S.	M.S.
Veg.	2	2.83	1.42	1	1.54	1.54	1	0.14	0.14
Size	1	2.56	2.56	1	1.06	1.06	1	1.56	1.56
Inter.	2	0.40	0.20	1	0.15	0.15	1	0.39	0.39
Error	42	2.47	0.06	28	1.23	0.04	28	1.81	0.07
Total	47	8.26		31	3.98		31	3.90	
	$F_{veg} = 23.67$ (signif)			$F_{veg} = 35.00$ (signif)			$F_{veg} = 2.15$ (not)		
	$F_{size} = 42.67$ (signif)			$F_{size} = 24.09$ (signif)			$F_{size} = 24.00$ (signif)		
	$F_{int} = 3.33$ (signif)			$F_{int} = 3.41$ (not)			$F_{int} = 6.00$ (signif)		

F. ABUNDANCE

Source	D.F.	S.S.	M.S.
Veg.	2	1793.38	896.69
Size	1	4543.52	4543.52
Inter.	2	4017.05	2008.53
Error	42	40539.86	965.23
Total	47	50893.81	
	$F_{veg} = 0.929$ (not)		
	$F_{size} = 4.707$ (signif)		
	$F_{int} = 2.081$ (not)		

Forest-cleared only (H', cont.)

Source	D.F.	S.S.	M.S.
Veg.	1	2.57	2.57
Size	1	2.70	2.70
Inter.	1	0.06	0.06
Error	28	1.90	0.07
Total	31	7.23	
	$F_{veg} = 36.71$ (signif)		
	$F_{size} = 38.57$ (signif)		
	$F_{int} = 0.86$ (not)		

TABLE 5. Urban park species list. Figures are mean number of birds observed per census per 762 m of transect.

Species	Lee Forest	Seward	Arbor.	Woodl.	North-acres	Govt. Locks	Roanoke
[1]*Lophortyx californicus*		.88*	.38	.13	2.20*	.83	3.15*
Columba fasciata	1.75*	.88*	.75*	.50*	2.83*		4.40*
[1]*C. livia*				.50*		1.65	
Bubo virginianus		.63*					
Selasphorus rufus	.25				.33		
Colaptes auratus	.25	.75*	.13	.50*	.95*		
Dendrocopos spp.	2.00*	1.25*					
Empidonax traillii	1.00*				.63		
E. difficilis	4.50*	.38	.25	.25			
Contopus sordidulus		.63*	.50	.25	.63		
Nuttallornis borealis		1.75*	.75*	.38			
[1]*Tachycineta thalassina*			3.75*	13.63*	.63	9.90*	30.65*
[1]*Hirundo rustica*				1.50*	.33	3.73*	4.40*
Cyanocitta stelleri	.25	2.13*		.13			1.25
[1]*Corvus brachyrhynchos*	.75*	2.25*	1.63*	11.13*	9.38*	5.38*	.65
Parus atricapillus	2.25*	5.13*	4.63*	4.50*	8.45*	3.73	1.25
P. rufescens	6.00*	6.13*	.13	.38	.63		
Psaltriparus minimus	.50*	16.25*	7.00*	3.00*	.33		
Sitta canadensis	1.50*	2.00*	.88*	.38	1.25*		
Certhia familiaris	.50*	.38*					
Troglodytes troglodytes	11.75*	2.38*					
Thyromanes bewickii	.50	3.00*			.95		
[1]*Turdus migratorius*	6.25*	6.63*	24.00*	8.38*	11.25*	22.70*	28.15*
Catharus ustulatus	3.00*	1.63	.38		.63		
Regulus satrapa	12.50*	.38			.95		
R. calendula	.75					.43	
Bombycilla cedrorum	.50		6.50*			1.65	
[1]*Sturnus vulgaris*	.25		1.75*	10.25*	.33	20.63*	11.25*
Vireo gilvus		.50		1.25*	.63	.43	
Vermivora celata		.13	.25	.38		.43	.65
Dendroica coronata	.75	.25	.38				
D. nigrescens	1.50*	4.13*	.38*		.33		
D. townsendii				.25			
Wilsonia pusilla	2.25*	2.50*	.50	2.25*	.95*	6.20*	.65
[1]*Passer domesticus*			.38	4.88*	2.20*	17.33*	8.75*
[1]*Molothrus ater*	2.00*	2.38*	6.63*	4.63*	8.45*	5.38*	1.25
Piranga ludoviciana	1.75*	1.38*	.13	2.25*	2.20*		
Pheucticus melanocephalus	.50*	.50	.13	.13	.33		
Hesperiphona vespertina		.25	7.25	3.50	1.25		
Carpodacus purpureus	1.25*	1.50*	1.00*				
[1]*C. mexicanus*			1.38*	1.13*		.43	18.15*
Spinus tristis	.25		.88*			.43	
Loxia curvirostra	1.00	1.00					
Pipilo erythrophthalmus	.25	8.13*	5.25*		11.25*		
Junco hyemalis	6.00*			.63			
Zonotrichia leucophrys			.13		2.20*	.43	
Z. atricapilla						.83	
Melospiza melodia	3.25*	6.63*	4.00*	.50	7.50*	6.20*	.65

[1] Typical urban species.
* Regularly occurring species.

modification of vegetation increased and park size decreased. These included the Chestnut-backed Chickadee (*Parus rufescens*), Bushtit (*Psaltriparus minimus*), Red-breasted Nuthatch (*Sitta canadensis*), Winter Wren (*Troglodytes troglodytes*), Bewick's Wren (*Thryomanes bewickii*), Swainson's Thrush (*Catharus ustulatus*), Black-throated Gray Warbler (*Dendroica nigrescens*), Purple Finch (*Carpodacus purpureus*), Rufous-sided Towhee (*Pipilo erythrophthalmus*), and Song Sparrow (*Melospiza melodia*). All of these species were generally more abundant in Seward Park, Lee Forest, and Northacres, and were much less abundant or absent in the parks with extensively modified vegetation.

This pattern was particularly evident for the Winter and Bewick's wrens, species that were seen only in the parks with natural forest floor vegetation. The Winter Wren and Brown Creeper (*Certhia familiaris*), species usually found only in dense forests with well-

developed forest floor vegetation, were seen only in Seward Park and Lee Forest. Other shrub-dwelling species, such as the Rufous-sided Towhee, Swainson's Thrush, and Black-throated Gray Warbler, were seen in the Arboretum along the patches of shrubbery and brush and in Northacres Park, but not in Woodland Park, Government Locks, or Roanoke Park. Even though shrubbery was absent in Woodland Park and Roanoke Park, Song Sparrows were seen there, but they were not abundant.

Other birds were more abundant and common as clearing and modification of vegetation increased and park size decreased. They included the species listed as "typical urban" (except for the Brown-headed Cowbird and California Quail). The Starling, House Sparrow, House Finch, and Barn and Violet-green swallows were not seen at all in Seward Park or in Lee Forest. (The one Starling seen at Lee Forest was probably a visitor from a nearby field.) The American Robin and Common Crow were abundant in all the study areas. The distribution of the House Finch was opposite that of the Purple Finch; as one declined in abundance, the other increased. Rock Doves, which are very characteristic of the urban areas most devoid of vegetation, were seen only at Government Locks, Woodland Park, and Roanoke Park (where they were most abundant). Here they occurred primarily near the edge of the parks in very open areas.

DISCUSSION

In this study I found a diverse avifauna characteristic of Pacific northwest lowland coniferous forests in a large urban park where this habitat was well preserved. However, in other parks, altering the forest through planting formal gardens or clearing natural brush and reducing park size were associated with decreased overall bird diversity, fewer regularly occurring species, and a greater proportion of species typically associated with the urban environment. These differences, particularly in the balance between the "urban" species and the total species numbers, indicate that not just location in an urban environment was responsible for many of the differences in the associated avifauna. The condition of the vegetation and the size of the park appeared to be important. I did not see major differences between the large urban forest park and the control area, but rather among the parks with different types of vegetation and between the large and small parks.

The importance of adequate vegetation to support a high diversity of urban birds is also seen in the results of other studies which compare bird communities in different urban habitats (Linehan et al. 1967, Burr and Jones 1968, Woolfenden and Rohwer 1969).

Other investigators have also reported dense populations of birds in urban or modifed areas, sometimes higher than in comparable natural areas (Pitelka 1942, Young 1949, Linehan et al. 1967, Woolfenden and Rohwer 1969, Emlen 1974). In my study, however, differences between the control area and the large forest park were not significant and differences due to park size had only marginal significance (table 2B, 3, 4).

My findings at least partially support the hypothesis that diversity of vegetation structure, especially foilage height diversity, is correlated with bird species diversity (H′) in natural habitats (MacArthur 1964). Although I did not calculate an index of vegetation structural diversity or foilage height diversity, the presence and condition of the major strata of forest vegetation can be used as subjective indicators of structural diversity. Here, the forest parks represented the most diverse habitats since each stratum (canopy, understory, shrub, ground cover) was well established over the entire area. The garden and cleared parks represented structurally less diverse habitats due to the selective removal of all or part of the vegetation in various strata, especially in the shrub layer. Also, these parks contained few, if any, man-made structures such as buildings, utility poles, etc., features that can be important for increasing habitat diversity in urban areas (Emlen 1974). In this study the significant reduction in bird species diversity (H′) which followed a change from forest vegetation to either of the two types of modified vegetation (tables 2B, 4) suggests the importance of modifying the structure of forest vegetation. However, the effect of changes in structural diversity between the garden and cleared vegetation patterns is not so clear, since the bird species diversities (H′) in these two parks types were not significantly different.

The different patterns of distribution of individual species also reflect changes in vegetation structure. Many of the species with decreased abundance in small parks or in parks with more modified vegetation are known to prefer brushy habitats, which were partially or completely cleared in the more modified parks. Clearing of the landscape in these parks also included removal of dead

stumps and logs. The Winter Wren is known to prefer nest sites at ground level among fallen logs and stumps. This was probably a factor contributing to the absence of this species in all parks but Seward, and even its lesser abundance there. The presence of adequate natural brush cover was evidently a habitat requirement for the Bushtit, Winter Wren, Bewick's Wren, Swainson's Thrush, Black-throated Gray Warbler, Rufous-sided Towhee, and Song Sparrow. Ornamental shrubbery at least partially compensated for removed brush cover for all of these species (except the wrens), since they were observed in the Arboretum but were generally less abundant there. Since shrub removal and/or modification is a major aspect of vegetation changes occurring in urban parks of the Pacific northwest, the presence or absence of shrub-dwelling species is a useful indicator of the extent of vegetation change.

Those species with increased abundance in more modified areas also have certain habitat requirements. The Rock Dove, Starling, and House Sparrow are among the major species which are associated with extensive urbanization. Their ability to use man-made structures as nesting sites in and near the parks has undoubtedly contributed to their abundance in these areas. Burr and Jones (1968) also reported a greater abundance of such typical urban bird species as the Robin, House Sparrow, and Starling in highly managed urban woodlots than in unmanaged ones.

CONCLUSIONS

My results show that a large forested park with a natural diversity of native vegetation was associated with a high diversity of native forest bird species, a diversity comparable to a forest tract outside the urban influence. While native diversity was preserved, there was no marked increase in number of species typical of the urban landscape. At the opposite extreme, the small or highly modified parks contained fewer species, a greater proportion of species typical of urban areas, few regularly occurring species, and most native forest species in reduced abundance or frequency.

More precise measurement of vegetation structure, measurement of bird populations over longer periods of time and of breeding status are among several aspects to be considered for future research on the relationship of forest birds to urban habitats. However, this initial short-term study shows that a diverse avifauna characteristic of Pacific northwest lowland forests can be supported in urban areas as long as large park areas with native forest vegetation are maintained.

ACKNOWLEDGMENTS

This study was done as part of graduate work in the Wildlife Science Department, College of Forest Resources, University of Washington. I thank all who helped with this project, especially Richard Taber who gave me continued suggestions and David Manuwal who reviewed this manuscript. I also thank my colleagues from the College of Forest Resources and Department of Zoology and the Seattle Audubon Society who assisted me in the field and gave me valuable suggestions. This work was partially supported by a graduate fellowship from the National Science Foundation.

LITERATURE CITED

ANON. 1970. Recommendations for an international standard for a mapping method in bird census work. Audubon Field Notes 24:723–726.

BURR, R. M., AND R. E. JONES. 1968. Influence of parkland habitat management on birds in Delaware. Trans. N. Am. Wild. and Nat. Resour. Conf. 33:299–306.

EMLEN, J. T. 1974. An urban bird community in Tucson, Arizona: derivation, structure, regulation. Condor 76:184–197.

KENDEIGH, C. S. 1944. Measurement of bird populations. Ecol. Monogr. 14:68–106.

LINEHAN, J. T., R. E. JONES, AND J. R. LONGCORE. 1967. Breeding bird populations in Delaware's urban woodlots. Audubon Field Notes 21:641–646.

MACARTHUR, R. H. 1964. Environmental factors affecting bird species diversity. Am. Nat. 98: 387–397.

MACARTHUR, R. H., AND J. W. MACARTHUR. 1961. On bird species diversity. Ecology 42:594–598.

PHILLIPS, E. A. 1959. Methods of Vegetation Study. Henry Holt & Co., New York.

PITELKA, F. A. 1942. High population of breeding birds within an artificial habitat. Condor 44: 172–174.

WOOLFENDEN, G. E., AND S. A. ROHWER. 1969. Breeding birds in a Florida suburb. Bull. Fla. State Mus. Biol. Ser. 13:1–83.

YOUNG, H. 1949. Comparative study of nesting birds in a five-acre park. Wilson Bull. 61:36–47.

Division of Science & Mathematics, Whitworth College, Spokane, WA 99251. Accepted for publication 4 September 1975.