Use of Saltcedar Vegetation by Landbirds Migrating Through the Bosque Del Apache National Wildlife Refuge

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Abstract—We compared diversity, abundance and energetic condition of migrant landbirds captured in four different vegetation types in the Bosque del Apache National Wildlife Refuge. We found lower species diversity among migrants caught in exotic saltcedar vegetation than in native willow or cottonwood. In general, Migrants were most abundant in agricultural edge and least abundant in cottonwood. There were no consistent patterns in energetic condition of common species among vegetation types. Ninety percent of statistical tests for variation in mass and fat score among vegetation types showed no significant difference. The few significant tests indicated that (1) Chipping Sparrows caught in saltcedar tended to be in poorer energetic condition than those caught in other vegetative types; (2) Ruby-crowned Kinglets captured in saltcedar tended to be in better energetic condition than those in other vegetative types; (3) The relationship between energetic condition of Wilson's Warbler's and vegetation type varied with year and season. The mixed evidence we report on the effects of exotic saltcedar on migrant birds parallels the existing literature on this topic. It is important to consider the configuration of vegetation types on the landscape when evaluating the effects of saltcedar on migrant birds.

Riparian vegetation that comprises the bosque of the Middle Rio Grande Valley is an important habitat component for both resident and migrant birds (Finch and Yong *in press*, Yong and others *in press*). Large numbers of en-route migrants use these riparian areas as stopover habitat and they likely represent a critical resource for successful migration (Farley and others 1994, Wauer 1977). The bosque was historically dominated by cottonwood-willow vegetative associations, but the abundance of these plants has been declining due to changes in the hydrograph of the Rio Grande and the invasion of saltcedar (*Tamarisk ramosissima*; Howe and Knopf 1988). Saltcedar has become a dominant component of lowland desert riparian communities of the Southwest (Hunter and others 1988). In addition to the obvious effects of saltcedar on native plant communities, there is also concern over its effects on the quality of riparian habitat for birds and other animals.

One of the primary concerns has been the potential loss of biodiversity that could result if many bird species cannot sustain themselves in saltcedar dominated habitats. For instance, over 240 species of birds are known to breed in the Middle Rio Grande Valley (Hink and Ohmart 1984). These species represent a large fraction (49 percent) of the 493 bird species that occur in New Mexico (Williams 1997). Furthermore, the concentration of endangered species in the Southwest is higher than in most other regions (Flather and others 1994, Reid 1998) and many of these species are riparian obligates. This loss of biodiversity may also have economic impacts. In New Mexico, 1.6 million people spent $428 million on activities associated with watching wildlife in 1996 (USDI and USDOC 1997). Bird watching and hunting alone generated $90 million in retail sales in New Mexico in 1991 (Inter. Assoc. Fish. & Wildl. Agencies 1992). So, there is substantial commerce that is derived from game and non-game wildlife in New Mexico. Thus, saltcedar has the potential to negatively impact both the biodiversity of New Mexico's fauna and the commerce that it supports.

For these reason's, there have been a number of studies on the effects of saltcedar on bird communities in the southwestern U.S. (Anderson and others 1977, Carothers 1974, Ellis 1995, Hunter and others 1985, Hunter and others 1988). The majority of these studies have found mixed results relative to the impact of saltcedar on bird communities. Interestingly, nearly all of these studies are based on community metrics and use point counts or other visual surveys as the primary means of assessing the response of birds to vegetation structure. While the results we report here are also derived from a community approach, our study differs from previous work in that we use data from mist nets to assess the relationship between vegetation structure and migrant diversity, abundance, and energetic condition. We reasoned that if saltcedar was poor migrant habitat, then we should catch fewer total number of birds of fewer species in this vegetation and these birds should in poorer energetic condition than those caught in native willow (*Salix* spp.) and cottonwood (*Populus* spp.) vegetation.

Methods

Our study area was at the north edge of the Bosque del Apache National Wildlife Refuge (N33°48', W106°52'; hereafter Bosque del Apache). This mist-net area was chosen because it contained a diversity of vegetation types in close proximity. That is, all nets were within a 1 km radius circle of the banding station. We used mist nets (12 m x 2.6 m, 30 or 36 mm mesh) to capture spring and fall migrants at the Bosque del Apache. We placed nets in four vegetation types. These types were: (1) cottonwood (*Populus fremontii*) forests with mixed native and exotic understory (14 nets in 1996 and 7 nets in 1997); (2) saltcedar monocultures (5 nets in 1996 and 7 nets in 1997); (3) willow strips along irrigation canals (18 nets in both years); and along an agricultural edge

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(3 nets in both years). Agricultural edge nets were located in strips of cottonwood (2 nets) and in fourwing saltbush (*Atriplex canescens;* 1 net). Nets were operated from mid April to early June (referred to hereafter as spring) and from early August until early November (referred to hereafter as fall) each year. Nets were operated 5 days per week, and were opened 15 minutes prior to sunrise for about 6 h/d except during inclement weather. Nets were checked at 20-30 minute intervals. Each bird captured was marked with a uniquely numbered aluminum leg band. The mass, morphological features (for example, unflattened wing chord, tarsus, and culmen lengths) and the fat condition of each bird were measured. Fat condition was scored on an integer scale from zero to six (Helms and Drury 1960).

To compare the diversity of birds captured among vegetation types we used rarefaction curves (James and Rathbun 1981, Ludwig and Reynolds 1988). These curves represent the number of species that we would expect to catch in any sample of individuals. These expected values were generated from the relative abundance of all species in the capture data. Comparison among rarefaction curves is limited by the number of individuals captured in the sparest subsample (James and Rathbun 1981). For this reason, we compared expected number of species in samples of 100 individuals from each vegetation type.

To compare abundance of migrants among vegetation types we calculated capture rates as number of birds/1000 net h. A single mist net operated for 1 hour equals one net hour. We calculated capture rates for: (1) all captures; (2) for the 5 most common families; and (3) for seven individual species that represented the most common families and had relatively large numbers of captures in saltcedar. These species were Brewer's Sparrow (*Spizella breweri*), Chipping Sparrow (*Spizella passerina*), Dark-eyed Junco (*Junco hyemalis*), Dusky Flycatcher (*Empidonax oberholseri*), Ruby Crowned Kinglet (*Regulus calendula*), White-crowned Sparrow (*Zonotrichia leucophrys*), Wilson's Warblers (*Wilsonia pusilla*). We also compare mass and fat score among vegetation types for these seven species. We used Kruskal-Wallis tests to compare capture rates, mass, and fat scores among vegetation types. We conducted separate tests for each year and season.

Results

We operated mist nets for a total of 41,652 net hrs. Effort was evenly divided between the two years; 21,082 net hrs (51 percent) in 1996 and 20,570 net hrs (49 percent) in 1997. More effort was used to catch birds in the fall (26,023 net hrs; 63 percent) than in the spring (15,629 net hrs; 37 percent). We captured a total of 5,466 birds in the two years. Unlike our effort, these captures were not evenly divided between the two years. Many more birds were captured in 1996 (3,732 individuals; 68 percent) than in 1997 (1,734 individuals, 32 percent). While we also captured more individuals in the fall (3,184 individuals; 58 percent) than in the spring (2,282 individuals; 42 percent), this pattern parallels the difference in effort between the seasons.

We captured individuals of 118 species that represented 25 families (table 1). Five families accounted for 80 percent of captures. These were: Warblers (Parulidae; 2,234

Table 1—Number of captures for 118 species of birds mist-netted at the Bosque del Apache during 1996 and 1997.

		1996			1997			
Common name	**Scientific name**	**Spring**	**Fall**	**Total**	**Spring**	**Fall**	**Total**	**Grand total**
HAWKS								
Northern Harrier	*Circus cyaneus*	0	1	0	0	0	0	1
Sharp-shinned Hawk	*Accipiter striatus*	0	0	0	1	0	1	1
Coopers Hawk	*Accipiter cooperii*	0	1	1	0	0	0	1
DOVES								
Mourning Dove	*Zenaida macroura*	0	0	0	1	3	4	4
White-winged Dove	*Zenaida asiatica*	0	0	0	1	0	1	1
Common Ground Dove	*Columbina passerina*	0	0	0	1	0	1	1
CUCKOOS								
Greater Roadrunner	*Geococcyx californianus*	0	1	1	2	1	3	4
Yellow-billed Cuckoo	*Coccyzus americanus*	2	2	4	0	2	2	6
HUMMINGBIRDS*								
Black-chinned Hummingbird	*Archilochus alexandri*	42	10	52	67	27	94	146
Calliope Hummingbird	*Stellula calliope*	0	0	0	0	1	1	1
Broad-tailed Hummingbird	*Selasphorus platycercus*	5	1	6	2	0	2	8
Rufous Hummingbird	*Selasphorus rufus*	0	6	6	0	3	3	9
KINGFISHERS								
Belted Kingfisher	*Ceryle alcyon*	0	0	0	0	2	2	2
WOODPECKERS								
Hairy Woodpecker	*Picoides villosus*	1	0	1	1	0	1	2
Downy woodpecker	*Picoides pubescens*	0	0	0	0	1	1	1
Ladder-backed Woodpecker	*Picoides scalaris*	0	0	0	1	0	1	1
Red-naped Sapsucker	*Sphyrapicus nuchalis*	0	2	2	0	1	1	3
Williamson's Sapsucker	*Sphyrapicus thyroideus*	0	1	1	0	0	0	1
Northern Flicker	*Colaptes auratus*	0	4	4	0	2	2	6

(con.)

Table 1 (Con.)

Common name	Scientific name	1996 Spring	1996 Fall	1996 Total	1997 Spring	1997 Fall	1997 Total	Grand total
FLYCATCHERS								
Western Kingbird	*Tyrannus verticalis*	0	1	1	1	1	2	3
Brown-crested Flycatcher	*Myiarchus tyrannulus*	0	1	1	0	0	0	1
Ash-throated Flycatcher	*Myiarchus cinerascens*	13	0	13	12	0	12	25
Say's Pheobe	*Sayornis saya*	1	1	2	0	0	0	2
Black Pheobe	*Sayornis nigricans*	8	1	9	9	2	11	20
Western Wood-pewee	*Contopus sordidulus*	20	20	40	7	3	10	50
Western Flycatcher	*Empidonax difficilis*	5	10	15	1	4	5	20
Willow Flycatcher	*Empidonax traillii*	27	23	50	29	12	41	91
Hammond's Flycatcher	*Enpidonax hammondii*	9	5	14	0	0	0	14
Dusky Flycatcher	*Empidonax oberholseri*	102	21	123	31	7	38	161
Gray Flaycatcher	*Empidonax wrightii*	10	2	12	1	2	3	15
VIREOS								
Red-eyed Vireo	*Vireo olivaceus*	1	0	1	0	0	0	1
Warbling Vireo	*Vireo gilvus*	45	46	91	12	18	30	121
Yellow-throated Vireo	*Vireo flavifrons*	1	0	1	0	0	0	1
Solitary Vireo	*Vireo solitarius*	13	5	18	2	1	3	21
Gray Vireo	*Vireo vicinior*	1	0	1	0	0	0	1
JAYS								
Western Scrub Jay	*Aphelocoma californica*	0	0	0	0	1	1	1
SWALLOWS								
Barn Swallow	*Hirundo rustica*	7	5	12	4	2	6	18
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	3	0	3	6	0	6	9
CHICKADEES								
Mountain Chickadee	*Poecile gambeli*	1	1	2	0	0	0	2
VERDINS								
Verdin	*Auriparus flaviceps*	0	2	2	0	0	0	2
BUSHTITS								
Common Bushtit	*Psaltriparus minimus*	0	1	1	0	19	19	20
NUTHATCHES								
White-breasted Nuthatch	*Sitta carolinensis*	1	0	1	0	0	0	1
Red-breasted Nuthatch	*Sitta canadensis*	0	3	3	0	0	0	3
CREEPERS								
Brown Creeper	*Certhia americana*	0	11	11	0	0	0	11
WRENS								
Cactus Wren	*Campylorhynchus brunneicapillus*	0	0	0	0	0	1	1
Rock Wren	*Salpinctes obsoletus*	0	1	1	0	0	0	1
Carolina Wren	*Thyrothorus ludovicianus*	1	0	1	0	0	0	1
Bewick's Wren	*Thyromanes bewickii*	15	24	39	13	22	35	74
House Wren	*Troglodytes aedon*	33	11	44	7	2	9	53
Winter Wren	*Troglodytes troglodytes*	0	1	1	0	0	0	1
Marsh Wren	*Cistothorus palustris*	1	2	3	0	0	0	3
GNATCATCHERS								
Blue-gray gnatcatcher	*Polioptila caerulea*	3	0	3	2	0	2	5
THRUSHES								
Townsend's Solitaire	*Myadestes townsendi*	1	1	2	1	0	1	3
Swainson's Thrush	*Catharus ustulatus*	3	2	5	1	0	1	6
Hermit Thrush	*Catharus guttatus*	15	9	24	3	1	4	28
American Robin	*Turdus migratorius*	13	2	15	11	0	11	26
Ruby-crowned Kinglet	*Regulus calendula*	25	132	157	30	115	145	302
MIMIC THRUSHES								
Northern Mockingbird	*Mimus polyglottos*	6	0	6	1	0	1	7
Gray Catbird	*Dumetella carolinensis*	2	3	5	0	0	0	5
WOOD WARBLERS								
Black and White Warbler	*Mniotilta varia*	1	2	3	0	0	0	3
Prothonotary Warbler	*Protonotaria citrea*	0	2	2	0	1	1	3
Blue-winged Warbler	*Vermivora pinus*	1	0	1	1	0	1	2
Golden-winged Warbler	*Vermivora chrysoptera*	0	0	0	2	0	2	2

(con.)

Table 1 (Con.)

Common name	Scientific name	1996 Spring	1996 Fall	1996 Total	1997 Spring	1997 Fall	1997 Total	Grand total
WOOD WARBLERS (Con.)								
Lucy's warbler	*Vermivora luciae*	1	0	1	2	0	2	3
Virginia's Warbler	*Vermivora virginiae*	18	34	52	5	12	17	69
Nashville Warbler	*Vermivora ruficapilla*	3	0	3	0	1	1	4
Orange-crowned Warbler	*Vermivora celata*	32	37	69	10	30	40	109
Yellow Warbler	*Dendroica petechia*	44	77	121	48	34	82	203
Black-throated Blue Warbler	*Dendroica caerulescens*	0	1	1	0	0	0	1
Yellow-rumped Warbler	*Dendroica coronata*	53	39	92	9	7	16	108
Magnolia Warbler	*Dendroica magnolia*	2	0	2	0	0	0	2
Chestnut-sided Warbler	*Dendroica pensylvanica*	2	0	2	0	0	0	2
Bay-breasted Warbler	*Dendroica castanea*	0	0	0	1	0	1	1
Black-throated Gray Warbler	*Dendroica nigrescens*	1	0	1	0	1	1	2
Townsend's Warbler	*Dendroica townsendi*	2	1	3	0	2	2	5
Prairie Warbler	*Dendroica discolor*	1	0	1	0	0	0	1
Ovenbird	*Seiurus motacilla*	4	0	4	0	0	0	4
Northern Waterthrush	*Seiurus noveboracensis*	0	8	8	0	4	4	12
Kentucky Warbler	*Oporornis formosus*	1	0	1	0	0	0	1
MacGillivray's Warbler	*Opornis tolmiei*	234	62	296	30	41	71	367
Common Yellowthroat	*Geothylpis trichas*	63	19	82	45	21	66	148
Yellow-breasted Chat	*Icteria virens*	26	4	30	10	8	18	48
Hooded Warbler	*Wilsonia citrina*	2	0	2	0	0	0	2
Wilson's Warbler	*Wilsonia pusilla*	348	380	728	124	294	418	1146
Canada Warbler	*Wilsonia canadensis*	1	0	1	0	0	0	1
American Redstart	*Setophaga ruticilla*	1	1	2	1	1	2	4
TANAGERS								
Western Tanager	*Piranga ludoviciana*	4	31	35	2	3	5	40
Hepatic Tanager	*Piranga flava*	0	2	2	0	0	0	2
Summer Tanager	*Piranga rubra*	13	37	50	6	10	16	66
SPARROWS								
Vesper Sparrow	*Pooecetes gramineus*	2	1	3	1	2	3	6
Savannah Sparrow	*Passerculus sandwichensis*	0	4	4	1	8	9	13
Lark Sparrow	*Chondestes grammacus*	4	7	11	0	8	8	19
Harris' Sparrow	*Zonotrichia querula*	0	0	0	1	0	1	1
White-crowned Sparrow	*Zonotrichia leucophrys*	77	211	288	132	60	192	480
White-throated Sparrow	*Zonotrichia albicollis*	0	2	2	0	0	0	2
Chipping Sparrow	*Spizella passerina*	33	265	298	9	17	26	324
Clay-colored Sparrow	*Spizella padilla*	0	0	0	0	11	11	11
Brewer's Sparrow	*Spizella breweri*	57	32	79	6	33	39	118
Dark-eyed Junco	*Junco hyemalis*	40	133	173	9	29	38	211
Black-throated Sparrow	*Amphispiza bilineata*	1	0	1	0	1	1	2
Sage Sparrow	*Amphispiza belli*	0	0	0	0	1	1	1
Song Sparrow	*Melospiza melodia*	3	115	118	2	28	30	148
Lincoln's Sparrow	*Melospiza lincolnii*	14	125	139	4	34	38	177
Swamp Sparrow	*Melospiza georgiana*	0	1	1	0	0	0	1
Fox Sparrow	*Passerella iliaca*	0	2	2	0	0	0	2
Spotted Towhee	*Pipilo maculatus*	22	37	59	10	19	29	98
Green-tailed Towhee	*Pipilo chlorurus*	18	12	30	6	8	14	44
Canyon Towhee	*Pipilo fuscus*	1	0	1	0	1	1	2
GROSBEAKS & BUNTINGS								
Pyrrhuloxia	*Cardinalis sinuatus*	0	1	1	0	0	0	1
Black-headed Grosbeak	*Pheucticus melanocephalus*	31	25	56	25	3	28	84
Blue Grosbeak	*Guiraca caerulea*	25	61	86	14	76	90	176
Indigo Bunting	*Passerina cyanea*	7	4	11	8	7	15	26
Lazuli Bunting	*Passerina amoena*	5	31	36	2	11	13	49
Painted Bunting	*Passerina ciris*	0	2	2	0	0	0	2
BLACKBIRDS								
Brown-headed Cowbird	*Molothurus ater*	8	0	8	21	0	21	29
Red-winged Blackbird	*Agelaius phoeniceus*	1	2	3	0	2	2	5
Northern Oriole	*Icterus galbula*	5	3	8	3	0	3	11
Common Grackel	*Quiscalus quiscala*	0	0	0	1	0	1	1
Great-tailed Grackel	*Quiscalus mexicanus*	0	0	0	3	0	3	3
FINCHES								
House Finch	*Carpodacus mexicanus*	15	1	16	7	1	8	24
American Goldfich	*Carduelis tristis*	2	1	3	1	0	1	4
Lesser Goldfinch	*Carduelis psaltria*	6	12	18	0	2	2	20

*Note that hummingbirds were not banded, So some of the captured birds may be repeats.

individuals; 41 percent), Sparrows (Emberizidae; 1,572 individuals; 29 percent of all captures), Flycatchers (Tyrannidae; 399 individuals: 7 percent), Thrushes (Turdidae; 368 individuals; 7 percent), and Grosbeaks (331 individuals; 6 percent). The remaining 20 families accounted for only 20 percent of all captures (562 individuals). We caught >200 individuals of seven species: Wilson's Warbler, MacGillivray's Warbler (*Oporornis philadelphia*), Yellow Warbler (*Dendroica petechia*), White-crowned Sparrow, Chipping Sparrow, Dark-eyed Junco, and Ruby Crowned Kinglet.

Rarefaction curves indicate that the diversity of migrants captured in saltcedar was lower than that captured in native cottonwood and willow in 3 of the 4 seasons examined (fig. 1); the exception was spring 1997. There was also a tendency for diversity of birds captured to be lower in agriculture edge than in native bosque vegetation.

Capture rates were higher in all vegetation types during 1996 than in 1997 (fig. 2) There was significant variation in capture rates among vegetation types in spring ($\chi^2 = 27.8$, df = 3, p<0.001) and fall ($\chi^2 = 6.3$, df = 3, p<0.1) of 1996 and in fall 1997 ($\chi^2 = 6.9$, df = 3, p<0.08), but this variation was not significant in spring 1997. Cottonwood had the lowest capture rate in both seasons of both years and saltcedar had the second lowest capture rate in both seasons of 1997 and spring of 1996. Agricultural edge had the highest capture rates in both seasons of 1997 and in the fall of 1996. Significant variation in capture rates among vegetation types was also evident in some of the common families in some seasons (table 2).

Of the seven species examined, six showed significant variation in abundance among vegetation types in at least one sampling period (table 3). All four sparrows showed significant variation in capture rates in spring and fall 1996, but the only significant pattern among these species in 1997 was for Dark-eyed Juncos in the fall. Chipping, White-crowned, and Brewer's sparrows tended to be most abundant in the agricultural edge and least abundant in the cottonwood. Dark-eyed Juncos differed from the other sparrows by being most abundant in cottonwood and saltcedar. Wilson's Warblers tended to be most abundant in willow, but were also abundant in the agricultural edge in 1996 and in saltcedar in both falls. While, Ruby-crowned Kinglets tended to be most common in willow, there was no significant variation in their abundance among vegetation types in any season. Finally, Dusky Flycatchers tended to be most abundant in saltcedar, followed by willow (3 of 4 seasons). However, significant variation in capture rates of Dusky Flycatchers among vegetation types was evident only in spring

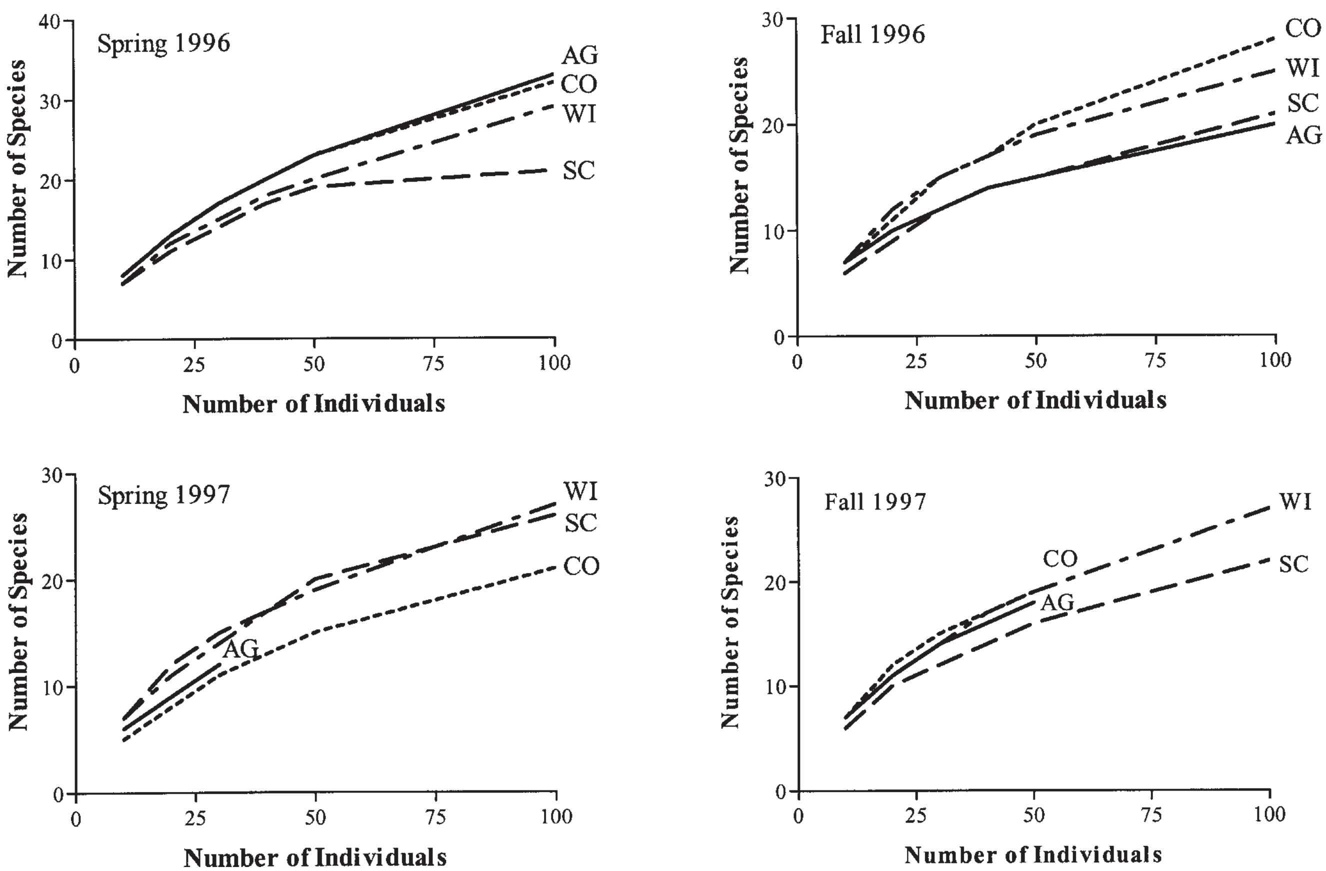

Figure 1—Rarefaction curves that describe how many migrating bird species we would expect to capture in a sample of individuals from vegetation types at the Bosque del Apache. The letters to the right of the curves indicate vegetation types (AG = agricultural edge, CO = cottonwood, SC = saltcedar, WI = willow). These curves indicate that diversity of migrants in saltcedar was generally lower than in willow or cottonwood habitat. Spring 1997 is the exception to this generality.

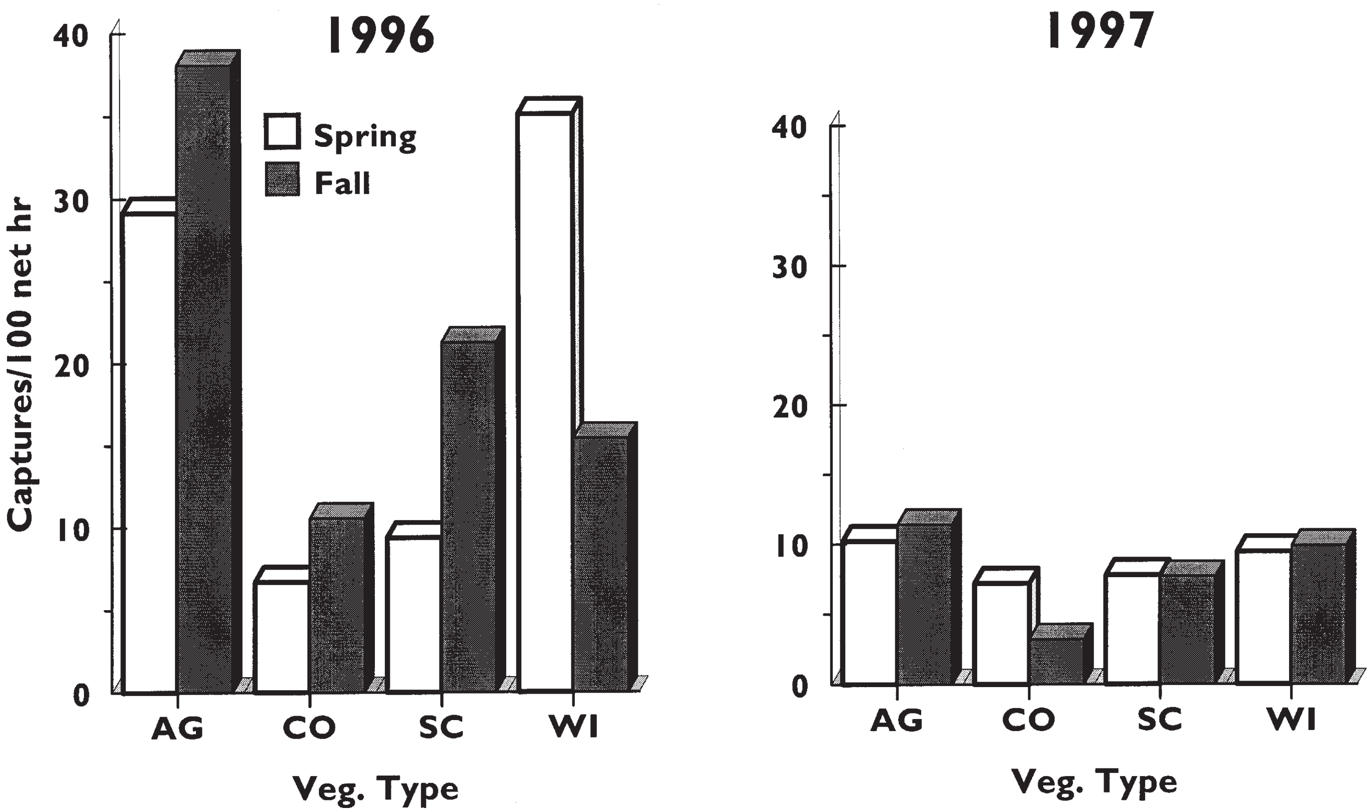

Figure 2—Capture rates/1000 net hours for en-route migrants in vegetation types at the Bosque del Apache. Vegetation types were agricultural edge (AG), cottonwood (CO), saltcedar (SC), and willow (WI). Note that (1) capture rates were higher in 1996 than in 1997; (2) agricultural edge tends to have the highest capture rates; and (3) cottonwood tends to have the lowest capture rates.

Table 2—Vegetation specific capture rates ($\bar{x} \pm SD$) for the five most common families of migrants in the Bosque del Apache of the Middle Rio Grande Valley. Differences among vegetation types were assessed with Kruskal-Wallis tests. Lines that are in boldface type had significant variation in capture rates among habitats.

			Vegetation type			
Family	**Year**	**Season**	**AG**	**CO**	**SC**	**WI**
Flycatcher	1996	**Spring*** **	**2.4 ± 0.7**	**0.9 ± 1.0**	**2.3 ± 0.5**	**4.0 ± 2.3**
		Fall	0.8 ± 0.6	0.6 ± 0.4	1.2 ± 0.6	0.5 ± 0.5
	1997	Spring	0.7 ± 0.6	1.1 ± 0.7	1.9 ± 1.5	0.9 ± 0.8
		Fall	0.2 ± 0.3	0.2 ± 0.3	0.2 ± 0.2	0.7 ± 0.6
Thrush	1996	Spring	1.0 ± 0.9	0.9 ± 0.7	0.3 ± 0.3	0.6 ± 0.7
		Fall	1.2 ± 0.5	0.8 ± 0.6	0.9 ± 0.4	1.5 ± 1.5
	1997	Spring	1.4 ± 2.4	0.5 ± 0.5	0.4 ± 0.5	0.6 ± 1.0
		Fall	0.3 ± 0.3	0.5 ± 0.6	1.3 ± 0.9	1.0 ± 1.3
Warbler	1996	**Spring*** **	**9.9 ± 6.5**	**2.5 ± 2.0**	**3.3 ± 0.4**	**20.0 ± 17.0**
		Fall	10.0 ± 13.0	3.8 ± 2.6	2.8 ± 2.4	5.9 ± 4.6
	1997	Spring	2.0 ± 3.0	2.5 ± 3.2	2.4 ± 1.9	4.8 ± 5.9
		Fall*	**1.1 ± 0.5**	**0.7 ± 1.1**	**3.5 ± 3.3**	**5.1 ± 5.7**
Sparrow	1996	**Spring*** **	**8.7 ± 3.4**	**1.2 ± 1.1**	**2.5 ± 1.2**	**4.8 ± 3.2**
		Fall **	**20.1 ± 17.8**	**2.3 ± 3.1**	**14.7 ± 4.5**	**5.7 ± 6.9**
	1997	Spring	5.0 ± 4.3	1.5 ± 1.5	2.0 ± 1.5	1.3 ± 1.5
		Fall	6.1 ± 9.5	0.6 ± 0.5	2.1 ± 0.7	2.0 ± 1.7
Grosbeak	1996	**Spring*** **	**1.8 ± 0.8**	**0.3 ± 0.3**	**0.1 ± 0.3**	**1.6 ± 1.8**
		Fall	4.8 ± 4.0	0.8 ± 0.9	0.4 ± 0.6	0.5 ± 0.9
	1997	Spring	0.2 ± 0.3	0.6 ± 0.3	0.5 ± 0.5	0.7 ± 0.8
		Fall*	**3.1 ± 3.0**	**0.4 ± 0.4**	**0.1 ± 0.2**	**0.8 ± 1.1**

* indicates P < 0.05; ** P < 0.01; ***P < 0.001

Table 3—Mean captures per 1000 net-h (SD) by vegetation type for 7 species of landbirds that migrate through the Middle Rio Grande. Kruskal-Wallis tests were used to examine differences among vegetation types.

Species	Year	Season	Vegetation type				P<
			Ag. Edge	Cottonwood	Saltcedar	Willow	
			Sparrows				
Chipping Sparrow	1996	Spring	5.9 (6.0)	0.9 (2.5)	3.2 (4.8)	7.9 (7.5)	0.02
		Fall	71.2 (84.9)	5.7 (13.7)	71.5 (34.1)	7.8 (12.2)	0.01
	1997	Spring	1.5 (2.7)	0.6 (1.7)	1.3 (3.4)	1.3 (3.1)	0.95
		Fall	1.8 (3.1)	0.0 (0.0)	1.9 (2.0)	1.5 (3.5)	0.20
White-crowned Sparrow	1996	Spring	32.5 (26.7)	1.9 (3.7)	0.0 (0.0)	16.3 (15.3)	0.01
		Fall	41.4 (59.3)	1.1 (1.9)	23.2 (16.8)	13.9 (20.2)	0.01
	1997	Spring	39.3 (34.3)	7.7 (13.0)	10.2 (9.8)	10.2 (13.4)	0.50
		Fall	21.7 (35.2)	1.2 (3.1)	3.5 (2.6)	5.3 (7.7)	0.30
Brewer's Sparrow	1996	Spring	10.3 (14.2)	1.2 (2.0)	16.3 (12.8)	8.8 (15.4)	0.05
		Fall	4.0 (3.4)	0.2 (0.8)	6.5 (8.8)	2.1 (2.7)	0.05
	1997	Spring	1.5 (2.6)	0.0 (0.0)	0.7 (1.8)	0.0 (0.0)	0.10
		Fall	3.6 (6.3)	0.0 (0.0)	3.9 (3.4)	2.9 (4.1)	0.07
Dark-eyed Junco	1996	Spring	22.2 (19.4)	5.3 (4.9)	2.2 (4.9)	2.1 (6.5)	0.02
		Fall	3.0 (3.0)	13.4 (15.2)	27.4 (15.7)	3.2 (4.3)	0.01
	1997	Spring	0.0 (0.0)	3.8 (8.3)	1.3 (2.2)	0.3 (1.1)	0.35
		Fall	0.9 (1.6)	2.3 (4.3)	6.5 (4.4)	0.8 (1.6)	0.01
			Warblers				
Wilson's Warbler	1996	Spring	35.6 (35.6)	4.3 (10.6)	8.7 (8.3)	85.4 (105.5)	0.01
		Fall	65.2 (3.0)	29.2 (23.4)	18.4 (16.7)	25.3 (23.9)	0.90
	1997	Spring	4.5 (7.8)	14.2 (28.1)	12.2 (8.8)	20.1 (30.4)	0.15
		Fall	5.4 (2.7)	5.0 (6.9)	25.4 (25.2)	31.6 (40.8)	0.05
			Thrushes				
Ruby-crowned Kinglet	1996	Spring	1.5 (2.6)	3.4 (4.3)	0.0 (0.0)	3.6 (4.7)	0.25
		Fall	10.9 (6.2)	5.5 (4.8)	7.1 (3.4)	14.5 (15.2)	0.10
	1997	Spring	0.0 (0.0)	3.2 (4.9)	2.5 (5.0)	5.3 (9.8)	0.35
		Fall	2.7 (2.7)	5.0 (6.1)	12.3 (8.6)	9.8 (13.2)	0.15
			Flycatchers				
Dusky Flycatcher	1996	Spring	3.0 (2.6)	4.7 (6.2)	15.3 (7.2)	20.8 (11.3)	0.01
		Fall	1.0 (1.7)	1.1 (1.5)	4.2 (3.4)	1.4 (1.9)	0.15
	1997	Spring	1.5 (2.7)	3.2 (4.2)	10.3 (12.8)	2.3 (2.8)	0.40
		Fall	0.0 (0.0)	0.0 (0.0)	1.2 (1.4)	0.6 (1.8)	0.15

of 1996 when this species was most abundant in willow. It appears that differences in abundance among vegetation types were more evident in 1996 when most species were more abundant than in 1997.

We conducted a total of 80 Kruskal-Wallis tests to detect variation in mass and fat score among the seven common species; 40 test for variation in fat and 40 tests for variation in mass. Of these 80 tests, eight showed significant variation among vegetation types (two for variation in mass and six for variation in fat; table 4). In three of the eight significant tests, after-hatch-year Chipping Sparrows caught in saltcedar had lower mass or fat score than those caught in other vegetation types. This relatively strong indication that saltcedar was associated with poor Chipping Sparrow habitat was not evident in other species. The only other indication that saltcedar might be poor quality vegetation for migrants was that after-hatch year male Wilson's Warblers caught in saltcedar in Spring 1996 had lower fat scores than those caught in other vegetation types. This pattern is interesting because in the following year after-hatch year male Wilson's Warblers caught in saltcedar had higher fat scores that those caught in other vegetation types. Overall there were three instances in which birds caught in saltcedar had higher fat scores than those captured in other vegetation types (two in Wilson's Warbler and one in Ruby-crowned Kinglets). Three of the seven species tested showed no significant variation in mass or fat score among vegetation types in either year or season.

Discussion

In general, migrants were more abundant in 1996 than in 1997. This pattern seems difficult to explain on the basis of changes in local habitat condition. That is, there was little change in the vegetation in our net area between years. There was a substantial fire in the Bosque del Apache NWR in 1996 that burned bosque habitats south of our netting area. It is possible that the loss of these nearby habitats affected captures in our net area, but we have no direct evidence of this effect. In addition, capture rates in 1997 were similar to those from 1994 and 1995 in this same area (D.M. Finch unpub data), which suggest that unusually high capture rates in 1996 are the phenomenon that requires explanation rather than the low capture rates of 1997.

Any likely explanation for annual variation in capture rates would have to include large scale weather patterns that affect both the condition of stopover habitats locally and regionally and the ability of migrants to get to those sites.

Table 4—Significant results of Kruskal-Wallis tests for variation in fat and mass among vegetation types in the Bosque del Apache National Wildlife Refuge. Number of tests conducted for each species is in parentheses following the species name. Age categories are after-hatch year (AHY), hatch-year (HY), and Unknown (UNK).

Species	Season	Year	Age	Sex	P-values[a] Fat	Mass
		Sparrows				
Chipping Sparrow (8)	Spring	1996	AHY	UNK	NS	0.05*
	Fall	1996	AHY	UNK	0.01*	0.03*
White-crowned Sparrow (12)	Spring	1997	AHY	UNK	0.04	NS
Brewer's Sparrow (4)	—	—	—	—	—	—
Dark-eyed Junco (8)	—	—	—	—	—	—
		Warblers				
Wilson's Warbler (32)	Spring	1996	AHY	Male	0.02+	NS
	Spring	1997	AHY	Male	0.03*	NS
	Fall	1996	HY	Female	0.01+	NS
		Thrushes				
Ruby-crowned Kinglet (12)	Fall	1996	UNK	Female	0.01+	NS
		Flycatchers				
Dusky Flycatcher (4)	—	—	—	—	—	—

[a]Asterisks indicate where birds caught in saltcedar habitat had the lowest mass/fat score and Plus signs indicate where birds caught in saltcedar had the highest mass/fat score.

As we expected, we found evidence that migrants were less diverse in exotic saltcedar than in native cottonwood and willow. This pattern appeared to be more pronounced in 1996. It is possible that the larger distinction in diversity between saltcedar and native habitats in 1996 is related to the occurrence of rare eastern migrants. That is, in 1996 we captured a relatively large number of uncommon eastern migrants and we might expect that these migrants would be more familiar with wet deciduous habitats rather dry desert scrub habitats. If so, the affinity of these uncommon species for willow and cottonwood habitats could account for the pronounced difference in diversity between saltcedar and native vegetation types in 1996.

Contrary to our expectations, we found that migrant abundance tended to be greatest in agricultural edge areas and intermediate in both saltcedar and willow. Cottonwood tended to have the lowest abundance of migrants. Variation in abundance among vegetation types was generally greater in 1996 than in 1997. This pronounced variation in 1996 may have been related to the density of migrants. Increased numbers of migrants may have increased competition for resources and forced individuals to be more selective in the vegetation types that they occupied.

Another consideration for comparing capture rates among vegetation types is that our ability to sample vegetation types is related to their morphology. Because of the short stature of agricultural, willow, and saltcedar vegetation our sampling of these vegetation types is fairly uniform in contrast to cottonwood forests where our samples reflect largely just the understory avifauna. So, variation in capture rates among habitats may reflect sampling bias as well as the distribution of birds. In particular, the low capture rates in cottonwoods may be a reflection of sampling bias.

Our evidence on the effects of saltcedar on energetic condition of migrants was mixed. Chipping Sparrow energetic condition provided some evidence that saltcedar was a component of poor stopover habitat. Other species (Dark-eyed Juncos, Brewer's sparrows, and Dusky Flycatchers) showed no variation among vegetation types. Wilson's Warbler was the only species for which evidence on the effects of saltcedar on energetic condition was conflicted. Finally, Ruby-crowned Kinglets provided evidence that at some times for some species, birds caught in saltcedar vegetation were in better energetic condition than those caught in native vegetation.

There are several potential causes for the general lack of consistent variation in energetic condition of migrants among vegetation types. For instance, perhaps there is no difference in the availability of arthropod food among vegetation types. This pattern would diminish the potential for variation in energetic condition of migrants among vegetation types. Evidence consistent with this explanation has been found by Mund-Meyerson and others. They found that, in general, the arthropod fauna of cottonwood, Russian olive, and saltcedar were similar and fairly stable during May through August in the Bosque del Apache NWR. In contrast to this evidence DeLay and others (this volume) show that in our net area there was significant variation in arthropod communities among vegetation types. Specifically there were fewer arthropods, primarily flies (diptera), in saltcedar than in the native vegetation types. Further, Delay and others (this volume) provide some evidence that migrants track the abundance of arthropods through time. Even with this evidence, however, it is difficult to link variation in total arthropod abundance to the availability of specific species of arthropods that comprise the diets of specific migrants.

Another difficulty in interpreting patterns in energetic condition is the close proximity of the vegetation types to one another. A single individual bird could readily move among these vegetation types. Thus, a birds' energetic condition might reflect the quality of the entire study area (or larger area), rather than the vegetation that it was captured in. We have some evidence that this is not a large problem. For instance, Yong and others (1998) show that, for Wilson's

Warblers in spring, 88 percent of recaptures occur in the same vegetation type where the original captured occurred; this pattern was weaker (53 percent) in the fall. Nonetheless, it is important to recognize that individuals captures in a particular vegetation type might not depend solely on that vegetation. For these same reasons, any negative effects that saltcedar may have on migrants would likely be less apparent when it is part of a mosaic of different vegetation types.

In summary, we found evidence that saltcedar contained a lower diversity of migrants, but that overall bird abundance in saltcedar was intermediate among other vegetation types. Evidence on the effects of saltcedar on mass and fat score of migrants was mixed. The mixed nature of our results is similar to those of other studies done on the effects of saltcedar on bird communities. An important consideration in interpreting these results is the configuration of the vegetation types on the landscape.

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