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# Ecology, Diversity, and Sustainability of the Middle Rio Grande Basin



# Ecology, Diversity, and Sustainability of the Middle Rio Grande Basin

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## Contents

The Authors .....	ii
Chapter 1	
Introduction: Ecosystem Research in a Human Context.....	1
<i>Deborah M. Finch and Joseph A. Tainter</i>	
Chapter 2	
Environmental History.....	12
<i>Dan Scurlock</i>	
Chapter 3	
Human Ecology and Ethnology .....	29
<i>Frank E. Wozniak</i>	
Chapter 4	
Geology, Climate, Land, and Water Quality .....	52
<i>Douglas G. Fox, Roy Jemison, Deborah Ulinski Potter, H. Maurice Valett, and Ray Watts</i>	
Chapter 5	
Desert Grassland and Shrubland Ecosystems .....	80
<i>Samuel R. Loftin, Richard Aguilar, Alice L. Chung-MacCoubrey, and Wayne A. Robbie</i>	
Chapter 6	
Pinyon-Juniper Woodlands .....	95
<i>Gerald J. Gottfried, Thomas W. Swetnam, Craig D. Allen, Julio L. Betancourt, and Alice L. Chung-MacCoubrey</i>	
Chapter 7	
Plants, Arthropods, and Birds of the Rio Grande.....	133
<i>Deborah M. Finch, Gale L. Wolters, Wang Yong, and Mary Jean Mund</i>	
Chapter 8	
Fish Fauna.....	165
<i>John N. Rinne and Steven P. Platania</i>	
Chapter 9	
Belowground Ecosystems .....	176
<i>Carole Coe Klopatek</i>	

# Chapter 7

## Plants, Arthropods, and Birds of the Rio Grande

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### INTRODUCTION

Human populations have increased dramatically along the Rio Grande since European settlement. Human use of water for irrigation and consumption, and human use of land for agriculture, urban centers, livestock grazing, and recreation have changed Rio Grande ecosystems by altering flood cycles, channel geomorphology, upslope processes, and water quality and quantity. Such abiotic changes have influenced the biological diversity and ecological functions of the Middle Rio Grande Basin, altering the distribution, structure, and composition of riparian plant and animal communities.

We review the literature and identify research needs pertaining to the flora and fauna of the Middle Rio Grande bosque, focusing on plants, arthropods, and birds. These groups serve as model taxa for monitoring population changes and trophic level interactions in response to natural and human-caused changes in function, structure, and dynamics of riparian ecosystems. Many arthropod species are first order herbivores, so the composition and structure of plant communities are likely to influence their presence, absence, and reproduction. Birds forage on food supplies that range from seeds, fruits, and leaves, to insects and small vertebrates. Thus, the distribution, dispersal, migration, and demography of avian species will likely be affected by changes in riparian plant communities and by interactions among plant and insect associations. Birds and insects are dispersal agents of seeds of many plant species, and so they contribute to the growth and composition of plant communities.

In this chapter, we focus on the Middle Rio Grande because of (1) the availability of cottonwood gallery

forest in this stretch, (2) the extent of past and current research conducted in the bosque, and (3) the apparent public, political, governmental, and academic interest in this area owing to its urbanization, recreational opportunities, habitat alteration, water usage and pollution, and need for conservation and restoration. We refer to the Middle Rio Grande as the portion of the river, restricted to New Mexico, from Elephant Butte Reservoir to Cochiti.

### RIPARIAN VEGETATION

#### Historical Overview

Riparian ecosystems, according to Lowe (1964), are associations of any kind in or adjacent to drainages and/or their floodplains. They are further characterized by species and/or life forms different from that of the immediate surrounding non-riparian association. Although riparian ecosystems have existed along the Rio Grande and its major tributaries for perhaps a million years (Scurlock 1988), they occupy less than 1 percent of the land area in New Mexico and adjacent states. Nevertheless, they are extremely important to the biological diversity and ecological integrity of arid southwestern ecosystems.

The Pleistocene epoch, lasting from around 2 million to 10,000 years ago, was characterized by southward glacial advances and retreats. Vegetation exhibited similar movement, by retreating south ahead of the advancing glacial ice and advancing to the north to occupy the land exposed by melting ice. Scurlock (1988) speculated that cottonwood bosque (woodland fringing a body of water) probably existed along the Rio Grande since the colder times of the early Pleistocene. During the late Pleistocene and

early Holocene epoch, the climate apparently dramatically changed to warmer and drier conditions. As a result, rich mixed coniferous forests expanded in range to occupy the area (Axelrod and Bailey 1976). As the climate became more arid, coniferous forests were replaced by woodlands, grasslands, and shrubland (Van Devender et al. 1984).

McKinley and Brown (1982) theorized that southwestern riparian deciduous forests reflect a contraction of the formerly widespread Early Tertiary mixed mesophytic forest. Riparian ecosystems are vernaly adapted to Early Tertiary climates and retreated to pockets where the warm temperate climate persisted (McKinley and Brown 1982). Nineteenth century southwestern riparian plant communities, as we know them today, probably developed during this period of climatic change.

In his comprehensive chronological description of 19th century riparian vegetation along the Rio Grande, Scurlock (1988) speculated that stands of valley cottonwood (*Populus fremontii* var. *wislizenii*) and willow (*Salix* spp.) were interspersed with marshes dominated by sedge (*Carex* spp.), tule bulrush (*Scirpus acutus*), cattail (*Typha latifolia*), and saltgrass (*Distichlis spicata*) at the end of the last ice age. He also suggested that the first significant human impact on the Rio Grande riparian ecosystem was probably clearing of the bosque vegetation for cultivation between 1,500 and 2,000 years ago. Woodbury and Zubrow (1979) reported that many large American Indian farming villages were centered along the Middle Rio Grande valley by the mid 1500s, and Harper et al. (1943) estimated about 100,000 acres of former bosque vegetation was under cultivation by the mid 18th century.

The first comprehensive description of Rio Grande floodplain vegetation was authored by Watson (1912) who described open and more or less pure forests of valley cottonwood along the Rio Grande where the water table was near the surface in the open. According to Watson, the trees were small because native ranchers harvested them for fuel and fenceposts, although protected individual trees were veritable giants in girth. Scattered throughout this forest and especially along the banks of the streams were a few willows, clumps of *Baccharis wrightii* and *Cassia bauhinioides*, and an herb layer consisting of *Juncus balticus*, *Trifolium rydbergii*, *Aster spinosus* and a few grasses. Watson described this riparian forest as monotonously uniform and poor in species. Watson (1912) also described a riverbank wet meadow asso-

ciation dominated by *Juncus balticus* and *Houttuynia californica*. Associated species were *Baccharis wrightii*, *Helianthus annuus*, *Dyssodia papposa*, *Onagra jamesii*, *Amorpha fruticosa*, and *Rumex berlandieri*.

Van Cleave (1935) described five Rio Grande floodplain plant communities: (1) cottonwood-willow forests several hundred yards wide along the stream with little understory vegetation except scattered clumps of saltgrass; (2) grass-woodland bosque occupying elevated floodplain sites dominated by coyote willow (*Salix exigua*), cottonwood, salt cedar (*Tamarix pentandra*, *T. chinensis*), and Russian olive (*Elaeagnus angustifolia*) with a herbaceous understory of saltgrass, yerba mansa (*Anemopsis californica*), fleabane (*Erigeron philadelphicus*), and horseweed (*Leptilon canadense*); (3) wet meadow-like community, with the water table at or just below the soil surface, dominated by sedges, rushes (*Juncus* spp.), saltgrass, and yerba mansa; (4) swampland (marsh) dominated by cattail, sedges, spikerush (*Eleocharis* spp.), scouring rush (*Equisetum hyemale*), watercress (*Radicula nasturtium-aquaticum*), and buttercup (*Ranunculus cymbaliria*) and generally encompassed by a band of woody vegetation; and (5) small lakes occupied by aquatic plants.

### Current Vegetation Composition and Structure

In New Mexico, floodplain riparian vegetation has probably been impacted more by human activities than any other type of riparian vegetation (Dick-Peddie 1993). Current Rio Grande floodplain vegetation greatly differs in both composition and extent from that described by Van Cleave (1935). Cottonwood and willow were, and remain, primarily restricted to the immediate floodplains. The bosque, though much reduced in extent, is still represented by some individual cottonwood trees of extremely large size. With some notable exceptions, the historic cottonwood and willow forests have been reduced to a narrow band of mid- to old-age forest stands between levees in the Middle Rio Grande floodplain. Many cottonwood/willow communities were lost to expanding agriculture, the demand for fuel and wood products, channelization and flood control projects, urbanization, transportation systems, inundation by large impoundments, and the introduction and escape of exotic plants.

The phreatophyte vegetation on the Rio Grande floodplain today is found in relatively hydric, mesic,

and xeric conditions (Campbell and Dick-Peddie 1964). Some species have moved into the bosque from up and down stream communities and other species have moved from adjacent upland plant communities, but the greatest factor influencing the composition of bosque communities, according to Campbell and Dick-Peddie (1964), has been the introduction of plants such as salt cedar and Russian olive.

In a comprehensive survey of the Middle Rio Grande, Hink and Ohmart (1984) recognized three major cottonwood-dominated community types with understories of Russian olive, coyote willow, salt cedar, seepwillow (*Baccharis wrightii*), indigo bush (*Amorpha fruticosa*), New Mexico olive (*Forestiera neomexicana*), and one-seed juniper (*Juniperus monosperma*). The most common subdominant species in the cottonwood/coyote willow type, named in descending order of abundance, were coyote willow, salt cedar, and Russian olive or seepwillow with a ground cover of mixed grasses and forbs; in the cottonwood/Russian olive type, Russian olive formed a monotypic understory with herbaceous plants being sparse to absent; and in the northern reaches of the Middle Rio Grande the cottonwood/juniper type was characterized by an understory of juniper (*Juniperus* spp.) mixed with Russian olive, New Mexico olive, hair-worm snakeweed (*Gutierrezia microcephala*), and rubber rabbitbrush (*Chrysothamnus nauseosus*). In addition to the cottonwood communities, Hink and Ohmart (1984) recognized a Russian olive community type dominated by young to intermediate-aged Russian olives interspersed among patches of young coyote willow, cottonwood, salt cedar, and seepwillow with a dense herbaceous layer of mixed grasses and forbs; and a marsh community type dominated by cattail with some tule bulrush, sedges, mixed forbs, and an occasional coyote willow. They found salt cedar to be a common understory species throughout the study area and a dominant species throughout much of the southern portion of the Middle Rio Grande. Campbell and Dick-Peddie (1964) also noted salt cedar was more common below Elephant Butte Reservoir than in the more mature woodland type upstream from Elephant Butte.

### Introduced Plant Species

Salt cedar was introduced into the United States as an ornamental in the early 1800s (Horton 1964). Watson (1908) reported that salt cedar was commonly

planted in Albuquerque as an urban ornamental. Salt cedar became naturalized and by the 1920s was a dominant shrub along many southwestern rivers (Horton 1977). Van Cleave (1935) also referred to both salt cedar and Russian olive as dominant plant species in the grass-woodland bosque floodplain of the Middle Rio Grande. The invasion of salt cedar on floodplains in New Mexico was rapid and dramatic. Scurlock (1988) reported salt cedar dominated 60,640 acres of the Rio Grande valley in 1947, and Robinson (1965) reported salt cedar occupied 155,000 acres in New Mexico by 1961.

Garcia (1903) described the presence of Russian olive, another Eurasian ornamental, at Mesilla Park, New Mexico, around the turn of the century. Wootton and Standley (1915) indicated that Russian olive was under cultivation at several locations throughout New Mexico. However, the exact date that Russian olive was introduced into the state is unknown (Campbell and Dick-Peddie 1964). Van Cleave (1935) reported Russian olive to be an important component of the floodplain vegetation, and Freehling (1982) suggested that Russian olive became naturalized and reached its present distribution in the Middle Rio Grande floodplain prior to 1935. Campbell and Dick-Peddie (1964) documented the spread of Russian olive throughout the valley north of Elephant Butte Reservoir, reporting that it grew equally well beneath heavy cottonwood overstories, in open areas, and in nearly pure stands of salt cedar. Freehling (1982) speculated that the Russian olive invasion into the Middle Rio Grande riparian woodlands was initiated by habitat alterations associated with land drainage.

Other exotic trees and shrubs have also become naturalized and invaded the Middle Rio Grande bosque ecosystem. For example, Crawford et al. (1993) reported that Siberian elm (*Ulmus pumila*), tree of heaven (*Ailanthus altissima*), and white mulberry (*Morus alba*) were rapidly becoming major components of riparian plant communities, particularly in the more urbanized areas of the Middle Rio Grande.

### Loss of Cottonwood and Willow

The slow demise of cottonwood and willow and the rapid invasion by salt cedar and Russian olive appear to have begun in the 1930's, about the time major flood control efforts (construction of dams, levees, and channelization) were being implemented (Ohmart et al. 1977). In their comprehensive review

of the impacts of river damming on cottonwoods, Rood and Mahoney (1993) cited numerous articles that reported reduced forest abundance, reduced seedling abundance, and conditions unsuitable for seedling establishment downstream. Declines of downstream poplar forests (*Populus* spp.) were probably caused by hydrological alterations and geomorphological changes of the river corridor, although other factors included direct harvesting for food, fuel, and material, and grazing by livestock (Rood and Mahoney 1990).

Introduction and escape of salt cedar and Russian olive in the last 50 years have changed the successional stages and ultimate dominants of many Rio Grande plant communities (Campbell and Dick-Peddie 1964). However, regulated stream flow, either directly or indirectly, is thought to be the most important factor contributing to the decline of cottonwood and willow woodlands in riparian ecosystems (Rood and Heinze-Milne 1989; Fenner et al. 1985; Rood and Mahoney 1990; Brown et al. 1977; and Crawford et al. 1993). Campbell and Dick-Peddie (1964) speculated that, if left undisturbed, cottonwood would probably replace salt cedar in the upper Rio Grande valley but not downstream from Elephant Butte Lake. Even if predisturbance conditions were restored in the Middle Rio Grande floodplain, Russian olive upstream from Elephant Butte Lake and salt cedar downstream from the Lake would probably retain subdominant status at minimum.

### Cottonwood and Willow Regeneration

Disturbance has played an integral role in establishing and developing native riparian vegetation in the Southwest. Flooding is the most common form of naturally occurring disturbance in riparian ecosystems (Szaro 1989). Glinski (1977) and Brady et al. (1985) suggested that flooding and aggradation were the major precursors in the natural sequence of cottonwood stand development on southwestern floodplains. However, disruption of normal flow patterns resulting from river impoundments can change the development of riparian communities (Szaro 1989). Riparian community development will deviate from normal as the programmed flow rate deviates in time and intensity from uncontrolled flow. Crawford et al. (1993) noted that Middle Rio Grande levees constructed in the 1920s and 1930s constrained the floodway and reduced the river's tendency to meander—a process considered critical to establishing native

bosque vegetation. Dams, channelization, levees, and agriculture are also reported to have adverse effects on regeneration of native riparian vegetation (Fenner et al. 1985; Rood and Heinze-Milne 1989; Rood and Mahoney 1990; and Barclay 1978). In contrast, however, Szaro and DeBano (1985) reported a case where dam construction increased the regeneration of riparian vegetation. They found a dramatic increase in regeneration of black willow (*S. gooddingii*), seepwillow, and salt cedar in deposited sediment immediately above the dam where flows from high intensity storms were stored to produce a near perennial flow.

Mahoney and Rood (1993) modeled the general hydrological elements necessary to establish riparian cottonwood seedlings. Glinski (1977) and Mahoney and Rood (1993) described the temporal aspects of hydrological cycles and their importance in cottonwood germination and seedling survival. The hydrological elements essential for cottonwood seedling establishment are river stage and rate of water table decline, but if either factor is improperly timed cottonwood establishment may fail.

Although the essential elements necessary for regeneration of native riparian plant communities are known, knowledge concerning the timing and specific quantitative characteristics of the essential regeneration elements is incomplete. For example, Rood and Heinze-Milne (1989) reported a situation in Alberta where the abrupt lowering of the water table, when water release from a dam was terminated, contributed directly to the loss of cottonwood seedlings. They implied that the rate of water table decline was more rapid than that needed for cottonwood root elongation, and therefore seedlings died from drought stress. Unfortunately, no quantitative data on maximum allowable rate or timing of water table decline were presented to predict optimum cottonwood establishment and survival.

In his report on tree establishment in riparian habitats, Anderson (1988) noted that practically nothing is known about the autecology and water requirements of native riparian plants. Likewise, little quantitative information is available regarding the specific regeneration requirements of cottonwoods and willows. Numerous authorities (Burns 1990; Rood and Mahoney 1993) report that cottonwood is able to regenerate from root and stem sprouts and from seed during favorable environmental conditions, yet these conditions are generally undefined. Schreiner (1974) reported most cottonwoods produce large seed

crops almost every year after they are 10 to 15 years old. Lightle (1969) noted that Fremont cottonwood (*P. fremontii*) generally flowers from April to May, and its seeds ripen and disperse in June to July. Schreiner (1974), however, reported that the longevity of poplar seeds under natural conditions may be only 2 weeks to a month. Thus, the window for successful natural regeneration of Fremont cottonwood from seed is very narrow. For successful regeneration, the timing and duration of rainfall or overflow events necessary for germination and seedling establishment must also correspond with the narrow window of seed viability.

Brinkman (1974) reported willow produce many small seeds that usually ripen in early summer, although seeds of some species mature in the fall. Like cottonwood seeds, willow seeds remain viable for only 2 weeks or less, and germination diminishes rapidly with age. We did not find information specific to seed ecology and germination requirements of coyote willow or black willow. Very moist exposed mineral soil is generally considered best for germination and vigorous early growth of willow (Pitcher and McKnight 1990). Brinkman (1974) also reported that root stock of young willow trees sprout prolifically, and propagation by cuttings is the usual method of artificial regeneration.

Anderson et al. (1978) and Anderson and Ohmart (1979) were successful in establishing black willow and Fremont cottonwood by watering the planted cuttings until roots reached the water table or sufficiently permanent supply of soil moisture. Anderson and Ohmart (1979) found that backhoeing or augering a hole to the water table for each cutting is good insurance that roots can penetrate to the water level. Anderson (1988) reported that Fremont cottonwood and black willow cuttings planted in holes augured to the water table exhibited a lower rate of mortality and grew up to three times the rate of cuttings planted in shallow-tilled holes. Artificial watering of cuttings planted in augered holes was still necessary until roots reached a permanent water supply.

The state-of-the-art knowledge on cottonwood and willow regeneration has not progressed substantially in the last 15 years. Natural regeneration of Middle Rio Grande riparian floodplain vegetation has essentially been precluded by unfavorable conditions produced by regulated water flow in combination with soil and light requirements—i.e., cottonwood and willow require nearly bare mineral soil and full sunlight for successful regeneration from seed. In addi-

tion, aggressive salt cedar and Russian olive, combined with associated riparian grasses and forbs, apparently outcompete native cottonwoods and willows, limiting the regeneration success of native woody plants.

Glinski (1977), Carothers (1977), and Kauffman et al. (1983) noted that even when environmental conditions are conducive to cottonwood and willow regeneration, stands can be destroyed by excessive grazing by livestock. Crouch (1979) also reported that beaver contributed to the decline of many small cottonwoods in northeastern Colorado. Though cottonwood is not a desired construction material, its use for lumber and fuel does contribute to cottonwood loss.

### Classification of Riparian Vegetation

Riparian zones were recognized and briefly described over a century ago by Townsend (1893) when he proposed a classification for New Mexico's Organ Mountain vegetation. Since then, numerous authorities have described and classified all or parts of the riparian and wetland vegetation of New Mexico (Pase and Layser 1977; Dick-Peddie 1993; Brown and Lowe 1974; Brown et al. 1977; Brown et al. 1980; and Hink and Ohmart 1984).

Dick-Peddie and Hubbard (1977) proposed a New Mexico riparian vegetation classification system based upon obligate species, and they assigned formation status to riparian vegetation due to its importance and relative independence of surrounding upland vegetation. Formations included a floodplain series and an arroyo scrub series in the arroyo-floodplain sub-formation. Donart et al. (1978) assigned regional status to New Mexico's riparian vegetation within the woodland formation. The riparian region was described by Donart et al. (1978) as four series: cottonwood-chilopsis (*Chilopsis* spp.) series, mesquite bosque series, walnut (*Juglans* spp.) series, and willow-sycamore (*Platanus* spp.) series with the cottonwood-chilopsis series subdivided into a desert willow (*C. linearis*)-narrowleaf cottonwood (*P. angustifolia*) association and a plains cottonwood association. In their classification of North America vegetation, Brown et al. (1980) characterized southwestern riparian deciduous forests and woodlands based upon tree height, canopy closure, and lifeform. They also identified a cottonwood-willow series and a mixed broadleaf series. Dick-Peddie's (1993) classification is most recent, wherein five riparian types

in New Mexico are described based upon elevation and hydrological conditions. These types are referred to as alpine, montane, floodplain-plains, arroyo, and the closed basin-playa-alkali sink riparian types.

Hink and Ohmart's (1984) classification system recognizes six structural types of Middle Rio Grande vegetation based upon two general factors: overall height of the vegetation and amount of vegetation in the lower layers. Their structural types were described as:

Type I—vegetation in all foliage layers and trees generally reaching 50 to 60 feet in height;

Type II—mature trees 50 to 60 feet in height with most of the foliage in a layer (30 feet in height with sparse patchy understory growth);

Type III—intermediate-aged trees with thick understories up to 30 feet in height but little above 30 feet;

Type IV—open intermediate-aged stands of trees with most of the foliage 20 to 40 feet in height, with widely spaced shrubs and sparse herbaceous vegetation;

Type V—dense stand of vegetation up to 15 feet in height that may contain some scattered taller trees and often includes a thick layer of herbs; and

Type VI—relatively sparse stand of herbaceous and/or shrubby vegetation with most of the foliage less than 5 feet high.

Szaro (1989), using quantitative community characteristics, identified 28 riparian community types in Arizona and New Mexico. Szaro's approach to community classification was based upon existing vegetation rather than on potential natural vegetation used by Kuchler (1964) to differentiate northern floodplain forests from southern floodplain forests. The existing vegetation approach permits resource managers to recognize, classify, describe, and discuss communities in common understandable language. However, in practical application the shortcoming is that not all communities fall neatly within a described type.

Most approaches to riparian classification have followed the more traditional floristic approach as used by Brown and Lowe (1974); Pase and Layser (1977); and Dick-Peddie (1993), although a notable exception is Hink and Ohmart's (1984) structural approach to riparian vegetation classification. In his treatise on riparian forest community types, Szaro (1989) posed the following question about community classification: "Is a classification based on species composition versus that based on growth form

or even genera necessary?" After a review of literature on bird, reptile, and amphibian species relationships with plant taxa, Szaro (1989) found that not enough was known to determine if groupings such as "tall" or "short" willow communities made ecological sense. He speculated that as ecological relationships are examined in more detail, the need for specific floristic information will become more apparent.

Most riparian classification systems developed to date are general to accommodate the full range of natural variation that occurs within the plant community type. As a result, the classification system permits managers to inventory and discuss land units on a regional basis but the value of the classification system diminishes with respect to making site-specific management decisions. Broad scale classification systems represent an "average" community type and they frequently do not adequately address extremes of the type.

Uresk (1990) described a classification and inventory procedure sensitive enough to classify and inventory plant community successional stages. He verified the suitability of this classification procedure using vegetation of grasslands (Uresk 1990) and deciduous woody draws in the Northern Great Plains. Ecological stages were quantitatively identified with an estimated 95 percent reliability, based upon principal component analysis (Uresk 1990). Threatened, endangered, and sensitive plant and animal species were then correlated with seral stages of community types (D. Uresk, personal communication, USDA Forest Service, 1994). Thus indices for predicting presence, absence, and relative abundance of species of interest based on vegetation classification systems can be developed.

## Research Needs

Long term sustainability of the natural Middle Rio Grande Basin riparian ecosystem is a growing concern among many resource users and management agencies. The detrimental effects of hydrological alterations, geomorphic changes, exotic plant species, and agricultural practices threaten the continued existence of natural riparian ecosystems. Crawford et al. (1993) recommended the development of a coordinated research program to study the ecological processes and biotic communities that characterize the Middle Rio Grande riparian ecosystem. The primary terrestrial research needs they listed were

(1) enhance existing cottonwood communities and create new native cottonwood communities, (2) contain the expansion of existing stands of nonnative vegetation, (3) study the ecology of nonnative species existing in the riparian ecosystem and develop ways to maximize their biological values, and (4) develop an integrated management plan compatible with biological quality and ecosystem integrity to avoid further fragmentation of the riparian ecosystem. Although some of these needs are under investigation, no satisfactory alternatives have been developed. Thus, the important and critical research need today is how to efficiently and effectively regenerate and sustain natural riparian bosque ecosystems.

To manage, restore, and sustain riparian ecological systems, managers need information on the following:

1. The tolerances of native riparian trees, shrubs, and herbs to natural and human-induced disturbances, especially fire, grazing, flooding (or lack of flooding), recreation, and urbanization.
2. Regeneration ecology, especially as it relates to the autecology of important riparian deciduous tree and shrub species such as Fremont cottonwood, black willow, coyote willow, seepwillow, Arizona sycamore (*P. wrightii*), velvet ash (*F. velutina*), and little and Arizona walnuts (*J. microcarpa* and *J. major*).
3. The effects of abiotic factors (e.g., climate, sedimentation processes, nutrient availability, water quality, and channel geomorphology) on development, composition, and health of plant communities.
4. The ecological linkages between upslope processes such as erosion, arroyo development, and road construction and bosque community dynamics and function.
5. The relationships and responses of animal communities to historical and recent changes in riparian plant associations.
6. The effects of flooding and the effects of surface water-groundwater interactions on major ecological processes such as decomposition, nutrient cycling, and primary production.
7. Classification models and matrixes for predicting animal species composition, habitat use, and population change based on composition and seral stage of riparian plant associations.

At a symposium on importance, preservation, and management of riparian habitat, Patton (1977) re-

ported that no comprehensive classification of riparian vegetation suitable either for research or management has been prepared for the Southwest. Brown et al. (1977) also noted that identification, classification, inventory, and mapping of habitats was needed in riparian zones. Although classification of riparian ecosystems has progressed, (Hink and Ohmart 1984; Dick-Peddie 1993; Szaro 1989), gaps in our knowledge still exist. Investigations to determine plant species composition and abundance for every identifiable successional stage of riparian vegetation was recommended by Patton (1977). Szaro (1989) also implied that a quantitative classification system for successional stages of riparian vegetation would be extremely useful for managing bird, reptile, and amphibian species. Once plant successional stages have been determined, Patton (1977) suggested the next logical step for research would be to identify animals that depend on a given stage or stages for their life requirements. Seral stage classification systems would not only be useful to wildlife managers but would provide land managers with the opportunity to predict changes in resource values associated with successional stage of the riparian type.

In the next two sections, we review the literature and research needs for arthropods and birds. These taxa were selected as model groups for evaluating trophic-level responses to structure, floristics, succession, disturbance, and human-induced changes in riparian plant communities. Many arthropod species are first order herbivores, so the composition and health of plant communities are likely to influence presence, absence, and successful reproduction of arthropod species. Birds forage on food supplies that range from seeds, fruits, and leaves to insects and small vertebrates. Thus, the distribution and demography of avian species are affected by changes in riparian plant communities and by interactions among plant and insect associations. In addition, birds and insects are dispersal agents of seeds of many plant species, so they contribute to the growth and composition of plant communities.

## ARTHROPOD ECOLOGY

Before European settlement, the Rio Grande experienced periodic flood cycles. Renewal of native cottonwood (*Populus fremontii*) and willow trees (*Salix* spp.) depended on flooding. With the advent of irrigation and its subsequent constrictions and controls, the flood cycles of the Rio Grande have largely been

eliminated, and consequently, the native flora and fauna have changed. Although the diversity and abundance of the Rio Grande arthropod community far exceeds that of plants, mammals, birds, reptiles, and amphibians combined, the ecology of bosque arthropod communities has not been well-studied, and therefore their role and importance in ecosystem interactions and processes have yet to be determined.

Arthropods of the Rio Grande bosque occupy almost every habitat and niche, from the tree canopy to the river bed (Crawford 1993). Because many species are habitat- or site-specific, arthropods are successful indicators of ecosystem change and stress. Data on the density and distribution of arthropod species can be used to monitor changes in the bosque such as channel constriction, flood control, and the introduction of exotic plants and animals. Arthropods also play an important role in food webs and decomposition cycles in the bosque and may influence the development and composition of other trophic levels.

To more fully understand and account for the role and importance of arthropods in the Bosque, three main avenues of research need to be initiated on (1) the distribution and composition of arthropod communities in different vegetation strata and across the bosque landscape; (2) the role of arthropods in decomposition cycles; and (3) the position and influence of arthropods in trophic webs.

### **Distribution and Composition of Arthropod Communities**

Evaluation of arthropod community structure is one means of determining historic conditions and the changes that have occurred. For example, molluscs were used by The New Mexico Bureau of Mines and Mineral Resources (1987) to interpret and define historic river drainages. Community structure can also indicate recent change. Molles and Crawford (1992) reported sharp ecological boundaries between communities of ground-dwelling forest arthropods and arthropods occupying open areas. Loss of periodic overbank flooding has undoubtedly led to dramatic changes in vegetation structure in riparian areas along the Middle Rio Grande, and such changes are predicted to have affected the abundance and distribution of invertebrate species (Crawford 1993).

At the landscape level, several habitats intermingle to form a mosaic, including aquatic/riverine areas, forests, shrublands, wetlands and marshes, and agricultural fields. Each habitat hosts unique arthro-

pod communities, and their composition varies among habitat substrates, e.g., forest canopy vs. forest floor. In addition, arthropods migrate and disperse among habitat "islands" across the landscape mosaic.

Currently, the aquatic habitat consists primarily of the Rio Grande, which is a warm water river. It has a low velocity and high turbidity (Winger 1981). Generally, rivers associated with riparian vegetation tend to have more diverse shading, ponds, and channel characteristics that lead to higher biological diversity (US Bureau of Land Management 1993). There has been some research into the arthropod communities that inhabit the river, particularly as they pertain to the fish populations. The New Mexico Department of Game and Fish is creating a database that relates aquatic insects to environmental parameters and fish populations (Jacobi et al. 1993). In addition, both the river (Jacobi 1983) and the riverside drains (City of Albuquerque Hydrology Division 1991) have been sampled for macroinvertebrates. There have also been studies that sample for individual species, e.g., predatory diving beetles were studied by Zimmerman (1971).

Other aquatic habitats in the Rio Grande bosque include marshes and wet meadows. Ephemeral and permanent ponds and marshes were common historically, but most have been drained or replaced by agricultural lands. As much as 33 percent of New Mexico's wetlands have been lost since Spanish settlement (Dahl 1990) owing primarily to conversion to agricultural drainages and levees (Van Cleave 1935). The Isleta marshes and Los Lunas wetlands have been fairly extensively studied (Alexander and Martinez 1982; Molles and Pietruszka 1983). Some marshes and wet meadows have been restored, primarily in association with ditches, drains, and agricultural fields. The artificial wetland areas created by drainage ditches provide habitats for different communities of arthropods (N. Runyan, Department of Biology, University of New Mexico, 1994).

Little is known about the extent of use of the Rio Grande's aquatic habitats by aerial insect communities. Molles and Crawford (1992) have sampled the bosque's aerial insects with sticky traps, and Molles (M.C. Molles Jr., Department of Biology, University of New Mexico, 1994) is currently evaluating the diversity of mayflies along New Mexico rivers, but no conclusions have been made pertaining to how these arthropod faunas contribute to the general ecology or complexity of biotic communities along the Rio Grande.

Ellis et al. (1993, 1994) studied the effects of controlled flooding on arthropod communities of the forest floor in both native and introduced vegetation. Heinzemann et al. (in press) examined the microhabitat selection of *Armadillidium vulgare*, an introduced ground-dwelling isopod.

Arthropod species composition and diversity in the bosque canopy is probably better known than arthropod community development in other vegetation stratas. Molles and Crawford (1992) studied the differences in diversity and abundance of canopy-dwelling arthropods between native cottonwood and introduced Russian olive and salt cedar trees in the Albuquerque bosque. In addition, Yong and Crawford (personal communication, 1994) investigated the impact of two species of leaf rollers on the leaf fall of cottonwoods at the Rio Grande Nature Center, a river state park in Albuquerque.

Research is needed on the effects of disturbance on arthropod communities by factors such as pollution, agricultural development, flooding, introduction of exotic plants, burning, and grazing. If disturbance significantly alters arthropod species composition and diversity, then the development and productivity of other biotic communities, such as plants and vertebrates used by or dependent on arthropods, may also be altered. Direct effects of air or surface-waste pollution on arthropods can be evaluated by comparing arthropod community structure and pollution levels in rural areas such as wildlife refuges to urban sites, or by conducting specialized experiments that assess effects of varying pollution levels on selected species in controlled environments. Water that is polluted from sewage, waste, industrial sources, and non-point sources may also influence the dynamics and health of aquatic arthropod communities by reducing or eliminating populations that are intolerant of pollution.

Stress or disturbance to the bosque plant community from grazing, pollution, burning, competition, or fragmentation may alter susceptibility of certain plant species to herbivory by arthropods, hence causing further changes to the vegetation and consequently the arthropod community. River management such as damming, channelization, flooding, conversion, and restoration affect the structure, composition, and regeneration of riparian tree and shrub communities. University of New Mexico researchers are evaluating some of these effects on the invertebrate fauna at the Bosque del Apache Wildlife Refuge (e.g., Ellis et al. 1993, 1994). Several introduced

species of plants (Russian olive and salt cedar) and arthropods (*Armadillidium vulgare* and *Porcellio* spp.) are well-established in the bosque, and research is needed to determine how these introductions have influenced arthropod communities and animal species dependent on arthropods for food.

### **The Role of Arthropods in the Decomposition Cycle**

Additional research is needed on the role of arthropods as detritivores, which serve a critical purpose in breaking down organic matter into energy and nutrients available to microbes, bacteria, and ultimately plants. The major sources of organic matter in the bosque are dead leaves, wood, roots, herbaceous vegetation, dead animals, and waste products. Arthropod and invertebrate detritivores in the bosque include earthworms, isopods, beetles, termites, crickets, fly larvae, and ants (Crawford 1993). As these detritivores move and forage, they disperse soil and soil microbes through their feces. Sub-surface detritivores also aerate the soil (i.e., isopods, termites, and earthworms). In addition, mites and collembola are extremely diverse and important components of the decomposition cycle. All of these macro-detritivores regulate the decomposition cycle by controlling the amount of litter that is broken down. Soil microbes and bacteria then break these organic materials prepared by macro-detritivores into usable compounds. The temporal, spatial, and population dynamics of bosque detritivores are little known, and research is needed to estimate their importance in ecosystem functioning, especially under altered or recovering environmental conditions.

### **The Position and Impact of Arthropods in the Trophic Web**

The position and role of arthropods in the ecological web of interactions is an important area of research. By serving as herbivore, predator, and prey in the food web, arthropods appear to be an important yet overlooked link between trophic levels. For example, a wide variety of bird, mammal (e.g., bats, shrews), amphibian, and reptile species feed on arthropods, and numerous arthropod species feed on plants or other arthropods. How the interactions and linkages among these different trophic levels affect overall structure, functioning, and productivity of riparian ecosystems along the Rio Grande is a ger-

mane topic of research. Arthropods may have an important regulatory role in controlling populations of plant species; for example, harvester ants are an important disperser of seeds, and cutworms and other lepidopteran larvae are significant herbivores (Crawford 1993). Some species may also act as regulators of other arthropod populations, providing an integrated system of checks and balances. If the integrity and energy flow of riparian ecosystems is dependent on arthropod interactions with other ecological components and trophic layers, then research designed to assess the consequences of human or natural disturbance on riparian ecosystems would be incomplete without further study of the arthropod role.

For many animal species, and especially birds, arthropods are the primary source of food. However, arthropods are often a patchy resource, and research is needed to determine if and how the patchy distributions of different species affect the diet, distribution, diversity, or abundance of predator species. Introduced tree species have different diversities and abundances of arthropods than native trees along the Rio Grande (Molles and Crawford 1992). So, does the species composition and abundance of birds inhabiting native and introduced riparian vegetation vary in relation to the patchiness, diversity, and abundance of the arthropod resource or to the area, physiognomic structure, and species composition of the plant community? To answer this question, the structures and composition of both arthropod faunas and plant communities must be measured in concert with censuses of bird species.

## CONSERVATION OF RIPARIAN LANDBIRDS

### Species Diversity

Birds are the most diverse vertebrate taxon in New Mexico, with 413 recorded species comprising 64 percent of the total terrestrial vertebrate species (Hubbard 1977). While riparian habitats of the Rio Grande comprise only a minor portion of the available habitat in New Mexico, they are extremely important to bird populations. Of the 325 landbird species with confirmed records in New Mexico (Hubbard 1978), a total of 241 species (74 percent) have been detected within the riparian habitat and adjacent agricultural areas of the Middle Rio Grande (table 1; see Appendix 1 at the end of this chapter), based on observations by Hink and Ohmart (1984),

Hoffman (1990), and the banding program of Rio Grande Bird Research Inc.

In addition to being rich in species, the Middle Rio Grande riparian habitat supports high densities of birds. The average density is 300–600 birds/100 acres and densities of over 1,000 birds/100 acres are recorded for some native riparian habitats such as cottonwood-willow in certain seasons (Freehling 1982; Hink and Ohmart 1984; Hoffman 1990). The high species richness and density in the Middle Rio Grande are consistent with the patterns observed in other Southwest riparian ecosystems (Hubbard 1971; Carothers et al. 1974; Ohmart and Anderson 1982; Rosenberg et al. 1982) and confirm the value of this limited riparian habitat to bird populations.

Most of the riparian avian species show a remarkable dependency on water-related habitat for breeding areas, wintering areas, and migratory corridors. Johnson et al. (1977) reported that of 166 breeding species in west Texas, southern New Mexico, and southern Arizona, 51 percent were completely dependent on riparian habitat, while another 20 percent were partially dependent on it. Of all the species listed as endangered by New Mexico Department of Game and Fish, 50 percent are associated with aquatic or riparian habitats. Johnson et al. (1977) estimated that loss of riparian habitat in the Southwest could result in the loss of 78 (47 percent) of the 166 avian species that breed in the region.

Only 54 (23 percent) species of the 241 landbird species in the Middle Rio Grande are residents and the rest are neotropical and short distance migrants (table 1). These migrants include summer residents (54 species, 22 percent) that breed in the area and are present during late spring and summer, winter residents (52 species, 22 percent) that are present for varying lengths of time between September and April, and the transient species (71 species, 30 percent) that occur in large numbers during spring and fall migrations. Based on the definition given by the Partners in Flight Program (1992), of the 241 landbirds in the Middle Rio Grande, 96 species (40 percent) are neotropical or long distance migrants (type A); 74 species (31 percent) are short distance migrants that breed and winter extensively in North America (type B); 4 species (2 percent) breed primarily south of the U.S./Mexican border and enter the United States along the Rio Grande Valley during the winter months (type C); and the remaining 67 species (27 percent) are residents or migrants not defined by the Partners in Flight list.

Table 1.—Species, migratory status, population trend, and wintering and breeding habitats of landbirds using the Middle Rio Grande.

SPP <sup>a</sup>	PTR <sup>b</sup>	MS <sup>c</sup>	MD <sup>d</sup>	B-HAB <sup>e</sup>	W-HAB <sup>f</sup>	MRGR <sup>g</sup>	p <sup>h</sup>	n <sup>i</sup>
AMCR		R	R	F	V			
AMGO	3	W	B	A,FS	A,FS	0.19	0.62	310
AMKE	1	R	B	V	V	-0.49	0.18	4
AMRE	3	M	A	F	FS	0.15	0.71	2
AMRO	2	R	B	V	V	-0.49	0.18	148
ATSP		W	B	S	S	-0.38	0.32	4
ATFL	2	B	A	S	S	-0.59	0.09	3
BAEA		W	B	W	W			
BTPI	3	B	A	F	F			
BANS	3	B	A	W	W			
BARS	2	B	A	W	W	-0.08	0.84	3
BBWA		M	A	F	FS			
BEVI	3	B	A	F	S			
BEKI	3	R	B	W	W	0.31	0.42	2
BETH	3	A	B	S	S			
BEWR		B	B	F	S	0.75	0.02	46
BLPH		R	B	W	W	0.09	0.81	15
BAWW	3	M	A	F	FS,U	-0.69	0.04	3
BBMA		R	B	FS	FS			
BCCH		R	B	F	F	0.67	0.05	40
BCHU	3	B	A	FS	FS			
BCSP	3	M	A	S	S			
BHGR	2	B	A	F	F	-0.02	0.96	180
BTGN		R	R	FS	S			
BTBW		M	A	FS	FS,U			
BTYW	3	M	A	FS	FS			
BTGW		M	A	FS	FS,U			
BTSP	4	B	B	S	S			
BLWA	3	M	A	F	FS			
BLGR	2	B	A	S	S	0.42	0.26	265
BLJA		A	R	F	F			
BGGN	3	B	A	FS	FS,U	-0.47	0.21	3
BWWA		A	A	FS	FS,U			
BOBO	3	B	A	G,A	G,A			
BRBL	3	W	B	W,S	W,S			
BRSP	3	W	A	S	S	-0.34	0.38	166
BTHU	3	M	A	FS	FS			
BWHA		M	A	F	FS,U			
BRCO	3	A	C	F	F			
BRCR	3	W	B	F,U	F	-0.41	0.28	14
BRTH		W	B	S	S			
BCFL	3	A	C	S	S			
BHCO	4	B	B	V	A	0.73	0.03	2
BUOW	4	B	A	G	G			
BUSH		R	R	S	S			
CAWR		R	R	S	S			
CAHU	3	M	A	U	F			
CAWA	3	M	A	F,W	F	-0.55	0.13	1
CATO		R	R	S	S	0.14	0.73	1
CANW	3	R	R	S	S			
CAFI	3	W	B	F	FS			
CAKI	2	B	A	FS	FS	-0.27	0.48	61
CASP	2	M	B	G	G			
CEDW	3	W	B	F	F			
CCLO	3	W	B	G	GA			
CSWA	3	M	A	FS	FS			
CHRA		B	B	S	S			
CHSW	3	A	A	H	H			
CHSP	4	B	A	FS	FS	0.52	0.15	3823
CCSP	2	M	A	S,W	S	0.50	0.17	72
CLSW	2	B	A	W	W			
COGD		R	R	G,A	G,A			
COBO		R	R	H	H			
COBH	3	B	C	F,W	F,W			
COGR		B	B	FS	V			
CONI	5	M	A	V	V			
COPO	3	M	B	FS	FS			

Continued on next page

Table 1.—Continued.

SPP <sup>a</sup>	PTR <sup>b</sup>	MS <sup>c</sup>	MD <sup>d</sup>	B-HAB <sup>e</sup>	W-HAB <sup>f</sup>	MRGR <sup>g</sup>	p <sup>h</sup>	n <sup>i</sup>
CORA		R	B	V	V			
COYE	3	B	A	W	S	0.27	0.48	15
COHA	3	R	B	F	FS	0.55	0.13	1
CRCA		B	C	G,A	G,A			
CRTH		R	R	S	S	-0.27	0.48	1
CBTH		R	R	S	S			
DEJU	3	W	B	FS	FS	-0.58	0.10	804
DICK	3	M	A	S	S	-0.47	0.21	2
DOWO		R	R	F	F	0.12	0.75	8
DUFL	3	M	A	F,W	FS	-0.38	0.32	85
EABL	3	W	B	F	F			
EAKI	3	B	A	FS	FS			
EAME	4	W	B	GA	GA			
EAPH	3	M	B	F,W	F,W			
EUST		R	B	V	V			
EVGR		M	B	U	F,H			
FEHA	3	B	B	G	G			
FOSP	3	M	B	S	S			
GAQU		R	B	S	S			
GOEA	3	R	B	FS	FS			
GCKI	3	W	B	U	FS	-0.55	0.13	1
GCSP		W	B	S	S	0.27	0.48	1
GRWA	3	M	A	F	F,U			
GRSP	3	M	A	G	G	0.00	1.00	1
GRCA	3	B	A	FS	FS	-0.03	0.94	2
GRFL	3	M	A	S	S	-0.15	0.71	8
GHOW		R	B	F	F			
GTGR		R	B	W	V			
GRRO		R	R	S	S	-0.21	0.59	2
GTOO	3	W	A	F,U	S	0.07	0.86	124
HAWO		R	R	F	F			
HAFL	3	M	A	U	FS	-0.06	0.88	9
HAHA		R	R	W	W			
HASP		W	B	S	S	0.00	1.00	2
HETA	3	M	A	U	F			
HETH	3	W	B	F	FS	0.82	0.01	245
HOWA		M	A	F,W	FS	0.27	0.48	1
HOLA	4	B	B	G,A	G,A			
HOFI		R	B	S	S	-0.43	0.24	1579
HOSP		R	R	H	H	0.00	0.00	
HOWR	3	M	A	V	V	0.01	0.98	88
INDO		A	R	G,A	G,A			
INBU	3	B	A	S	S	0.09	0.83	6
KEWA		M	A	F	F			
LBWO		R	R	F	F			
LALO		W	B	G	G,A			
LARB	3	M	A	G	G,A	-0.45	0.22	4
LASP	4	M	A	S	S	0.33	0.39	385
LAGO	3	A	B	FS,W	FS,W			
LAZB	2	M	A	S	S	0.74	0.02	428
LEFL	3	M	A	FS	FS	0.21	0.59	2
LEGO	4	B	B	F	V	0.49	0.18	65
LENI	3	B	A	S	V			
LEWO	3	R	B	F	F			
LISP	3	W	A	S	S	0.40	0.30	250
LOSH	3	R	B	S	S	0.00	1.00	1
LEOW	3	B	B	F,W	F,W			
LUWA	3	B	C	FS	FS			
MGWA	3	M	A	FS	FS	-0.30	0.44	314
MAWA		M	A	FS	FS,M			
MAWR	3	W	B	W	W	0.52	0.15	5
MCLO	3	W	B	G,A	G,A			
MERL	3	M	A	F	V			
MIKI	3	B	A	F	U			
MOQU		R	R	FS	FS			
MOBL	4	W	B	U	V			
MOCH		W	B	F,U	F	-0.40	0.29	37

Continued on next page

Table 1.—Continued.

SPP <sup>a</sup>	PT,R <sup>b</sup>	MS <sup>c</sup>	MD <sup>d</sup>	B-HAB <sup>e</sup>	W-HAB <sup>f</sup>	MRGR <sup>g</sup>	p <sup>h</sup>	n <sup>i</sup>
MODO	5	R	B	V	V	0.02	0.97	25
MOWA		A	A	FS	FS			
NRWS	3	B	A	W	W			
NAWA	3	M	A	FS	FS			
NOCA		A	R	S	S			
NOFL	5	R	B	F	F	0.03	0.97	22
NOGO	3	W	B	FS	FS			
NOHA	3	B	B	G	G,A	0.55	0.13	1
NOMO	2	R	B	S	V	-0.53	0.15	2
NOOR	2	B	A	F	S	-0.06	0.88	79
NOPA		M	A	F	FS			
NSWO		W	B	F	FS			
NSHR		W	B	F	FS	-0.14	0.73	1
NOWA	3	M	A	F,W	F,W	-0.26	0.51	9
OSFL	3	M	A	F,U	F	-0.14	0.94	1
OCWA	3	M	A	FS	FS	-0.23	0.54	401
OROR	3	M	A	FS	FS	-0.27	0.48	1
OSPR	3	M	B	W	W			
OVEN	3	W	A	F	FS	0.27	0.47	1
PABU	3	M	A	S	S	0.21	0.59	2
PARE	3	A	C	F	F			
PAWA		A	A	F,W	FS			
PEFA	3	W	A	W	V			
PHAI	3	B	A	S	S			
PISI	3	W	B	FS	FS	-0.26	0.49	265
PIJA		R	B	S	S			
PLTI		R	B	F	F			
PRFA	3	B	B	G	G			
PRWA		M	A	F,W	FS,U			
PUMA	3	B	A	V	V			
PYNU		M	B	F	F			
PYRR	R	R	S	S				
RECR		M	B	F	FS			
RBNU		W	B	F,U	F	-0.35	0.36	3
REVI	3	M	A	FS	S,U	0.41	0.27	1
RHWO		B	B	F	F			
RNSA	3	B	B	F	FS	-0.14	0.73	1
RTHA	2	R	B	FS	FS			
RWBL	5	R	B	W	G,A	-0.24	0.54	33
RNPH		R	R	S,A	S			
RODO		R	B	H	H			
ROWR	5	R	B	O	O			
RBGR	3	M	A	F	FS	0.00	1.00	2
RLHA		W	B	G	FS			
RCKI	3	W	B	U	FS	-0.08	0.84	109
RUHU		M	A	FS	FS			
RCSP		R	R	S	S			
RSTO	4	R	B	FS	FS	-0.56	0.12	106
RUBL		W	B	F,W	A			
SAGS	3	W	B	S	S			
SATH	3	W	B	S	S			
SAVS	3	W	B	G	G	-0.18	0.63	90
SAPH	4	B	B	S	S	0.25	0.52	6
SCQU		R	R	S	S			
SCTA		M	A	F	FS	-0.27	0.48	1
STFL	3	A	A	S,A	G,A			
SCOR	4	B	A	S	S			
SCJA		B	B	S	S	0.00	1.00	1
SEWR	3	W	B	G,W	G			
SSHA	3	W	B	F	F	0.06	0.88	5
STSP		W	B	W	S			
SEOW	3	W	B	G	G			
SOVI	3	B	A	F	FS,U	-0.31	0.41	31
SOSP	3	W	B	S,W	S,W	0.41	0.28	226
STJA		W	B	F	F	-0.55	0.13	2
SUTA	3	B	A	F	S	-0.19	0.63	4
SWHA	1	B	A	S	G,A			

Continued on next page

Table 1.—Continued.

SPP <sup>a</sup>	PTR <sup>b</sup>	MS <sup>c</sup>	MD <sup>d</sup>	B-HAB <sup>e</sup>	W-HAB <sup>f</sup>	MRGR <sup>g</sup>	p <sup>h</sup>	n <sup>i</sup>
SWTH	3	M	A	F	FS,U			
SWSP		W	B	W	S	0.49	0.19	8
TEWA	3	M	A	FS	FS,U	0.27	0.48	1
TOSO	3	W	B	U	FS			
TOWA	3	M	A	F,U	FS,U	-0.14	0.73	1
TRSW	3	B	B	W	W			
TUVU	2	B	B	V	V			
VEER	3	M	A	F,W	FS			
VERD		R	R	S	S			
VEFL	3	B	A	V	V			
VESP	4	M	B	S	G	-0.30	0.43	56
VGSW	1	M	A	F,U	FS			
VIWA	3	M	A	FS	FS	-0.41	0.28	118
WAVI	3	M	A	F	FS	-0.52	0.15	34
WAPI	3	W	B	W,S	W			
WEBL	4	M	B	F	F			
WEFL		M	A	F,U	F,U	0.13	0.75	9
WEKI	4	B	A	S,A	G,A	-0.72	0.03	24
WEME	4	R	B	G,A	G,A	0.36	0.34	10
WESO		R	B	FS	FS	-0.19	0.63	3
WETA	3	M	A	F,U	F,U	-0.78	0.01	139
WEWP	2	B	A	F	F,U	-0.18	0.64	36
WBNU		R	R	F	F	-0.47	0.20	13
WCSP	3	W	B	S	S	0.72	0.03	963
WTSP	3	W	B	FS	FS	0.53	0.14	6
WTSW	3	M	A	W,U	U			
WWDO	3	M	C	S	S			
WITU		R	R	F	F			
WISA	3	W	B	U	F			
WIFL	3	B	A	W,FS	FS	-0.21	0.59	55
WIWA	3	M	A	S,W	FS	0.66	0.05	827
WIWR		M	B	F,W	FS			
YWAR	3	B	A	S	S	-0.33	0.39	169
YBSA	3	M	B	U	U			
YBCU	3	B	A	F	FS,U	-0.45	0.23	5
YBCH	3	B	A	S	S			
YHBL	3	W	A	W	W			
YRWA	3	W	B	F	FS	-0.20	0.61	481
YTVI		M	A	F	F,U			
ZTHA	3	A	C	F,W	FS			

<sup>a</sup>SPP = species, based on Hink and Ohmart (1984), Hoffman (1990), and Rio Grande Bird Inc. banding program (personal communication). For species names, see Appendix (at the end of this chapter).

<sup>b</sup>PTR = population trend rank (Carter and Barker 1993). Species with higher rank are more vulnerable to extirpation.

<sup>c</sup>MS = migratory status. B = breeding resident, W = wintering resident, M = transient, and R = resident. The information is based on Hubbard (1975), The AOU Checklist of North American Birds (1983), and Hink and Ohmart (1984).

<sup>d</sup>MD = migration distance, is based on the Preliminary Lists of Migrants for Partners in Flight Neotropical Migratory Bird Conservation Program (1992). A = species breeding in North America and wintering primarily south of the United States (neotropical migrants); B = species breeding and wintering extensively in North America; C = species whose breeding range is primarily south of the U.S.-Mexico border and who enter the United States along the Rio Grande Valley and where the Mexico Highlands extend across the U.S. border; R = resident.

<sup>e</sup>B-Hab = major breeding habitat type(s), based on information from Hubbard (1978), AOU (1983), Ehrlich et al. (1988). A = agriculture lands, F = forest, FS = forest shrub, G = grassland, H = human related habitat, S = scrub, U = upland forest, V = variable, W = water related habitat.

<sup>f</sup>W-Hab = major wintering habitat type(s), based on information from Hubbard (1975), AOU (1983), Ehrlich et al. (1988). A = agriculture lands, F = forest, FS = forest shrub, G = grassland, H = human related habitat, S = scrub, U = upland forest, V = variable, W = water related habitat.

<sup>g</sup>MRGR = *r* value of the regression between year and number of birds captured/100 net-hours from 1985-1993 at Rio Grande Nature Center (data from Rio Grande Bird Research Inc., Albuquerque, NM).

<sup>h</sup>p = significant level of the regression analysis.

<sup>i</sup>n = total birds captured from 1985 to 1993 at Rio Grande Nature Center, Albuquerque, NM.

## Recent Studies

Early research studies on bird use of riparian habitats of the Rio Grande were limited to breeding populations and game species (table 2). Monson (1946) was one of the first to note the importance of riparian habitats to various avian species in the Middle Rio Grande. The avifauna of Elephant Butte Marsh was documented by Hundertmark (1978), whose study

area supported the largest known rookery of nesting water birds in New Mexico. The New Mexico Department of Game and Fish conducted a long term gamebird population study in riparian areas during the 1970s (Zapatka 1980). Jojola (1977) reported 43 species including 20 migratory species during a breeding study at Isleta Indian Reservation. He also found that breeding density in the study area was low and suspected that this was related to habitat

Table 2.—Recent avian studies in the Middle Rio Grande, New Mexico.

Researcher(s)	Year	Study location	Study season(s)	Objectives	Species studied
G. Monson	1946	Rio Grande Valley Socorro County	Breeding	Field note	Some species
A.E. Borell	1951	MRG	Breeding	Use of Russian Olive	Some species
H.T. King	1976	Southern New Mexico Bosque	Breeding	Species abundance and habitat relation	All species
J.R. Jojola Sr.	1977	Isleta Indian Reservation	Breeding	Population and habitat	Breeding species
D.C. Cole	1978	MRG, Bernardo to San Felipe Pueblo	Breeding	Vegetation structure and breeding bird density	Breeding species
C.A. Hundertmark	1978	Elephant Butte Marsh	Breeding	Inventory	Breeding species
R.J. Raitt & M.C. Delasantro	1980	Elephant Butte and Caballo Reservoirs	All seasons	Inventory	All species
T.P. Zapatka	1980	MRG	All seasons	Game-bird population	Mourning Dove
M. D. Freehling	1982	MRG	All seasons	Bird abundance in relation to Russian Olive	All species
V.C. Hink & R.D. Ohmart	1984	MRG	All seasons	Inventory, abundance, and habitat use	All species
Hunter et al.	1987	MRG	Summer	Breeding status	Breeding riparian-obligators
S.W. Hoffman	1990	MRG	Spring, summer and winter	Inventory and abundance in relation to habitat	All species
G.H. Farley et al.	1994	MRG	All seasons	Use of different aged riparian forest	All species
D.A. Leal & R.A. Meyer	1994	MRG	All seasons	Community composition and habitat importance	All species

disturbance. Cole (1978) investigated the relationship between vegetation structure, breeding bird densities, and habitat utilization in five mature cottonwood stands from Bernardo to San Felipe Pueblo. These sites were dominated by closed canopies of mature cottonwoods with varying understory composition. She recorded 40 breeding or probable breeding species and 30 nonbreeding species from late May to August 1977. Borell (1951) and Freehling (1982) studied the use of Russian olive by riparian birds. Their data provide evidence that Russian olive is used by many landbirds for food (berry crops), cover, and nesting habitat.

The most systematic and thorough bird community study of the Middle Rio Grande was conducted by Hink and Ohmart (1984). During a two-year biological survey, they confirmed that avian species used Rio Grande riparian habitats extensively. They also found that species occupancy patterns varied with season, habitat type, and vegetation structure. A follow-up study of a less extensive scale was conducted by Hoffman (1990) who surveyed birds in the state parks of the Middle Rio Grande. He further described the relative abundance and diversity of birds in the riparian habitat. Four rare or endangered species were detected: bald eagle (*Haliaeetus leucocephalus*), willow flycatcher (*Empidonax trailii*), common blackhawk (*Buteogallus anthracinus*), and yellow-billed cuckoo (*Coccyzus americanus*). An assessment of population trends was intended but was hampered by too few years of data and variations in observers. However, he made several management recommendations for preserving and enhancing the avian resources in the Middle Rio Grande.

Recently, Farly et al. (1994) compared year-round avian use of revegetated riparian sites with mature cottonwood forest sites at the Bosque del Apache National Wildlife Refuge and at a site near Las Palomas, Sierra County. Their data suggest that the revegetated areas are especially important for neotropical migrants. Leal and Meyer (1994) studied species diversity and density of neotropical migrants during breeding and migration in representative riparian woodland types along the Middle Rio Grande. Comparing contemporary species composition to that reported from early records, they found that three historically "regular" species, red-headed woodpecker (*Melanerpes erythrocephalus*), purple martin (*Progne subis*), and hooded oriole (*Icterus cucullatus*), had disappeared from the Middle Rio Grande. Species with populations at the border of

their ranges such as these three may be more susceptible to disturbance by dropping out of the system as habitats change. In contrast, Leal and Meyer's (1994) multivariate approach showed that sites having an exotic woody species component, i.e., a type of disturbance, had a positive influence on overall importance scores for migratory landbirds.

Thus, kind and change of habitat have helped determine presence, absence, and abundance of bird species along the Middle Rio Grande, but bird species may differ in their responses to various habitat factors such as seral stage, presence of exotic plant species, and degree of disturbance. To ultimately ensure that necessary habitats are provided for all native bird species, further research is needed to clarify differences in habitat selection among species. This involves developing a program of research that evaluates (1) patterns of species habitat use in different seasons and (2) underlying reasons for species presence, absence, and abundance, including roles of competition, predation, brood parasitism, and availability of food, cover, and nesting substrate, which ties into (3) linkages between habitat use and demographic factors such as nesting success, recruitment, and adult survival.

### Population Trends

Population trends of neotropical and short-distance migratory landbirds in North America have received nationwide and worldwide attention in recent years as evidence documenting declines of many migratory bird populations has accumulated (Finch 1991). Unfortunately, population trend information is extremely limited in New Mexico, although Hoffman (1990) reported a decline in numbers of summer tanagers and yellow warblers using riparian habitats of the Middle Rio Grande.

The Breeding Bird Survey (BBS) coordinated by the U.S. Fish and Wildlife Service and Canadian Wildlife Service (Robbins et al. 1986, 1989a, 1989b) is a national data base providing quantitative information on temporal and spatial changes in breeding populations of landbirds. Using the last 10 years of BBS data, Carter and Barker (1992) derived a population trend rank (PTR) for migratory landbird species in each of the 11 western states. The PTR scale ranged from 1 to 5, with 1 = large increase ( $\geq 5$  percent/year); 2 = small increase (1 to 5 percent/year); 3 = trend unknown (between -1 percent and 1 percent/year); 4 = decrease (-1 percent to -5 percent/

year); and 5 = large decrease ( $> -5$  percent/year). We evaluated those migratory landbird species of the Middle Rio Grande that had PTR assignments. Of the 161 scored species, 21 were ranked as having declining populations (rank 4 or 5), whereas 18 species were scored as having positive trends (rank 1 or 2; fig. 1; and table 1). Yet, a majority of the species (122 species, 76 percent) were ranked 3, trend unknown or minor. Three possibilities could explain a species being ranked 3: relative stable population size; small sample because of limited survey routes or lower detectability of the species; or no quantitative monitoring information exists for the species in the area. Because BBS routes are not designed to sample rare or long linear habitats such as riparian corridors and because the number of BBS routes in the western United States are insufficient for accurate trend determination (Finch 1991), the latter two reasons may very well explain why most Middle Rio Grande landbirds had ranks of 3.

Under the initiative of C.A. Hundertmark, Rio Grande Bird Research Inc. has studied landbirds at the Rio Grande Nature Center in Albuquerque, New Mexico, since 1979 by using mist nets (Cox 1994). The program has been standardized and the banding efforts have been relatively constant since 1985. The sample sizes are small for most of the species captured (see table 1) because the operations are staffed by volunteers and are limited to weekends. Regression analyses on the number of birds captured per year from 1984 to 1993 suggest that overall bird abundances within three taxonomic groups—tanagers, fly-

catchers, and vireos—have declined (Finch and Yong, unpublished) (see table 1 for trends in individual species). On the other hand, wrens and several sparrow species showed significant or insignificant population increases (table 1). All the warbler species with a sample size (20 had a negative insignificant trend except Wilson's warbler, which had a significant positive trend ( $r = 0.66$ ,  $p = 0.05$ ).

Declines in populations have been attributed to events associated with both breeding and overwintering areas. The rapid rate of deforestation in tropical areas, for example, has been implicated in population declines of many forest-dwelling landbird migrants (Lovejoy 1983; Rappole et al. 1983; Robbins et al. 1989a). Other data point to the importance of changes in suitability of breeding habitat (Whitcomb 1977; Hutto 1988). For example, many forest-interior migrants are reported to be "area-sensitive" (Robbins 1980; Robbins et al. 1989b), which explains, in part at least, why fragmentation of forested breeding habitat has been implicated in population declines of migratory birds (Lynch and Whigham 1984; Wilcove 1988). Habitat succession and disturbance are additional factors that may explain bird population changes detected on the breeding grounds (Finch 1991).

Population trends and their relationship with breeding habitats of the Middle Rio Grande generally agree with findings based on regional and national trends. The banding data of Rio Grande Bird Research Inc. suggest that more forest-breeding migrants and long distance migrants have negative population trends than birds using other breeding habitats or those having short migration distances (figs. 2, 3). Unfortunately, no long-term studies have been conducted to link population trends of resident or migratory birds to habitat or landscape changes along the Rio Grande. We can speculate, however, that a variety of changes along the river are likely to have been influential in causing bird populations to change. Mostly related to increases in human populations in the Middle Rio Grande Basin (Crawford et al. 1993), these factors include (1) increases of exotic woody plants and associated loss of native vegetation, (2) draining and loss of marshes, (3) habitat succession, especially that associated with lack of cottonwood regeneration, (4) habitat conversion to urban and agriculture environments, (5) changing rates of cowbird parasitism, and (6) increasing disturbance of nesting birds by humans and domesticated animals.

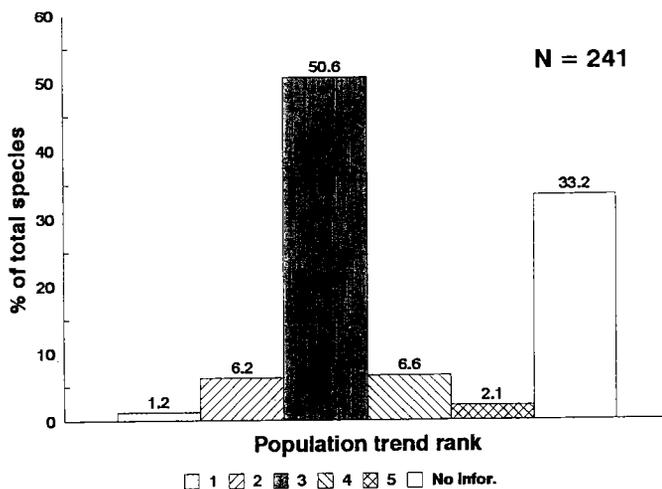


Figure 1.—Population trend rank (Carter and Barker 1993) of the middle Rio Grande landbirds ( $n = 241$ ). Species with higher rank are more vulnerable to extirpation.

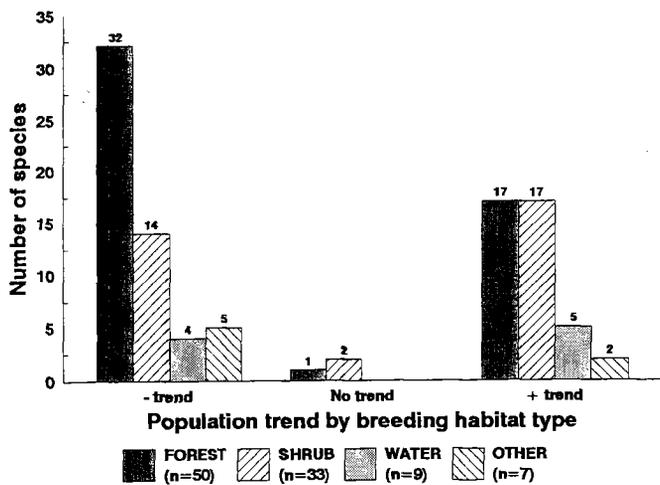


Figure 2.—Population trends in relation to the breeding habitats, based on the banding data at Rio Grande Nature Center.

### Use of Migratory Corridors

Riparian zones along the Middle Rio Grande are probably important stopover sites for landbirds migrating through desert country that might otherwise be inhospitable to some species. Yet, information on migratory bird use of riparian corridors during spring and fall passage is limited, especially for western drainages (Finch 1991). Neotropical and shorter distance landbird migrants that use the Great Plains-Rocky Mountain "flight route" may depend on riparian habitats for resting, for replenishment of energy stores, and as places to avoid unfavorable weather conditions during migration.

About one-third of the landbird species occupy the Middle Rio Grande only during annual migrations between their breeding and wintering grounds. Furthermore, although many short-distance migrants breed and winter in the United States, they have populations that use the Middle Rio Grande only as a stopover site. Studies from other areas suggest riparian systems may attract more than 10 times the number of migratory birds as surrounding upland sites during spring and fall migration (Stevens et al. 1977; Hehnke and Stone 1979).

When migrants stop over, they must adjust their foraging behavior to unfamiliar habitats, resolve conflicting demands of predator avoidance and food acquisition, compete with other migrants and resident birds for limiting resources, respond to unpredictable and sometimes unfavorable weather, and correct for orientation errors (Moore and Simons

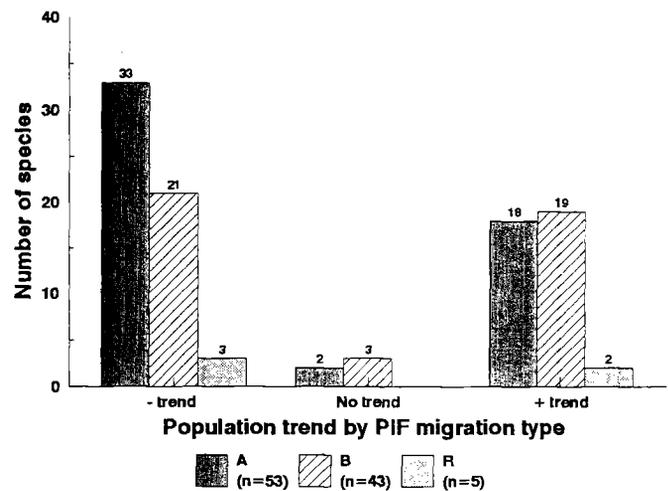


Figure 3.—Population trends in relation to the migration distance, based on the banding data at Rio Grande Nature Center. The migration distance is based on the Preliminary Lists of Migrants for Partners in Flight Neotropical Migratory Bird Conservation Program (1990). A = species breeding in North America and wintering primarily south of the United States (Neotropical migrants); B = species breeding and wintering extensively in North America; R = resident.

1992). These problems are magnified when migrants cross inhospitable environments, such as deserts, and arrive at stopover sites with depleted energy stores. Consequently, riparian corridors may provide suitable habitat at an especially critical time for migrating birds. Riparian corridors may also facilitate orientation during migration by virtue of their "leading line" effect (Geyr v. Schweppenber 1933).

Stopover time may vary with species, reflecting the relative importance or use of Middle Rio Grande riparian habitats as fueling sites during migration. Our banding data from spring 1994 at two sites along the Middle Rio Grande suggest that the species-specific stopover biology may be determined by migration distance (Finch and Yong, unpublished). For example, recaptured McGillivray's warblers, dusky flycatchers, and hermit thrushes have relatively short stopover lengths (1.5 days, 1.75 days, and 2.71 days respectively), and relatively large amounts of mass (fat) gain (4.07 percent, 13.44 percent, and 3.01 percent respectively) on average. However, blue grosbeak, a local breeding and short distance migratory species, has a longer stopover length (11 days) and small mass change (-0.15 percent) on average.

We also found that numbers of landbirds captured and counted in riparian habitats during spring migration are not the same among habitat types, sug-

gesting that migratory landbirds select different habitats during stopover. Selection could be species-specific based on our finding that certain species occurred in certain habitats more often than others did. For example, among four habitats of the Middle Rio Grande—cottonwood, mesquite, salt cedar, and agricultural fields—that we surveyed in 1994, the relative distribution of black-headed grosbeaks was 50.57 percent, 16.09 percent, 24.14 percent, and 8.00 percent respectively, while that of the closely related Blue Grosbeaks was 15.79 percent, 19.55 percent, 19.55 percent, and 45.11 percent, respectively (Finch and Yong, unpublished). Habitat use also changed through the migration season: more birds were detected from mid-April to the beginning of May than in later months and migrants were also distributed more evenly among habitats during this period. The seasonal habitat shifts of migrants may be due to changes in food availability, leafing phenology, competitive pressure, or predation rates of different habitats through the migration season.

The persistence of migrant populations depends on the bird's ability to find favorable conditions for survival throughout the annual cycle (Morse 1980). Consequently, factors associated with the *en route* ecology of migrants must figure in any analysis of population dynamics (Moore and Simons 1992). How well migrants "offset" costs of migration, i.e., satisfy their energy demands and meet contingencies that arise *en route*, determines the success of an individual's migration as well as the future status of the population itself. As stopover habitat is degraded or lost, cost of migration increases and the probability of a successful migration decreases.

Riparian habitats are under increasing pressure from agriculture, livestock grazing, logging, water management, and recreation (Tellman et al. 1993). More than 90 percent of the original desert riparian habitat in the West has been eliminated by flood control and irrigation projects (Knopf 1988). Effective conservation strategies for neotropical and short-distance landbird migrants that travel through the Southwest cannot be established without basic information on the importance of riparian corridors as stopover habitat.

To account for the habitat needs of migrating birds in management and restoration plans, evaluation of spring and fall use of desert riparian corridors by landbird migrants is urgently needed. We recommend that studies be designed to (1) identify species that use riparian habitats along the Middle Rio

Grande and their seasonal pattern of passage; (2) quantify the volume and timing of spring and fall migration in association with the Middle Rio Grande; (3) characterize the *en route* habitats used by migrants, including daily and seasonal patterns of avian diversity and abundance among habitats; and (4) interpret the biology of landbird migrants when they stopover in riparian habitats. Specific questions on migrant biology and ecology that have yet to be answered are (1) How long do migrants stay at riparian stopover sites? (2) What is their energetic status when they stop over? (3) Do migrants (re)deposit energy stores during stopover? (4) How do these aspects vary among species and between seasons?

Different types of riparian habitats may vary in suitability for use by migrating landbirds. Moreover, alteration of particular riparian habitats may reduce or enhance suitability as a stopover area. Thus, responses of landbird migrants to variation in riparian habitats, including human-induced alteration caused by urban encroachment, burning, conversion, draining, and flooding, should be assessed. We need to know (1) whether, how, and why migrants select among riparian habitats; (2) how habitat variation affects stopover biology, including foraging behavior, stopover length, and rate of fat (re)deposition; and (3) how responses to different habitat types or to habitat changes vary among species.

## Breeding Biology

During the nonbreeding portion of the life cycle, the major problem faced by landbirds is survival. During the breeding season, however, landbirds cope with the additional demands of finding nest sites, securing enough food to feed young, and protecting their nests against predators and brood parasites. Studies from other parts of the country indicate that population declines of some migratory landbird species may be linked to low reproductive success in unfavorable habitats (Whitcomb 1977; Lynch and Whigham 1984; Hutto 1988; Wilcove 1988).

Most breeding studies conducted along the Middle Rio Grande have been restricted to bird inventories (Manson 1946; Hundertmark 1978; Raitt and Delasandro 1980). Recent studies have focused on the habitat utilization and relative abundance of the species (Borell 1951; King 1976; Jojola 1977; Cole 1978; Freehling 1982; Hink and Ohmart 1984; Hunter et al. 1987; Hoffman 1990). Most of these studies are short term, applying seasonal survey(s) as the study

technique. BBS could provide some breeding information, but they are limited to areas with major roads and are not confined to riparian areas. Using survey data to infer the breeding biology of a species could also result in bias. For example, species detected on a BBS route could be foraging in the area but breeding somewhere else. Foraging birds could also be nonbreeding individuals, e.g., "floaters." Because foraging habitat may not represent breeding or nesting habitat, interpretations based merely on bird presence may give misleading results.

Intensive studies of breeding and demographic parameters are needed to decipher the population dynamics of birds breeding in riparian vegetation of the Middle Rio Grande. Not only do we need to identify the abundance and species of landbirds that breed in riparian habitats, we also need to determine whether their breeding populations are source populations (defined as those that exceed the carrying capacity of the habitat) or sink populations (in which reproductive outputs are inadequate to maintain local population levels). Knowledge of species habitat requirements in the context of macro- and microhabitat selection would help to clarify patterns of species distributions. In addition, an understanding of how variation among habitat types, structures, seral stages, conditions, landscape features, and land uses affect fitness components such as productivity and survival is essential for conserving landbirds.

To identify causes of population changes, information on population size must be coupled with data on the internal composition of a population, i.e., its demographics (Temple and Wiens 1989). For example, data on nesting success, yearly recruitment rate, survivorship, sex ratio, and age distribution can all provide valuable cues in distinguishing factors or events regulating a population. Moreover, such primary population parameters can provide early warning signals of population problems prior to actual declines.

Choice of habitats that increase reproductive output should be favored over evolutionary time. Hink and Ohmart's study (1984) suggests that habitat breadth and preference of breeding landbirds in the Middle Rio Grande may vary among species (table 3). Variation in relative availability of habitat types may affect the habitat selection of breeding birds and, hence, their reproductive success. A decrease of favorable breeding habitat (e.g., native cottonwood-willow) may increase competition among breeding individuals, forcing some birds to use less suitable

or marginal habitats, which may reduce their productivity.

Breeding species may be sensitive to changes in microhabitats such as abundance of nest locations, foliage coverage, and understory structure. Unfavorable changes in microhabitats could reduce the chance of successful reproduction directly by increasing the probability of predation, brood parasitism, and/or competition for nest sites among breeding individuals, or indirectly by lowering food availability.

Factors that limit the breeding success of landbirds in the Middle Rio Grande may include predation, cowbird parasitism, mating success, food availability, weather, and flooding. Studies from other areas have suggested that nest predation is a major mortality factor, accounting for 50 percent or more of the nest failures in some locations. Experiments with artificial nests have shown that there are unusually high numbers of mammalian and avian nest predators near edges and in the vicinity of human habitations (Wilcove 1985); therefore edge-nesting birds may be more prone to nest failure. Cowbird parasitism, another important limiting factor, has reached such high levels in some areas that certain species seem to be unable to raise any young of their own (Brittingham 1983; Terborgh 1992). Unfavorable weather and starvation are the other frequent causes of some nesting mortality. The role and importance of these limiting factors may vary in relation to bird species, habitat composition and structure, seral stage, proximity to disturbance, and environmental conditions.

### **Potential Effects of Brown-headed Cowbirds**

Over the last century, the distribution, abundance, and host range of the brown-headed cowbird has increased dramatically in the West because of anthropogenic habitat changes such as urbanization, deforestation, habitat fragmentation, and agriculture development (Rothstein 1994). Its remarkable colonizing ability comes from its brood parasitism behavior that frees it from nesting responsibilities; its foraging flexibility (apparently related to its emancipation from on-duty nesting), such that it can commute daily between widely disjunct feeding and breeding sites; its flexibility in mating systems; and its extraordinary fecundity.

Brood parasitism by the brown-headed cowbird has become one of the major threats to populations

Table 3.—Distribution of landbirds (percent of total birds detected) among habitat types during the breeding season<sup>a</sup>.

SPP	C/RO <sup>b</sup>	C/CW	RO	DR	MH	SB/RV	Hb <sup>c</sup>	% Max. HB <sup>d</sup>
YBCU	42	45	12	1			1.02	27
LEWO		100					0.00	0
DOWO	47	47	1	5			0.91	51
HAWO	100						0.00	0
NOFL	60	31	5	4			0.95	53
WEWP	67	26	2	5			0.85	47
WEKI	70	14	4	10		2	0.88	49
BLPH				100			0.00	0
ATFL	53	38	7	2			0.97	54
BCCH	68	24	5	3			0.86	48
MOCH	85		15				0.42	24
WBNU	60	37	2	1			0.80	46
AMRO	46	42	6	6			1.06	59
GRCA	35	18	29	18			1.34	75
EUST	44	51					0.85	48
YWAR	35	13	43	9			1.58	88
COYE	3	9	12	29	47		1.18	66
YBCH	16	40	42	2			1.10	62
SUTA	66	19		15			0.87	49
BHGR	42	35	17	6			1.20	67
BLGU	24	30	30	15			1.40	78
INBU	24	52	4	20		1	1.11	62
SPTO	49	20	27	4			1.15	64
RWBL		3	21		76		0.64	36
YHBL				100			0.00	0
NOOR	25	56	12	7			1.11	62
LEGO	53	30	13	2		2	1.12	62
BHCO	40	28	20	12			1.17	65

<sup>a</sup>Modified from Hink and Ohmart (1984).

<sup>b</sup>Habitat type: C = cottonwood, RO = Russian olive, CW = coyote willow, DR = drain, MH = marsh, SB = sandbar, RV = river channel.

<sup>c</sup>HB = habitat breadth, calculated using the information theory equation:  $HB = -\sum p_i \ln p_i$ , where  $p_i$  is the proportion of the density of each species in the  $i^{\text{th}}$  habitat type.

<sup>d</sup>Percent of maximum HB is calculated by dividing the HB for the species by the maximum possible HB value, which is  $\ln 6 = 1.7918$  when all birds are evenly distributed among all six habitat types.

of many landbirds on their breeding grounds (Mayfield 1977, Brittingham and Temple 1983). Because of its abundance and fecundity, the cowbird has a potential to lower the recruitment rate of host species. Cowbird parasitism reduces host productivity because cowbirds remove host eggs; break host eggs; have shorter incubation periods than hosts, thus nestlings hatch earlier and have a competitive head start over host nestlings; produce larger eggs and nestlings than most hosts; and have faster nestling growth rates. Most Neotropical migrants use an open-cup nest strategy and overlap in timing of breeding with migratory brown-headed cowbirds, thus making them especially vulnerable to parasitism.

At least 10 landbird species, including southwestern species such as least Bell's vireo and southwestern willow flycatcher, have experienced population declines and local population extinctions since the

cowbird's spread. These declines are attributed to brood parasitism, riparian habitat loss, and habitat fragmentation in the western United States (Rothstein and Robinson 1994). Both least Bell's vireo and willow flycatcher are riparian obligate breeders in most of their breeding ranges. The least Bell's vireo was designated as an endangered species by the U.S. Fish and Wildlife Service in 1982. The parasitism rate reached over 50 percent in the later 1970s throughout most of the vireo's breeding range (Goldwasser et al. 1980; Franzreb 1989). Removal of cowbirds (Beezely and Rieger 1987) from vireo habitat has greatly increased vireo productivity, and the species is much more numerous now than when the alarm about its near extinction was first raised in the late 1970s.

Southwestern willow flycatchers nest in cottonwood-willow associations and structurally similar riparian

vegetation. Its populations have declined throughout the Southwest through the 20th century. Although the cumulative long-term effects of cowbird parasitism on the southwestern willow flycatcher is unknown, it seems likely that parasitism is an imminent threat to the flycatcher's population persistence or recovery. This, coupled with continued loss, conversion, and deterioration of native riparian shrub habitats that flycatchers prefer, increases its vulnerability to local and widespread extinction. In July 1993, the USFWS proposed to list the species as an endangered species and to designate critical habitat under the Act. New Mexico contains a major portion of the southwestern willow flycatcher's historic and current range, and the Middle Rio Grande bosque in particular has been identified as critical habitat owing to the year-to-year presence of locally nesting pairs.

Earlier studies showed that cowbird abundance and parasitism rates decreased as distance of host nests increased from edges, although recent studies report that the "cowbird edge effect" varies within and among regions in response to landscape-level variation and cowbird abundance. The existing contiguous riparian zones associated with the Middle Rio Grande are comprised of long narrow strips of woodlands, representing typical edge habitat selected by host-searching cowbirds. In the southern half of the valley where the riparian zone is at its widest, the habitat is only 4–5 km across. Conversion of riparian habitats to agricultural or residential areas reduces the total width and area of the riparian zone, consequently decreasing the average distance from edges.

Little information is available on abundance and trends of brown-headed cowbird populations in the Southwest, and even less is known about how cowbird parasitism affects the population dynamics of landbird migrants using the Middle Rio Grande bosque. However, the dramatic environmental changes related to urbanization, livestock industry, recreation, agriculture, power lines, fences, and dam constructions within and surrounding riparian habitats along the Middle Rio Grande create suitable habitats and conditions for brown-headed cowbirds. During the 1994 spring migration of songbirds at Bosque del Apache National Wildlife Refuge, we found that the brown-headed cowbird was one of the most abundant species (244 individuals, or 9.16 percent of all the landbirds detected) (Finch and Yong, unpublished). The 244 observations were distributed

evenly among habitats (23.77 percent, 23.36 percent, 27.46 percent, and 25.41 percent for agriculture, cottonwood, mesquite, and salt cedar habitat type respectively). Hoffman (1990) also reported that brown-headed cowbirds were abundant throughout the Middle Rio Grande bosque and speculated that local population declines of the summer tanager and yellow warbler were due to heavy parasitism.

BBS data indicate that New Mexico is one of the states with the lowest brown-headed cowbird breeding population (0–10 individuals/route, see Robinson et al. 1992). However, survey data may not reflect the true parasitism rate because parasitism levels vary locally. More intensive studies on cowbird distribution, abundance, and levels of nest parasitism are required before any decisions can be made regarding the extent to which cowbird management efforts are necessary. The vulnerability of landbird species to cowbird parasitism, as indexed by high rates of reproductive loss or failure, need to be determined. Knowledge of habitat features that stimulate, or conversely inhibit, nest searching facility of cowbirds or movement and reproduction of hosts is critical for managing and restoring habitats to enhance breeding success and juvenile dispersal of landbirds.

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## APPENDIX I

### Landbirds of the Middle Rio Grande

Code <sup>a</sup>	Common name	Scientific name <sup>b</sup>
AMCR	American Crow	<i>Corvus brachyrhynchos</i>
AMGO	American Goldfinch	<i>Carduelis tristis</i>
AMKE	American Kestrel	<i>Falco sparverius</i>
AMRE	American Redstart	<i>Setophaga ruticilla</i>
AMRO	American Robin	<i>Turdus migratorius</i>
ATSP	American Tree Sparrow	<i>Spizella arborea</i>
ATFL	Ash-throated Flycatcher	<i>Myiarchus cinerascens</i>
BAEA	Bald Eagle	<i>Haliaeetus leucocephalus</i>
BTP1	Band-Tailed Pigeon	<i>Columba fasciata</i>
BANS	Bank Swallow	<i>Riparia riparia</i>
BARS	Barn Swallow	<i>Hirundo rustica</i>
BBWA	Bay-breasted Warbler	<i>Dendroica castanea</i>
BEVI	Bell's Vireo	<i>Vireo bellii</i>
BEKI	Belted Kingfisher	<i>Ceryle alcyon</i>
BETH	Bendire's Thrasher	<i>Toxostoma bendirei</i>
BEWR	Bewick's Wren	<i>Thryomanes bewickii</i>
BLPH	Black Phoebe	<i>Sayornis nigricans</i>
BAWW	Black-and-white Warbler	<i>Mniotilta varia</i>
BBMA	Black-billed Magpie	<i>Pica pica</i>
BCCH	Black-capped Chickadee	<i>Parus atricapillus</i>
BCHU	Black-chinned Hummingbird	<i>Archilochus alexandri</i>
BCSP	Black-chinned Sparrow	<i>Spizella atrogularis</i>
BHGR	Black-headed Grosbeak	<i>Pheucticus melanocephalus</i>
BTGN	Black-tailed Gnatcatcher	<i>Poliopitila melanura</i>
BTBW	Black-throated Blue Warbler	<i>Dendroica caerulescens</i>
BTYW	Black-throated Gray Warbler	<i>Dendroica nigrescens</i>
BTGW	Black-throated Green Warbler	<i>Dendroica virens</i>
BTSP	Black-throated Sparrow	<i>Amphispiza bilineata</i>
BLWA	Blackpoll Warbler	<i>Dendroica striata</i>
BLGR	Blue Grosbeak	<i>Guiraca caerulea</i>
BLJA	Blue Jay	<i>Cyanocitta cristata</i>
BGGN	Blue-gray Gnatcatcher	<i>Poliopitila caerulea</i>
BWWA	Blue-winged Warbler	<i>Vermivora pinus</i>
BOBO	Bobolink	<i>Dolichonyx oryzivorus</i>
BRBL	Brewer's Blackbird	<i>Euphagus cyanocephalus</i>
BRSP	Brewer's Sparrow	<i>Spizella breweri</i>
BTHU	Broad-tailed Hummingbird	<i>Selasphorus platycercus</i>
BWHA	Broad-winged Hawk	<i>Buteo platypterus</i>
BRCO	Bronzed Cowbird	<i>Molothrus aeneus</i>
BRCR	Brown Creeper	<i>Certhia americana</i>
BRTH	Brown Thrasher	<i>Toxostoma rufum</i>
BCFL	Brown-crested Flycatcher	<i>Myiarchus tyrannulus</i>
BHCO	Brown-headed Cowbird	<i>Molothrus ater</i>
BUOW	Burrowing Owl	<i>Athene cunicularia</i>
BUSH	Bushtit	<i>Psalttriparus minimus</i>
CAWR	Cactus Wren	<i>Campylorhynchus brunneicapillus</i>
CAHU	Calliope Hummingbird	<i>Stellula calliope</i>
CAWA	Canada Warbler	<i>Wilsonia canadensis</i>
CATO	Canyon Towhee (Brown T.)	<i>Pipilo fuscus</i>
CANW	Canyon Wren	<i>Catherpes mexicanus</i>
CAFI	Cassin's Finch	<i>Carpodacus cassinii</i>
CAKI	Cassin's Kingbird	<i>Tyrannus vociferans</i>
CASP	Cassin's Sparrow	<i>Aimophila cassinii</i>
CEDW	Cedar Waxwing	<i>Bombycilla cedrorum</i>
CCLO	Chestnut-collared Longspur	<i>Calcarius ornatus</i>
CSWA	Chestnut-sided Warbler	<i>Dendroica pensylvanica</i>
CHRA	Chihuahuan Raven	<i>Corvus cryptoleucus</i>
CHSW	Chimney Swift	<i>Chaetura pelagica</i>
CHSP	Chipping Sparrow	<i>Spizella passerina</i>

Code <sup>a</sup>	Common name	Scientific name <sup>b</sup>
CCSP	Clay-colored Sparrow	<i>Spizella pallida</i>
CLSW	Cliff Swallow	<i>Hirundo pyrrhonota</i>
COGD	Common Ground Dove	<i>Columbina passerina</i>
COBO	Common Barn-owl	<i>Tyto alba</i>
COBH	Common Black Hawk	<i>Buteogallus anthracinus</i>
COGR	Common Grackle	<i>Quiscalus quiscula</i>
CONI	Common Nighthawk	<i>Chordeiles minor</i>
COPO	Common Poorwill	<i>Phalaenoptilus nuttallii</i>
CORA	Common Raven	<i>Corvus corax</i>
COYE	Common Yellowthroat	<i>Geothlypis trichas</i>
COHA	Cooper's Hawk	<i>Accipiter cooperii</i>
CRCA	Crested Caracara	<i>Polyborus plancus</i>
CRTH	Crissal Thrasher	<i>Toxostoma dorsale</i>
CBTH	Curve-billed Thrasher	<i>Toxostoma curvirostre</i>
DEJU	Dark-eyed Junco	<i>Junco hyemalis</i>
DICK	Dicksissel	<i>Spiza americana</i>
DOWO	Downy Woodpecker	<i>Picoides pubescens</i>
DUFL	Dusky Flycatcher	<i>Empidonax oberholseri</i>
EABL	Eastern Bluebird	<i>Sialia sialis</i>
EAKI	Eastern Kingbird	<i>Tyrannus tyrannus</i>
EAME	Eastern Meadowlark	<i>Sturnella magna</i>
EAPH	Eastern Phoebe	<i>Sayornis phoebe</i>
EUST	European Starling	<i>Sturnus vulgaris</i>
EVGR	Evening Grosbeak	<i>Coccothraustes vespertinus</i>
FEHA	Ferruginous Hawk	<i>Buteo regalis</i>
FOSP	Fox Sparrow	<i>Passerella iliaca</i>
GAQU	Gambel's Quail	<i>Callipepla gambelii</i>
GOEA	Golden Eagle	<i>Aquila chrysaetos</i>
GCKI	Golden-crowned Kinglet	<i>Regulus satrapa</i>
GCSP	Golden-crowned Sparrow	<i>Zonotrichia atricapilla</i>
GRWA	Grace's Warbler	<i>Dendroica graciae</i>
GRSP	Grasshopper Sparrow	<i>Ammodramus savannarum</i>
GRCA	Gray Catbird	<i>Dumetella carolinensis</i>
GRFL	Gray Flycatcher	<i>Empidonax wrightii</i>
GHOW	Great Horned Owl	<i>Bubo virginianus</i>
GTGR	Great-tailed Grackle	<i>Quiscalus mexicanus</i>
GRRO	Greater Roadrunner	<i>Geococcyx californianus</i>
GTTO	Green-tailed Towhee	<i>Pipilo chlorurus</i>
HAWO	Hairy Woodpecker	<i>Picoides villosus</i>
HAFL	Hammond's Flycatcher	<i>Empidonax hammondii</i>
HAHA	Harris' Hawk	<i>Parabuteo unicinctus</i>
HASP	Harris' Sparrow	<i>Zonotrichia querula</i>
HETA	Hepatic Tanager	<i>Piranga flava</i>
HETH	Hermit Thrush	<i>Catharus guttatus</i>
HOWA	Hooded Warbler	<i>Wilsonia citrina</i>
HOLA	Horned Lark	<i>Eremophila alpestris</i>
HOFI	House Finch	<i>Carpodacus mexicanus</i>
HOSP	House Sparrow	<i>Passer domesticus</i>
HOWR	House Wren	<i>Troglodytes aedon</i>
INDO	Inca Dove	<i>Columbina inca</i>
INBU	Indigo Bunting	<i>Passerina cyanea</i>
KEWA	Kentucky Warbler	<i>Oporornis formosus</i>
LBWO	Ladder-backed Woodpecker	<i>Picoides scalaris</i>
LALO	Lapland Longspur	<i>Calcarius lapponicus</i>
LARB	Lark Bunting	<i>Calamospiza melanocorys</i>
LASP	Lark Sparrow	<i>Chondestes grammacus</i>
LAGO	Lawrence's Goldfinch	<i>Carduelis lawrencei</i>
LAZB	Lazuli Bunting	<i>Passerina amoena</i>
LEFL	Least Flycatcher	<i>Empidonax minimus</i>
LEGO	Lesser Goldfinch	<i>Carduelis psaltria</i>
LENI	Lesser Nighthawk	<i>Chordeiles acutipennis</i>
LEWO	Lewis' Woodpecker	<i>Melanerpes lewis</i>
LISP	Lincoln's Sparrow	<i>Melospiza lincolnii</i>
LOSH	Loggerhead Shrike	<i>Lanius ludovicianus</i>

Code <sup>a</sup>	Common name	Scientific name <sup>b</sup>
LEOW	Long-eared Owl	<i>Asio otus</i>
LUWA	Lucy's Warbler	<i>Vermivora luciae</i>
MGWA	MacGillivray's Warbler	<i>Oporornis tolmiei</i>
MAWA	Magnolia Warbler	<i>Dendroica magnolia</i>
MAWR	Marsh Wren	<i>Cistothorus palustris</i>
MCLO	McCown's Longspur	<i>Calcarius mccownii</i>
MERL	Merlin	<i>Falco columbarius</i>
MIKI	Mississippi Kite	<i>Ictinia mississippiensis</i>
MOQU	Montezuma Quail	<i>Cyrtonyx montezumae</i>
MOBL	Mountain Bluebird	<i>Sialia currucoides</i>
MOCH	Mountain Chickadee	<i>Parus gambelli</i>
MODO	Mourning Dove	<i>Zenaida macroura</i>
MOWA	Mourning Warbler	<i>Oporornis philadelphia</i>
NRWS	N. Rough-winged Swallow	<i>Stelgidopteryx serripennis</i>
NAWA	Nashville Warbler	<i>Vermivora ruficapilla</i>
NOCA	Northern Cardinal	<i>Cardinalis cardinalis</i>
NOFL	Northern Flicker	<i>Colaptes auratus</i>
NOGO	Northern Goshawk	<i>Accipiter gentilis</i>
NOHA	Northern Harrier	<i>Circus cyaneus</i>
NOMO	Northern Mockingbird	<i>Mimus polyglottos</i>
NOOR	Northern Oriole	<i>Icterus galbula</i>
NOPA	Northern Parula	<i>Parula americana</i>
NSWO	Northern Saw-whet Owl	<i>Aegolius acadicus</i>
NSHR	Northern Shrike	<i>Lanius excubitor</i>
NOWA	Northern Waterthrush	<i>Seiurus noveboracensis</i>
OSFL	Olive-sided Flycatcher	<i>Contopus borealis</i>
OCWA	Orange-crowned Warbler	<i>Vermivora celata</i>
OROR	Orchard Oriole	<i>Icterus spurius</i>
OSPR	Osprey	<i>Pandion haliaetus</i>
OVEN	Ovenbird	<i>Seiurus aurocapillus</i>
PABU	Painted Bunting	<i>Passerina ciris</i>
PARE	Painted Redstart	<i>Myioborus pictus</i>
PAWA	Palm Warbler	<i>Dendroica palmarum</i>
PEFA	Peregrine Falcon	<i>Falco peregrinus</i>
PHAI	Phainopepla	<i>Phainopepla nitens</i>
PISI	Pine Siskin	<i>Caduelis pinus</i>
PIJA	Pinyon Jay	<i>Gymnorhinus cyanocephalus</i>
PLTI	Plain Titmouse	<i>Parus inornatus</i>
PRFA	Prairie Falcon	<i>Falco mexicanus</i>
PRWA	Prairie Warbler	<i>Dendroica discolor</i>
PRWA	Prothonotary Warbler	<i>Protonotaria citrea</i>
PUMA	Purple Martin	<i>Progne subis</i>
PYNU	Pygmy Nuthatch	<i>Sitta pygmaea</i>
PYRR	Pyrrhuloxia	<i>Cardinalis sinuatus</i>
RECR	Red Crossbill	<i>Loxia curvirostra</i>
RBNU	Red-breasted Nuthatch	<i>Sitta canadensis</i>
REVI	Red-eyed Vireo	<i>Vireo olivaceus</i>
RHWO	Red-headed Woodpecker	<i>Melanerpes erythrocephalus</i>
RNSA	Red-naped Sapsucker	<i>Sphyrapicus varius</i>
RTHA	Red-tailed Hawk	<i>Buteo jamaicensis</i>
RWBL	Red-winged Blackbird	<i>Agelaius phoeniceus</i>
RNPH	Ring-necked Pheasant	<i>Phasianus colchicus</i>
RODO	Rock Dove	<i>Columba livia</i>
ROWR	Rock Wren	<i>Salpinctes obsoletus</i>
RBGR	Rose-Breasted Grosbeak	<i>Pheucticus ludovicianus</i>
RLHA	Rough-legged Hawk	<i>Buteo lagopus</i>
RCKI	Ruby-crowned Kinglet	<i>Regulus calendula</i>
RUHU	Rufous Hummingbird	<i>Selasphorus rufus</i>
RCSF	Rufous-crowned Sparrow	<i>Aimophila ruficeps</i>
RSTO	Rufous-sided Towhee	<i>Pipilo erythrophthalmus</i>
RUBL	Rusty Blackbird	<i>Euphagus carolinus</i>
SAGS	Sage Sparrow	<i>Amphispiza belli</i>
SATH	Sage Thrasher	<i>Oreoscoptes montanus</i>
SAVS	Savannah Sparrow	<i>Passerculus sandwichensis</i>

Code <sup>a</sup>	Common name	Scientific name <sup>b</sup>
SAPH	Say's Phoebe	<i>Sayornis saya</i>
SCQU	Scaled Quail	<i>Callipepla squamata</i>
SCTA	Scarlet Tanager	<i>Piranga olivacea</i>
STFL	Scissor-tailed Flycatcher	<i>Tyrannus forficatus</i>
SCOR	Scott's Oriole	<i>Icterus parisorum</i>
SCJA	Scrub Jay	<i>Aphelocoma coerulescens</i>
SEWR	Sedge Wren	<i>Cistothorus platensis</i>
SSHA	Sharp-shinned Hawk	<i>Accipiter striatus</i>
STSP	Sharp-tailed Sparrow	<i>Ammodramus caudacutus</i>
SEOW	Short-eared Owl	<i>Asio flammeus</i>
SOVI	Solitary Vireo	<i>Vireo solitarius</i>
SOSP	Song Sparrow	<i>Melospiza melodia</i>
STJA	Steller's Jay	<i>Cyanocitta stelleri</i>
SUTA	Summer Tanager	<i>Piranga rubra</i>
SWHA	Swainson's Hawk	<i>Buteo swainsoni</i>
SWTH	Swainson's Thrush	<i>Catharus ustulatus</i>
SWSP	Swamp Sparrow	<i>Melospiza georgiana</i>
TEWA	Tennessee Warbler	<i>Vermivora peregrina</i>
TOSO	Townsend's Solitaire	<i>Myadestes townsendi</i>
TOWA	Townsend's Warbler	<i>Dendroica townsendi</i>
TRSW	Tree Swallow	<i>Tachycineta bicolor</i>
TUVU	Turkey Vulture	<i>Cathartes aura</i>
VEER	Veery	<i>Catharus fuscescens</i>
VERD	Verdin	<i>Auriparus flaviceps</i>
VEFL	Vermillion Flycatcher	<i>Pyrocephalus rubinus</i>
VESP	Vesper Sparrow	<i>Pooecetes gramineus</i>
VGSW	Violet-green Swallow	<i>Tachycineta thalassina</i>
VIWA	Virginia Warbler	<i>Vermivora virginiae</i>
WAVI	Warbling Vireo	<i>Vireo gilvus</i>
WAPI	Water Pipit	<i>Anthus spinoletta</i>
WEBL	Western Bluebird	<i>Sialia mexicana</i>
WEFL	Western Flycatcher	<i>Empidonax difficilis</i>
WEKI	Western Kingbird	<i>Tyrannus verticalis</i>
WEME	Western Meadowlark	<i>Sturnella neglecta</i>
WESO	Western Screech-owl	<i>Otus kennecotti</i>
WETA	Western Tanager	<i>Piranga ludoviciana</i>
WEWP	Western Wood-Pewee	<i>Contopus sordidulus</i>
WBNU	White-breasted Nuthatch	<i>Sitta carolinensis</i>
WCSP	White-crowned Sparrow	<i>Zonotrichia leucophrys</i>
WTSP	White-throated Sparrow	<i>Zonotrichia albicollis</i>
WTSW	White-throated Swift	<i>Aeronautes saxatalis</i>
WWDO	White-winged Dove	<i>Zenaida asiatica</i>
WITU	Wild Turkey	<i>Meleagris gallopavo</i>
WISA	Williamson's Sapsucker	<i>Sphyrapicus thyroideus</i>
WIFL	Willow Flycatcher	<i>Empidonax traillii</i>
WIWA	Wilson's Warbler	<i>Wilsonia pusilla</i>
WIWR	Winter Wren	<i>Troglodytes troglodytes</i>
YWAR	Yellow Warbler	<i>Dendroica petechia</i>
YBSA	Yellow-bellied Sapsucker	<i>Sphyrapicus varius</i>
YBCU	Yellow-billed Cuckoo	<i>Coccyzus americanus</i>
YBCH	Yellow-breasted Chat	<i>Icteria virens</i>
YHBL	Yellow-headed Blackbird	<i>Xanthocephalus xanthocephalus</i>
YRWA	Yellow-rumped Warbler	<i>Dendroica coronata</i>
YTVI	Yellow-throated Vireo	<i>Vireo flavifrons</i>
ZTHA	Zone-Tailed Hawk	<i>Buteo albonotatus</i>

<sup>a</sup>Species codes are from Bird Banding Laboratory, National Biological Survey.

<sup>b</sup>Scientific names are based on the A.O.U. Check-list of North American Birds (1983).