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An Approach for Monitoring Bird Communities to Assess Development of Restored Riparian Habitat

BARBARA E. KUS AND PETER P. BECK

U.S. Geological Survey, Western Ecological Research Center, 5745 Kearny Villa Road, Suite M, San Diego, CA 92123

ABSTRACT. A common goal of riparian restoration is to create habitat for bird species threatened by habitat loss. Birds are readily detected and monitored and thus useful in evaluating the progress of restored sites towards achieving structural and functional attributes of "natural" habitat. However, riparian bird communities are large and diverse, and simple comparisons of typical measures, such as species richness, between natural and restored sites can be uninformative and even misleading. We sought to identify a subset of riparian species that best reflect habitat changes at developing restoration sites by examining changes in guild structure and abundance over time at a southern California restoration site. We compared breeding season richness and abundance of bird guilds defined by habitat type preference, structural association, and foraging style from 1998-2000 at a 17-ha restoration site and adjacent natural reference site, and quantified vegetation structure at both sites annually. Guilds showing the greatest response to increases in foliage cover and height included woodland species and, to a lesser extent, willow riparian specialists; species requiring high canopy or a stratified canopy with both high and low cover; and foliage gleaners and aerial foragers. Birds common to these guilds comprised a list of 13 species, roughly one-tenth of the species typical of southern California woodlands. We suggest that focusing monitoring effort on this subset of species, half of which are sensitive, will not only promote more efficient use of scarce time and resources, but will provide a standardized and quantitative means for using bird community development to track restoration success.

INTRODUCTION

Riparian habitat in California, as in most of the American southwest, has been reduced to less than ten percent of its former extent, resulting in declines in many riparian-dependent bird species (Faber et al. 1989). Restoration offers a way to reverse the loss of riparian habitat and associated species, and birds are a common focus of such efforts. In some cases, the target of restoration may be a single species, such as endangered birds like the least Bell's vireo (*Vireo bellii pusillus*) (Kus 1998) and southwestern willow flycatcher (*Empidonax traillii extimus*) (Boucher et al. in review). In other instances, restoration takes a broader focus and is used to re-establish riparian bird communities in general (Anderson et al. 1989, Hunter et al. 1989, Rigney et al. 1989). Even when not the specific focus of restoration, birds provide a useful means for evaluating restoration site performance and similarity to natural habitat. Birds as a group are abundant, largely diurnal, and conspicuous, and they are typically among the taxa, and sometimes the only taxon, monitored as restoration sites develop. Although they are readily observed and quantified, birds present challenges in analyses used to assess restoration sites through comparison with natural habitats. Riparian bird communities are large and diverse, and not easily characterized. Attempts to compare bird communities through simple measures such as species richness often fail to consider community composition and thus risk producing erroneous or misleading conclusions regarding community similarity. Decisions regarding how species should be weighted in such analyses are often arbitrary and based on factors other than demonstrated relationships between species occurrences and abundance, and specific habitat features of interest (Morrison 1986, Landres et al. 1988).

Whether explicit or implicit, the goal of restoration is to create habitats that possess the structural and functional attributes of the natural habitats they are intended to replace. This presents a dilemma in identifying an appropriate model by which to gauge restoration site performance in that natural habitats typically used as models are mature stands while restoration sites created through plantings are in the earliest stages of development. The result is that monitoring restoration site performance is largely an effort in documenting progress towards achievement of the model habitat attributes. To be useful in this context as indicators of progress in restored habitats, birds must exhibit predictable and measurable responses to specific changes in habitat condition. Monitoring of such species would provide an additional measure of habitat development to supplement that possible through direct sampling of vegetation, and might even be used to replace it as an assessment tool where such effort is prohibitively costly or time-consuming.

We sought to identify a subset of riparian species that best reflect changes in habitat structure at developing riparian restoration sites. Restricting our analysis to breeding birds, we sub-divided species into habitat and foraging guilds and compared guild composition and

abundance in a restored habitat to those in a natural reference habitat. Our emphasis in this analysis was not on the degree of similarity between the restored and reference bird communities, but rather on the magnitude of change exhibited by guilds during three years of vegetation growth at the restoration site, which we hypothesized was indicative of a response to that growth.

STUDY SITE AND METHODS

Study Site

We monitored vegetation development and bird use of restored habitat at a 17-ha site along Pilgrim Creek, a tributary of the San Luis Rey River in northern San Diego County, California. Formerly used for agriculture, the site was established in 1996 by the California Department of Transportation as partial mitigation for impacts to native habitats of a nearby highway expansion project. The site was graded, and planted with 1-, 5-, and 15-gallon container nursery stock of native riparian trees and shrubs typical of the area, including Black Willow (*Salix gooddingii*), Arroyo Willow (*S. lasiolepis*), Sandbar Willow (*S. exigua*), Mule Fat (*Baccharis glutinosa*), Fremont Cottonwood (*Populus fremontii*), and Western Sycamore (*Platanus racemosa*). Plantings were configured to mimic the structure and composition of natural riparian habitat, using a model developed from vegetation measurements taken at several San Diego county rivers (Baird 1989, Baird and Rieger 1989, Hendricks and Rieger 1989). The restored habitat receives maintenance to control herbaceous weeds, and is irrigated through a combination of overhead sprinklers and flood watering within bermed areas. A pond and freshwater marsh covering 0.6 ha occurs in one corner of the restoration site. Vegetation structure and attributes of the bird community in the restored habitat were compared to those of natural mature habitat along Pilgrim Creek, which served as the reference habitat for analyses. The reference site includes seven ha of willow-dominated vegetation along a narrow channel adjacent to the planted habitat.

Vegetation Monitoring

Data quantifying vegetation structure were collected annually in both the restored and reference habitats beginning in 1997. Data were collected at points spaced every 10 m along permanently marked transects arrayed to provide uniform coverage of both sites. A total of 506 quads along 28 transects in the restored habitat, and 54 quads along 16 transects in the reference habitat, were measured, yielding sampling densities of 30 quads per ha and eight quads per ha, respectively. Foliage volume at 1-m height intervals was estimated using the "stacked cube" method, developed specifically to characterize canopy architecture in structurally diverse riparian habitat (Kus 1998). By this method, field workers record percent cover of vegetation, by species, within 2- by 2- by 1-m high sampling volumes "stacked" vertically between the ground and the top of the canopy above the point. Four 2-m lengths of PVC pipe are placed on the ground to define the quadrat boundaries, and connectible lengths of PVC, marked at 1-m intervals, are used to determine height within the canopy. Percent cover is scored in the field using a modified Daubenmire (1959) scale with cover classes < 1, 1-10, 11-25, 26-50, 51-75, 76-90, and >90 percent. For analysis, cover codes were converted to class midpoints, which were then used to quantify vegetation structure at each sampling point and for the site as a whole. Canopy height at each point was recorded as the height of the tallest vegetation within the sampling quad.

Bird Monitoring

Bi-weekly bird surveys were conducted year-round at the restored and reference sites between 1998 and 2000. Surveys were conducted during early morning hours, and typically lasted 2-3 hours in each habitat, which were surveyed on sequential days weather permitting. Birds were surveyed by observers following established routes designed to provide coverage of the entire site. Species, age, sex, and behavior were recorded for every bird encountered, as were plant species and bird height for birds perched in vegetation. Any nests or nesting behavior observed during surveys were noted. Flyovers were noted, but not included in analyses.

Analyses

Birds were categorized relative to seasonal occurrence (year-round resident, migratory breeding species, migratory wintering species, and migrant/transient) based upon the species' use of the Pilgrim Creek site, not necessarily their occurrence in the region as a whole. Only breeding species, both resident and migratory, were included in the analysis presented here, excluding raptors and waterbirds whose association with the vegetative component of the habitats of interest here are weak. Birds were grouped for analysis into guilds (groups of species exploiting environmental resources in similar ways; Root 1967) describing (1) habitat preference, (2) vegetation structure association, and (3) foraging style, using Ehrlich et al. (1988), Unitt (1984), and our own experience to assign species to guilds. Habitat preference was defined to reflect a spectrum of habitat use from open country species to willow riparian specialists, and included five categories: open habitat and grasslands, shrublands, multiple habitats (e.g. habitat generalists), woodlands, and willow riparian habitat. Habitat structural association was categorized as "no structure", describing species that inhabit open areas lacking vegetation, "variable" or generalists with regard to structure, "low" for species characteristically associated with low shrub cover independent of habitat type, "high" for species requiring a tall canopy associated with woodlands, and "high and low" describing those species dependent upon woodlands

with a highly stratified canopy structure. Foraging style was assigned based upon the species' primary feeding mode (Ehrlich et al. 1988) and condensed to four categories: hawk and/or hover-glean, bark glean, ground glean, and foliage glean.

Species richness (number of species detected) was determined for the restoration and reference sites in each year, using only data for the breeding season (April-July). Species densities were calculated and expressed as the average number of individuals per survey per ha, using site areas calculated from coordinates obtained in the field using a Global Positioning System. Richness and density, both overall and by guild, were compared between the two sites using the ratio of each variable in the restoration site to the reference site, allowing us to control for any interannual variability in the reference habitat. The percent change in these ratios between 1998 and 2000 was compared across guilds to identify which of them most strongly responded to changes in vegetation structure at the restoration site, predicting that the greatest increases would occur in guilds most closely associated with the particular habitat feature (e.g. height of vegetation, cover at particular canopy heights) undergoing change.

RESULTS

Development of Restored Habitat

Vegetation in the reference site along Pilgrim Creek displays the structure typical of southern California riparian habitat, with a diverse multi-layered canopy reaching over eight m in height (Figure 1). Foliage cover is greatest in the lowest portions of the canopy, tapering off with increasing canopy height. Cover in the reference habitat increased slightly between 1998 and 2000 at several canopy heights below six m, but the overall foliage height profile was unchanged.

Vegetation at the restored site, in its third growing season by 1998, lacked the density and height of the reference habitat in all canopy layers except that between 0-2 m (Figure 1). Foliage cover of the restored habitat increased between 1998 and 2000 as planted vegetation continued to grow in height and lateral cover, with the greatest growth occurring at mid-canopy heights between 2-5 m. By 2000, cover of the restored

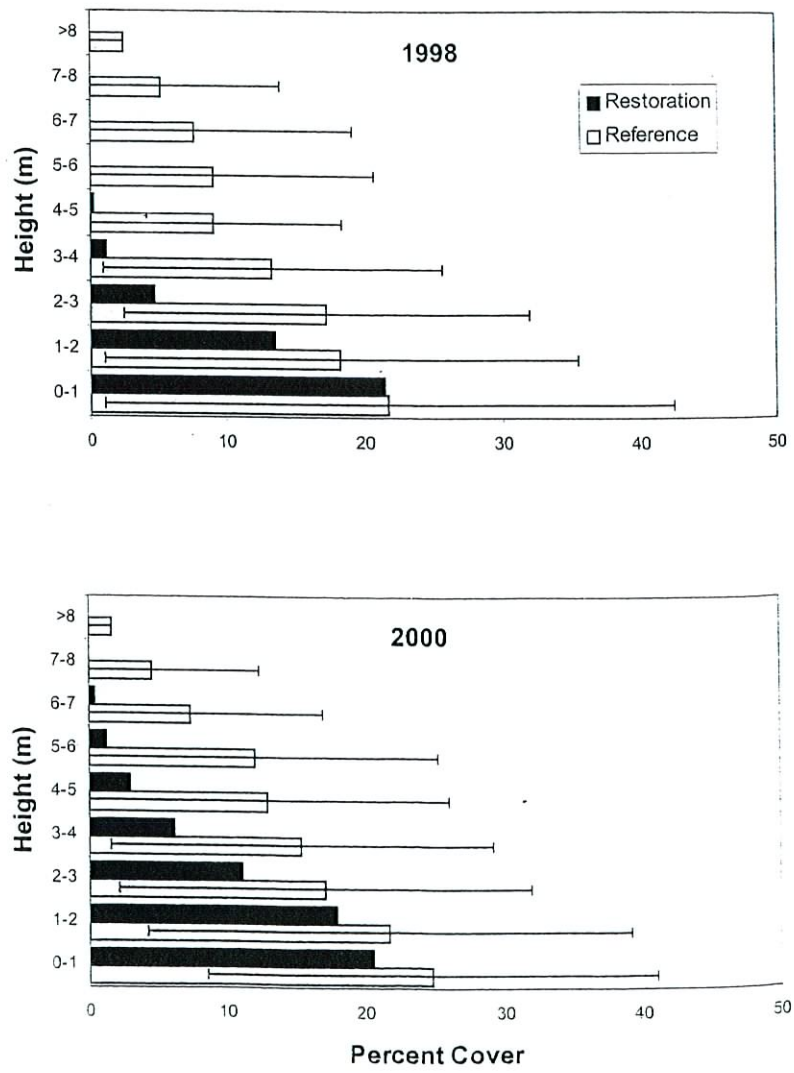

FIGURE 1. Percent cover +/- s.d.of vegetation, by height, in riparian restoration and reference sites, Pilgrim Creek, 1998 and 2000.

TABLE 1. Bird species observed at riparian restoration and reference sites, Pilgrim Creek, 1998 and 2000.

Common Name	Taxonomic Name	Residency[1]	Reference Habitat		Restored Habitat	
			1998	2000	1998	2000
Mallard	*Anas platyrhynchos*	R	x	x	x	x
Gadwall	*Anas strepera*	W			x	x
Green-winged teal	*Anas crecca*	W			x	x
Cinnamon teal	*Anas cyanoptera*	W			x	x
Northern shoveler	*Anas clypeata*	W			x	
Ruddy duck	*Oxyura jamaicensis*	R			x	
White-faced ibis	*Plegadis chihi*	R				x
Great blue heron	*Ardea herodias*	R		x		
Great egret	*Egretta alba*	R	x		x	
Snowy egret	*Egretta thula*	R	x		x	
Cattle egret	*Bubulcus ibis*	R			x	
Green heron	*Butorides virescens*	R		x		x
Sora	*Porzana carolina*	W			x	x
American coot	*Fulica americana*	R			x	x
American avocet	*Recurvirostra americana*	R			x	
Black-necked stilt	*Himantopus mexicanus*	R			x	
Common snipe	*Gallinago gallinago*	W			x	x
Least sandpiper	*Calidris minutilla*	W			x	x
Western sandpiper	*Calidris mauri*	W			x	
Greater yellowlegs	*Tringa melanoleuca*	W			x	x
Lesser yellowlegs	*Tringa flavipes*	W				x
Spotted sandpiper	*Actitis macularia*	W			x	
Killdeer	*Charadrius vociferus*	R	x		x	x
California quail	*Callipepla californica*	R	x			x
Mourning dove	*Zenaida macroura*	R	x	x	x	x
Common ground-dove	*Columbina passerina*	R			x	
White-tailed kite	*Elanus leucurus*	R	x	x		
Sharp-shinned hawk	*Accipiter striatus*	W	x	x		
Cooper's hawk	*Accipiter cooperii*	R	x	x		x
Red-tailed hawk	*Buteo jamaicensis*	R	x	x		
Red-shouldered hawk	*Buteo lineatus*	R	x	x		
American kestrel	*Falco sparverius*	R	x	x	x	
Barn owl	*Tyto alba*	R	x			
Greater roadrunner	*Geococcyx californianus*	R			x	x
Belted kingfisher	*Ceryle alcyon*	R	x	x	x	
Downy woodpecker	*Picoides pubescens*	R	x	x	x	x
Nuttall's woodpecker	*Picoides nuttallii*	R	x	x	x	x
Northern flicker	*Colaptes auratus*	R	x	x	x	x
Vaux's swift	*Chaetura vauxi*	M				x
White-throated swift	*Aeronautes saxatalis*	R		x		
Black-chinned hummingbird	*Archilochus alexandri*	S	x	x		x
Anna's hummingbird	*Calypte anna*	R	x	x	x	x
Western kingbird	*Tyrannus verticalis*	S				x
Cassin's kingbird	*Tyrannus vociferans*	R	x		x	
Ash-throated flycatcher	*Myiarchus cinerascens*	S	x	x	x	
Say's phoebe	*Sayornis saya*	W	x	x	x	x
Black phoebe	*Sayornis nigricans*	R	x	x	x	x
Pacific-slope flycatcher	*Empidonax difficilis*	S	x	x		x
Willow flycatcher	*Empidonax traillii*	S	x			x
Common raven	*Corvus corax*	R	x	x	x	x

TABLE 1 (continued). Bird species observed at riparian restoration and reference sites, Pilgrim Creek, 1998 and 2000.

Common Name	Taxonomic Name	Residency[1]	Reference Habitat		Restored Habitat	
			1998	2000	1998	2000
American crow	*Corvus brachyrhynchos*	R	x	x		
European starling	*Sturnus vulgaris*	R	x	x		x
Brown-headed cowbird	*Molothrus ater*	S		x		
Red-winged blackbird	*Agelaius phoeniceus*	R	x	x	x	x
Western meadowlark	*Sturnella neglecta*	R			x	x
Hooded oriole	*Icterus cucullatus*	S	x	x	x	x
Bullock's oriole	*Icterus bullockii*	S	x	x		x
Great-tailed grackle	*Quiscalus mexicanus*	R		x		
House finch	*Carpodacus mexicanus*	R	x	x	x	x
American goldfinch	*Carduelis tristis*	R	x	x	x	x
Lesser goldfinch	*Carduelis psaltria*	R	x	x	x	x
Lawrence's goldfinch	*Carduelis lawrencei*	R	x			
Pine siskin	*Carduelis pinus*	W		x		
Vesper sparrow	*Pooecetes gramineus*	W			x	
Savannah sparrow	*Passerculus sandwichensis*	W	x	x	x	x
White-crowned sparrow	*Zonotrichia leucophrys*	W	x	x	x	x
Golden-crowned sparrow	*Zonotrichia atricapilla*	W	x			
Song sparrow	*Melospiza melodia*	R	x	x	x	x
Lincoln's sparrow	*Melospiza lincolnii*	W	x	x	x	x
Spotted towhee	*Pipilo maculatus*	R	x	x	x	x
California towhee	*Pipilo crissalis*	R	x	x	x	x
Black-headed grosbeak	*Pheucticus melanocephalus*	S	x	x		x
Blue grosbeak	*Guiraca caerulea*	S	x	x	x	x
Lazuli bunting	*Passerina amoena*	S	x			x
Western tanager	*Piranga ludoviciana*	S	x			
Cliff swallow	*Petrochelidon pyrrhonota*	S		x	x	x
Barn swallow	*Hirundo rustica*	S		x		
Tree swallow	*Tachycineta bicolor*	S	x	x	x	x
Violet-green swallow	*Tachycineta thalassina*	S				x
Northern rough-winged swallow	*Stelgidopteryx serripennis*	S	x	x		x
Warbling vireo	*Vireo gilvus*	M	x	x		x
Hutton's vireo	*Vireo huttoni*	R	x	x		x
Least Bell's vireo	*Vireo bellii pusillus*	S	x	x	x	x
Nashville warbler	*Vermivora ruficapilla*	M	x	x		
Orange-crowned warbler	*Vermivora celata*	R	x	x	x	x
Yellow warbler	*Dendroica petechia*	S	x	x	x	x
Yellow-rumped warbler	*Dendroica coronata*	W	x	x	x	x
Black-throated gray warbler	*Dendroica nigrescens*	M	x	x		
Townsend's warbler	*Dendroica townsendi*	M	x	x		
Hermit warbler	*Dendroica occidentalis*	M		x		
Common yellowthroat	*Geothlypis trichas*	R	x	x	x	x
Yellow-breasted chat	*Icteria virens*	S	x	x	x	x
Wilson's warbler	*Wilsonia pusilla*	S	x	x		x
American pipit	*Anthus rubescens*	W	x		x	x
California thrasher	*Toxostoma redivivum*	R				x
Bewick's wren	*Thyromanes bewickii*	R	x	x	x	x
House wren	*Troglodytes aedon*	B/W	x	x	x	x
Marsh wren	*Cistothorus palustris*	R	x	x	x	x

TABLE 1 (continued). Bird species observed at riparian restoration and reference sites, Pilgrim Creek, 1998 and 2000.

Common Name	Taxonomic Name	Residency[1]	Reference Habitat		Restored Habitat	
			1998	2000	1998	2000
Wrentit	*Chamaea fasciata*	R	x	x		x
Bushtit	*Psaltriparus minimus*	R	x	x	x	x
Ruby-crowned kinglet	*Regulus calendula*	W	x	x	x	x
Blue-gray gnatcatcher	*Polioptila caerulea*	W	x	x	x	x
Swainson's thrush	*Catharus ustulata*	S		x		
Hermit thrush	*Catharus guttatus*	W	x	x	x	x
American robin	*Turdus migratorius*	R		x		
Total			**69**	**68**	**64**	**69**

[1] R = Year-round resident; S = Summer; W = Winter; M = Migrant/transient

habitat at 0-2 m was 83 percent of that in the reference site, and 65 percent of that at 2-3 m. Measurable cover had also developed at heights of 5-8 m, and the average maximum canopy height increased from 2.4 +_ 1.1 m to 3.8 +_ 1.8 m.

Composition and Abundance of Bird Communities

A total of 105 bird species were documented in the study area during 1998 and 2000 (Table 1). Overall species richness differed little between the restoration and reference sites in either year; however, in both years the proportion of shared species was low (49 percent and 54 percent, respectively), indicating substantial differences in species composition between the two sites. Of these 105 species, 41 breeders or potential breeders representing 39 percent of the total bird community were selected for further analysis and assigned to guilds (Table 2).

Species richness of breeders in the restored habitat was two-thirds that in the reference habitat in 1998 (Table 3), and the proportion of shared species was relatively low at 59 percent (22/37). Unlike for the entire bird community, breeding bird richness in the restored habitat increased by 2000 to exceed that in the reference site, although still only 72 percent (28/39) of the species were common to both habitats.

Guilds differed in richness between the two habitats, as well as in the degree to which richness in the restored habitat relative to the reference habitat changed over time (Table 3). Of the habitat preference guilds, open country and shrubland species were absent from the reference site in both years with the exception of a single shrub species in 1998. Habitat generalists, constituting the largest of the habitat preference guilds, made up the majority of breeding species in both the restored and reference sites, but changed little in terms of relative species richness between years. In contrast, woodland species, although fewer in number, increased in richness in the restored habitat by 8-fold during the three years such that by 2000, richness was equivalent to that in the reference habitat. Willow riparian specialists also exhibited equal species richness in both habitats by 2000, although the proportionate increase in the restored habitat between 1998 and 2000 was considerably lower than that of woodland species.

Of the structural association guilds, that comprising species occupying habitats with no cover and thus no vegetation structure was the smallest, represented by a single species (Killdeer, *Charadrius vociferus*) which occurred only in the restoration site. Species more generalized in their use of habitats with regard to structure (="variable" in Table 3) were well represented in both habitats in both years, and increased only slightly in the restored site between 1998 and 2000. Guilds reflecting stronger associations with particular habitat components showed the greatest change over time as richness in the restored habitat increased to match or exceed that in the reference habitat. The largest increase in similarity to the reference habitat was observed for species requiring high structure, which tripled over the three years to achieve the richness documented for the reference habitat. Low canopy specialists, equivalent in richness in the two habitats in 1998, increased in the restoration site and by 2000 exceeded the richness in the reference habitat. Species associated with vertically stratified habitats possessing both high and low canopy elements made up the largest of the structural guilds and displayed substantial increase in similarity between the restored and reference habitats over the three years.

The two largest foraging guilds, ground gleaners and foliage gleaners, differed in the extent to which they changed over the three years of vegetation development. Ground gleaners were well-represented in both habitats from early on and thus showed little change in richness in the restored vegetation over time. In contrast, foliage gleaners nearly doubled in richness at the restored site to achieve a richness comparable to that in the reference habitat. Species foraging primarily by hawking or hovering were less numerous than the ground and foliage gleaners, but exhibited increased similarity in use of the two habitats. Bark gleaners,

TABLE 2. Guild assignments of breeding birds at riparian restoration and reference sites, Pilgrim Creek.

Common Name	Habitat Preference	Habitat Structure Association[1]	Foraging Mode
California quail	Shrubland	L	Ground glean
Killdeer	Open / Grassland	N	Ground glean
Mourning dove	Multiple	V	Ground glean
Common ground-dove	Multiple	L	Ground glean
Downy woodpecker	Willow Riparian	H/L	Bark glean
Nuttall's woodpecker	Woodland	H	Bark glean
Black-chinned hummingbird	Woodland	H/L	Hawk, hover glean
Anna's hummingbird	Multiple	H/L	Hawk, hover glean
Western kingbird	Open / Grassland	V	Hawk, hover glean
Ash-throated flycatcher	Multiple	H/L	Hawk, hover glean
Black phoebe	Multiple	V	Hawk, hover glean
Pacific-slope flycatcher	Woodland	H	Hawk, hover glean
Willow flycatcher	Willow Riparian	H/L	Hawk, hover glean
Common raven	Multiple	V	Ground glean
American crow	Multiple	V	Ground glean
Red-winged blackbird	Multiple	V	Ground glean
Hooded oriole	Multiple	H/L	Foliage glean
Bullock's oriole	Woodland	H	Foliage glean
Great-tailed grackle	Multiple	V	Ground glean
House finch	Multiple	V	Ground glean
American goldfinch	Willow Riparian	H/L	Foliage glean
Lesser goldfinch	Multiple	V	Foliage glean
Song sparrow	Multiple	L	Ground glean
Spotted towhee	Multiple	H/L	Ground glean
California towhee	Multiple	V	Ground glean
Black-headed grosbeak	Woodland	H	Foliage glean
Blue grosbeak	Multiple	H/L	Ground glean
Lazuli bunting	Multiple	H/L	Ground glean
Hutton's vireo	Woodland	H	Foliage glean
Least Bell's vireo	Willow Riparian	H/L	Foliage glean
Orange-crowned warbler	Woodland	H/L	Foliage glean
Yellow warbler	Willow Riparian	H	Foliage glean
Common yellowthroat	Multiple	L	Foliage glean
Yellow-breasted chat	Willow Riparian	H/L	Foliage glean
Wilson's warbler	Woodland	H/L	Foliage glean
California thrasher	Shrubland	L	Ground glean
Bewick's wren	Multiple	H/L	Ground glean
House wren	Woodland	H/L	Ground glean
Wrentit	Multiple	L	Foliage glean
Bushtit	Multiple	H/L	Foliage glean
Swainson's thrush	Willow Riparian	H/L	Foliage glean

[1]N = No structure; L = Low structure; H = High structure; H/L = High & Low; V = Variable

which included two species of woodpeckers, were identical in occurrence across sites and years.

Bird densities were significantly higher in the reference habitat than in the restored habitat for nearly all guilds in both years, differing generally by an order of magnitude across the two sites (Table 4). Nevertheless, densities in the restored habitat increased for many guilds over the study period, reflecting the patterns observed in species richness. Both woodland and willow riparian species doubled in abundance in the restoration site and exhibited larger relative increases than any other habitat preference guilds. Similarly, species associated with stratified canopies ("high and low") doubled in their ratio of similarity to the reference habitat. High structure species, which increased in similarity to the reference site as well, did so not through an absolute increase in bird densities, but rather through a relative increase created by a decline in density of this guild in the reference habitat in 2000. Densities of low canopy species, although more similar to the reference densities in both years

than those of any other structure guilds, increased only slightly over the three years. Of the foraging guilds, foliage gleaners showed the greatest positive change in relative density, nearly doubling in three years; ground gleaners, while more abundant, changed little during this time. Both bark gleaners and hawk/hover foragers declined slightly in density and similarity to the reference habitat.

The six guilds exhibiting the greatest increases in species richness and bird densities in the restored habitat shared many species in common. Of the 26

TABLE 3. Species richness, by guild, of breeding birds in restored and reference riparian habitats.

Guild		# Species in Guild	Reference		Restoration		# Shared Species		Rest./Ref.		Change in Rest./Ref.
			1998	2000	1998	2000	1998	2000	1998	2000	
Habitat Preference	Open / Grassland	2	0	0	1	2	0	0	-	-	-
	Shrubland	2	1	0	1	2	1	0	1.00	-	-
	Multiple	21	19	18	16	15	15	14	0.84	0.83	-0.01
	Woodland	9	9	9	1	9	1	9	0.11	1.00	8.00
	Willow Riparian	7	6	6	5	6	5	5	0.83	1.00	0.20
Structural Preference	No structure	1	0	0	1	1	0	0	-	-	
	Variable	10	8	8	6	7	6	6	0.75	0.88	0.17
	Low	6	4	3	4	5	3	3	1.00	1.67	0.67
	High & Low	18	17	16	11	15	11	13	0.65	0.94	0.45
	High	6	6	6	2	6	2	6	0.33	1.00	2.00
Primary Foraging Mode	Hawk, Hover-glean	7	6	5	3	6	3	4	0.50	1.20	1.40
	Bark Glean	2	2	2	2	2	2	2	1.00	1.00	0.00
	Ground Glean	17	13	11	11	12	9	8	0.85	1.09	0.29
	Foliage Glean	15	14	15	8	14	8	14	0.57	0.93	0.63
Total	All Breeders	41[1]	35	33	24	34	22	28	0.69	1.03	0.49

[1]Total for both years combined. 37 species present in 1998; 39 present in 2000.

TABLE 4. Density (ave. # individuals/survey/ha), by guild, of breeding birds in restored and reference riparian habitats.

Guild		Reference		Restoration		Rest./Ref.				Change in Rest./Ref.
		1998	2000	1998	2000	1998	P	2000	P	
Habitat Preference	Open / Grassland	0.00	0.00	0.14	0.03	-	**	-	*	-
	Shrubland	0.02	0.00	0.03	0.03	1.62	NS	-	*	-
	Multiple	13.43	13.80	5.77	7.54	0.43	****	0.55	****	0.27
	Woodland	2.41	1.46	0.06	0.14	0.02	****	0.10	**	3.12
	Willow Riparian	5.35	4.50	0.46	0.90	0.09	****	0.20	****	1.35
Structural Preference	No structure	0.00	0.00	0.14	0.02	-	**	-	NS	-
	Variable	2.56	3.39	1.20	1.45	0.47	**	0.43	**	-0.09
	Low	7.36	7.52	3.72	4.88	0.51	****	0.65	**	0.28
	High & Low	8.33	6.73	1.27	2.17	0.15	****	0.32	****	1.12
	High	2.95	2.12	0.12	0.12	0.04	****	0.06	****	0.40
Primary Foraging Mode	Hawk, Hover-glean	1.40	1.25	0.43	0.33	0.31	****	0.26	***	-0.16
	Bark Glean	0.70	0.36	0.06	0.03	0.09	****	0.08	****	-0.12
	Ground Glean	7.97	6.50	3.40	3.68	0.43	****	0.57	**	0.33
	Foliage Glean	11.14	11.66	2.56	4.62	0.23	****	0.40	****	0.72
Total	All Breeders	21.20	19.76	6.46	8.65	0.30	****	0.44	****	0.44

* P < 0.05, ** P < 0.01, *** P < 0.001, **** P < 0.0001; one-tailed t-tests comparing density in the restored habitat to density in the reference habitat for a given year.

species total in these six guilds, we extracted a group of 13 meeting three criteria: (1) they belonged to either the woodland or willow riparian guilds, (2) they were associated with high or high-and-low cover, and (3) they were foliage gleaners or aerial foragers (Table 5). Collectively, these 13 species exhibited increases in species richness and density of restoration site birds as great or greater than all but one (woodland) of the individual guilds analyzed.

DISCUSSION

Riparian ecosystems are dynamic, both in terms of their plant communities and the animal populations they support. Successional in nature and prone to periodic natural disturbance, riparian vegetation is remarkably resilient and capable of rapid establishment given proper conditions of soil and moisture. From the perspective of restoration, this resilience renders riparian habitat one of the easiest habitat types to create, and it has become possible to establish habitat supporting target species within a few years of planting (Kus 1998). We detected substantial changes in the structure of planted vegetation over three growing seasons at our Pilgrim Creek study site, evidence that the restored habitat is progressing towards achievement of the structural attributes of natural riparian habitat. Is the restored habitat progressing in terms of achievement of *functional* attributes as well? How does bird use of the site reflect changes in habitat structure as the vegetation matures?

We found analyzing bird communities by guilds to be a useful approach for comparing bird use of our restored and reference sites as we addressed this question. First, it allowed reduction of the large number of species using the sites to a more tractable number of subdivisions, and avoided the pitfalls of comparing large communities with broadly different composition. It also avoided multiple single-species comparisons and the associated problem of how to weight and synthesize results into a coherent conclusion. Aggregating species into guilds produced sample sizes adequate for analysis where such are often lacking for individual species. Most important, the guild approach allowed us to assess the response to habitat change of species sharing an association with particular habitat features of interest; in this case, development of foliage cover and canopy architecture typical of natural riparian habitat.

We found large differences among guilds in their response to changing structure of the restored habitat, and consequently their usefulness as indicators of habitat change. Open country and shrubland species never or rarely occurred in the reference habitat, making their contribution to evaluating restoration site performance negligible. Least responsive of the guilds occurring in both sites were habitat generalists, which also were the most numerous and abundant species found there. Species richness of this guild was high in both the restored and reference habitats by 1998 and has changed little since then. Densities of habitat generalists in the restored habitat, at half those in the reference site, increased only slightly in comparison with increases exhibited by other guilds. The large proportion of ground feeders such as Mourning Doves (*Zenaida macroura*) and California Towhees (*Pipilo crissalis*) among the habitat generalists suggests that these species found suitable foraging habitat in the restoration site early on, and may explain the weak response to foliage development of the restored vegetation since then.

Not surprisingly, the guilds most responsive to restoration site development were those associated with woodlands and willow-dominated habitat - the very habitat type being created. We considered increases in

TABLE 5. Species richness and density (ave. # individuals/survey/ha) of habitat change indicator species in restored and reference riparian habitats.

Component Species	Reference		Restoration		Rest./Ref.		Change in Rest./Ref.
	1998	2000	1998	2000	1998	2000	
Black-chinned hummingbird	*Species Richness*						
Pacific-slope flycatcher	12	12	4	12	0.33	1.00	2.00
Willow flycatcher[1]							
Bullock's oriole							
American goldfinch	*Density*						
Black-headed grosbeak[3]	6.50	5.37	0.45	1.00	0.07	0.19	1.69
Hutton's vireo							
Least Bell's vireo[1]							
Orange-crowned warbler							
Yellow warbler[2]							
Yellow-breasted chat[2]							
Wilson's warbler[3]							
Swainson's thrush[3]							

[1]Federally endangered (Southwestern willow flycatcher; other subspecies California State endangered)
[2]California Special Concern species
[3]Partners in Flight Riparian Conservation Focal Species

bird densities to be particularly indicative of functional habitat change in that they avoided potentially spurious conclusions regarding trends in species richness where species can be represented by a single individual. Of the guilds we examined, foliage gleaners and willow/woodland species associated with high canopy complexity were those exhibiting the greatest increases in density during the time that restored vegetation increased in cover and height. While the densities of these guilds in the restoration site remain below those in the reference habitat, the degree of change exhibited suggests that the availability of habitat possessing the features required by these species has increased, allowing their population numbers to grow. Increases in species richness of these guilds suggests that increased habitat availability and complexity is allowing partitioning among a larger bird community.

Although we emphasize changes in guild density as those most indicative of habitat change, we also view as informative two guilds for which species richness but not density increased substantially during the three year period: species associated with high canopy, and aerial foragers (hawk or hover-glean foraging mode). It is possible that density increases did not match those of species richness in these guilds because only limited suitable habitat meeting their specific requirements may currently exist in the restoration site. For example, flycatchers, which make up the majority of the aerial feeders, typically forage from high canopy perches, which may not be sufficiently available to support larger flycatcher populations. It is likely that these guilds will show a greater density response to future development of the canopy overstory than they have to recent changes in the mid-canopy region.

Although low shrubby understory is a critical component of riparian habitat and supports many species of nesting birds, we found the low canopy guild by itself to be largely uninformative regarding habitat development in the restoration site during the last three years. This is because low canopy species, particularly song sparrows (*Melospiza melodia*) and common yellowthroats (*Geothlypis trichas*), are the first to colonize restoration sites once an understory develops, which in southern California generally occurs within one or two growing seasons (Kus 1998). Thus, by 1998, the low canopy guild at our site was well established in the restored habitat, and currently shows the highest degree of similarity to the reference community, both in terms of species richness and bird densities, of all guilds using the site. Low canopy species are thus more appropriate for evaluating restoration site performance in the earliest stages of development. However, we would caution that because this guild consists primarily of habitat generalists and ground feeders, early similarities to a reference habitat may not necessarily indicate that the restored vegetation is developing along a trajectory that will ultimately yield a multi-layered riparian woodland.

Our guilds were not mutually exclusive, and broad overlap exists in the component species of guilds found most useful in tracking habitat change. The 13 species we found most useful for evaluating habitat structure collectively form a group that better reflects habitat change in the restored vegetation than all but one of the individual guilds we examined. It is noteworthy that of these 13 species, over half are sensitive species threatened by habitat loss and degradation, affirming the potential of this group to track both positive and negative habitat change.

How applicable is this approach to other settings? We maintain that although adjustments will be required in guild assignments to incorporate regional differences in bird communities and species' biology, the use of guilds for evaluating restoration site performance offers many advantages and has broad utility (Severinghaus 1981, Verner 1984, Szaro 1986, Canterbury et al. 2000). The subset of 13 species we propose for monitoring and analysis reduces the number of species that occur at our site by an order of magnitude, producing a more manageable number in terms of both field data collection and analysis. Although we have not performed a similar analysis for the non-breeding season, the approach we present here requires field surveys during only part of the year, producing a potential cost-saving with regard to field effort. It is our hope that with further testing, this approach will provide a basis for more specificity in the development of success criteria and monitoring programs for restoration projects performed as mitigation, and that it will allow standardization across sites being evaluated for restoration success.

Time, and further research, will be required to complete our understanding of the progression of riparian restoration at sites currently in the early- to mid-stages of development. We encourage researchers and managers to take advantage of opportunities to develop long-term data sets needed to address questions about plant and animal community development, and ways to monitor them.

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