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Literature Review on Water Needs of the Southwestern Willow Flycatcher

Prepared for:

Bureau of Reclamation

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Contents

TABLES

FIGURES

APPENDICES

Executive Summary

Since the Southwestern Willow Flycatcher (*Empidonax traillii extimus*; hereafter "SWFL") was listed as federally endangered in 1995, its distribution, habitat use, and nest success have been studied extensively. General habitat characteristics have been identified, including dense vegetation and the proximity of breeding locations to surface water or soil moisture (Sogge and Marshall 2000, USFWS 2002). Water availability affects food availability, the density and vigor of riparian vegetation, and microclimate within the habitat that SWFLs use for nesting (USFWS 2005), and may affect reproductive success including predation and parasitism rates.

Bureau of Reclamation (Reclamation), one of the main water managers in the Southwest, would like to improve its understanding of the water-related requirements for SWFLs to develop habitat restoration projects and manage limited water resources. In 2003, Reclamation, along with Army Corps of Engineers, State of New Mexico, and the Middle Rio Grande Conservancy District, consulted with the U.S. Fish and Wildlife Service (USFWS) on water operations of the Middle Rio Grande in New Mexico (Reclamation 2003). According to the Biological Opinion (USFWS 2003), Reclamation must maintain moist soils throughout the breeding season in the delta of Elephant Butte Reservoir, an area with a large population of breeding SWFLs, and conduct hydrological monitoring.

With new information available related to hydrology, Reclamation's goal was to conduct a comprehensive literature review focusing on water resources needed for SWFL territory establishment (or habitat selection) and nest success. ERO Resources Corporation (ERO), under contract with Reclamation, screened 92 reports for direct and indirect relationships between hydrology and SWFL habitat use or demographics. Few reports were peer reviewed and methods varied greatly, making comparisons difficult. Of 78 independent studies, 27 contained information on direct relationships between hydrology and SWFLs. Only 10 reports related SWFL demographics to hydrology. Three studies examined effects of seasonal water availability on nest success. Due to the paucity of information, reports also were screened for descriptions on seasonal water availability.

Due to climate, hydrology, geomorphology, and water management, water availability varies temporally and spatially among SWFL sites. Hydrology varies among SWFL sites, which include riverine systems, reservoirs, cienegas, swamps, marshes, and agricultural ditches. Some SWFL sites are affected by monsoon weather, while other sites are affected by water management, including water diversions and groundwater pumping. Differences in climate and hydrology may in turn affect vegetation and insect communities that SWFLs depend on for breeding. Despite these site differences, SWFLs are found near water, often less than 50 meters from surface water. It is common for surface water or saturated soils to be present at the beginning of the breeding season, although areas may dry out during the breeding season. In dry years, SWFLs may occupy areas with no surface water or saturated soils, as long as suitable vegetation characteristics and structure are present.

SWFLs appear to have adapted to some variation in annual water availability. Historically, southwestern riparian areas were dynamic; habitat was removed after catastrophic events such as floods, fire, and drought, and new habitat became established after flooding. Year after year and from site to site, SWFLs select areas near surface water or saturated soils at multiple spatial scales. Twelve studies found a positive relationship between proximity to water and SWFL habitat selection: two on site selection, three on patch selection, two on territory selection, and five on nest site selection. Five studies did not find a relationship to proximity to water: one on patch selection, and four on nest site selection. Because more studies found a positive relationship between proximity to water and SWFLs at spatial scales larger than nest sites, other factors besides the nest site itself are likely affected by hydrology and affect SWFL fitness (e.g.,

food availability, foraging efficiency, microclimate, and possibly predator access). SWFLs also select other variables related to water availability, including floodplain extent and percent riparian forest. Selection for areas with available water is consistent with breeding habitats and wintering habitats of other Willow Flycatcher subspecies. Also consistent with Willow Flycatcher winter ecology is that many areas with breeding SWFLs may dry out through the season.

Winter rainfall and streamflow were the best explanatory variables for annual variation in SWFL nest success, but nest height and predation rates also affected nest success. The highest reproductive rates occurred at intermediate levels of winter precipitation. Both drought years and years with high reservoir levels resulting in inundation of habitat had negative effects on SWFL reproductive success. To date, only three studies have examined effects of seasonal water availability on reproductive success. Results among studies were inconclusive, because some found a positive relationship, whereas other studies found no or a negative relationship. One study found that reproductive success was positively related to streamflow early in the breeding season, but later in the season was negatively related to streamflow. The second study did not find a difference in nest success or productivity between nests partially or completely inundated. The third study found that when comparing successful nests alone, those that were over water or saturated soils all season produced more young than nests that were over dry soil all season.

SWFLs select areas with available water, probably because of its effect on reproductive success, although how water availability affects SWFL fitness is unknown at this time. Too much or too little water has negative effects on habitat selection due to changes in vegetation density and structure, and on reproductive success due to food availability, microclimate, vegetative cover, and predator access. There may be an optimum range of water availability for SWFLs to reproduce successfully. Above this range, inundation or flooding results in removal or degradation of habitat; below this range, drought or low water tables may result in desiccation, tree mortality, and salinization. Within this optimum range (which may differ among sites according to climate, hydrology, and geomorphology), territories may differ in quality. Water availability may be a component of territory quality; but only one study has examined territory quality, focusing on vegetative characteristics and food availability. It is also possible that territories with water availability similar to natural flow regimes of southwestern rivers (i.e., surface water dries out in the season) may be of higher quality and result in higher fitness. To date, there is insufficient information to answer questions on the extent and duration of water availability and how water benefits SWFL reproductive success during the breeding season.

ERO suggests standardizing methods to make comparisons among future studies. We also stress the need for studies with methods and statistical analyses with the rigor of peer-reviewed studies. Inferences from these types of studies will be invaluable and help with future management decisions. ERO also suggests that future studies focus on the scale of territories to measure resources that may affect SWFL fitness, including nest sites, as well as the amount of water availability and the duration of water because of their effect on nest success and food availability.

Literature Review on Water Needs of the Southwestern Willow Flycatcher

Introduction

More than 20 million people in the Southwest depend on water from regional rivers (USFWS 2002). With increased demands, water managers are challenged to meet the needs of all users including irrigation, urban, and downstream water rights, as well as maintaining habitat for federally listed species such as the Southwestern Willow Flycatcher (*Empidonax traillii extimus*, hereafter "SWFL") and the Rio Grande Silvery Minnow (*Hybognathus amarus*). Water management on the Middle Rio Grande (MRG) in New Mexico is one example of the complex water issues in the Southwest. Besides downstream requirements for Texas and Mexico, the Bureau of Reclamation (Reclamation) is required to maintain surface water and moist soils in areas where many SWFLs breed (USFWS 2003). Information is generally lacking on the explicit water requirements for SWFL habitat selection and reproductive success. Reclamation contracted with ERO Resources Corporation (ERO) to conduct a comprehensive literature review to compile, critically review, summarize, and expand upon this limited knowledge base.

Project Goals and Objectives

Reclamation would like to improve its understanding of water-related requirements for SWFLs, and to determine if water is required to sustain suitable nesting vegetation, insect populations, or other SWFL life history needs. Reclamation's goal is to identify explicit water requirements for SWFL nest success so that impacts on SWFL populations associated with water management can be minimized. Objectives are to assess relationships between the timing, duration, and proximity of water availability and SWFL habitat use, density, and reproductive rates (i.e., nest success, parasitism and predation, and productivity).

Report Structure

To address Reclamation's objectives, the report is organized into subsections on variation in water availability among SWFL sites, and the relationship between hydrology and SWFL habitat selection and demographics. The Introduction section provides background on SWFL status and ecology, southwestern riparian areas, water management, and project history. The Methods section describes how studies were screened and evaluated. The Results section identifies problems with the reviewed studies and contains syntheses on direct relationships between water and SWFLs (grouped by subsections listed above), as well as indirect relationships (i.e., riparian vegetation and food availability). Direct relationships between water and other Willow Flycatcher subspecies (hereafter "WIFL") are also included in the synthesis. A summary follows on the known direct and indirect relationships between water and SWFLs and WIFLs. The Discussion section compares the results with other studies and explores relationships between water availability and SWFL fitness. In the Conclusions section, ERO makes determinations on the importance of water availability to SWFL habitat selection and reproductive success, taking into consideration gaps in knowledge, and makes suggestions for future research to better address Reclamation's questions.

Southwestern Willow Flycatcher

Status and Distribution

Once a common breeder in southwestern riparian areas (Sedgwick 2000), the SWFL was listed as federally endangered in 1995 (USFWS 1995). It breeds in dense vegetation near surface water or saturated soils and is currently found in Arizona, New Mexico, southern California, southern Nevada, southern Utah, and southwestern Colorado (Sogge 2000, Sogge and Marshall 2000). Habitat loss, degradation, and fragmentation are the main reasons for its decline (Marshall and Stoleson 2000, USFWS 2002). In some areas, remnant riparian forests have been lost, altered, or degraded by changes in flow regimes, groundwater diversions, grazing, and invasion of nonnative plants. The SWFL also has been affected by brood parasitism by Brown-headed Cowbirds (*Molothrus ater*) and nest predation (Marshall and Stoleson 2000).

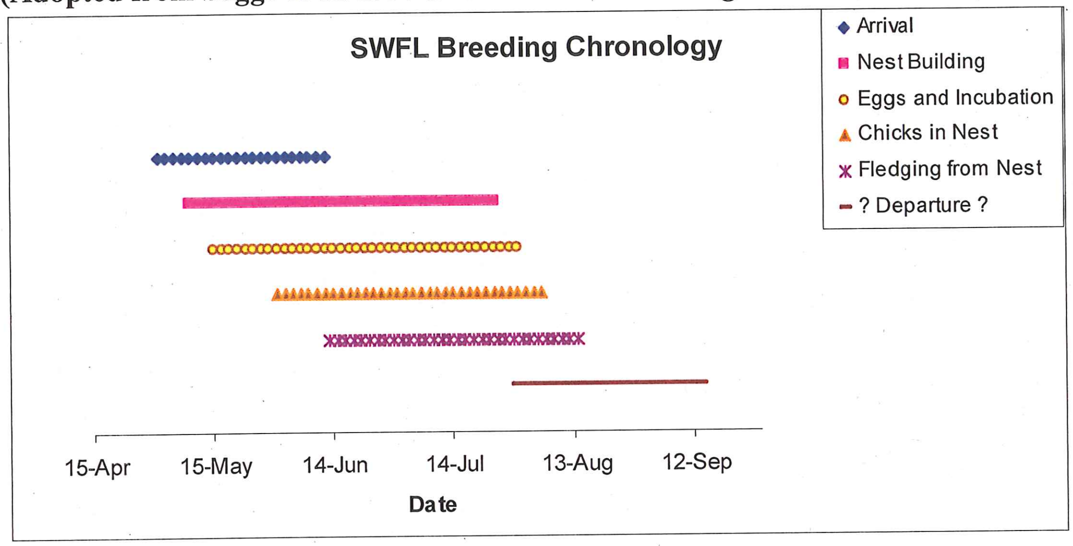
In 2008, the SWFL is still listed as endangered throughout its entire range. A total of 831 territories at 126 sites were detected during 2006 surveys (Durst et al. 2007). When known territories from earlier surveys at other sites are included, the total number of territories may be as high as 1,262. Arizona, California, and New Mexico combined, account for 89% of all SWFL territories (Sogge et al. 2003, Durst et al. 2007), with 35% in New Mexico in 2006. The largest populations of SWFL occur along the Gila River in Arizona and New Mexico, and along the Rio Grande in Colorado and New Mexico, representing 26% and 21%, respectively, of all territories across the range (Durst et al. 2007).

In recent years, the SWFL population along the MRG has grown to one of the largest populations within the Rio Grande Recovery Unit and across the range. Overall, the Rio Grande population grew from 78 territories between 1993 and 2001 (Sogge et al. 2003) to 226 territories in 2006 (Durst et al. 2007). At the delta of Elephant Butte Reservoir alone, the number of territories increased from 13 in 1996 to 197 in 2007 (Moore and Ahlers 2008). Since reservoir levels dropped in the mid- to late-1990s, young native riparian forest has developed in this area (Moore 2005). Similar population growth has been observed in areas with the recruitment and establishment of riparian forests at Roosevelt Lake, Arizona (Paxton et al. 2007) and in the Cliff-Gila Valley, New Mexico (Stoleson and Finch 2000b, Brodhead et al. 2002).

Life History

The SWFL is a neotropical migrant that overwinters in Mexico, Central America, and South America. The first birds arrive in breeding areas between early May and early June, and the breeding season lasts through late August (Figure 1; USFWS 2002). Older males arrive first and establish territories and younger males often arrive with females 1 to 2 weeks later. Females build open-cup nests, typically 2 to 7 meters (m) above the ground (range 0.5 to 18 m; USFWS 2002). Clutches are initiated as early as mid-May, but as late as the first week of August (Sogge 2000, USFWS 2002, Ellis et al. 2008). After an average 2.6 days for egg laying and 12 days for incubation (Rourke et al. 1999), eggs may hatch as early as late May (Ellis et al. 2008). Young fledge after 12 to 14 days and are independent within 14 to 25 days post-fledging (Rourke et al. 1999, Sedgwick 2000). SWFLs are typically single-brooded, but will readily renest after nest failure (Stoleson et al. 2000), and may double brood in some instances (Ellis et al. 2008).

Figure 1. SWFL breeding chronology (arrival, nest building, egg laying, incubation, nestlings, fledglings, departure). Dates for each stage may vary by site and year. (Adopted from Sogge et al. 1997 and modified according to Ellis et al. 2008).



SWFLs and other Willow Flycatcher subspecies exhibit high philopatry to their breeding areas (Sedgwick 2000). The majority of breeding SWFLs return to the same drainage (98% of adults, 99% of juveniles), but some may move to a different patch (i.e., contiguous riparian vegetation separated by non-riparian habitat such as open ground, scrub, grass, or river) (Paxton et al. 2007). Dispersal to another patch is common, with adults dispersing on average 9.5 kilometers (km), and juveniles 20.5 km. Some adults return to the same patch (32%) and some return to the same territory, depending on reproductive success from the previous year (Paxton et al. 2007).

SWFLs are insectivores and feed on a variety of terrestrial insects and terrestrial forms of aquatic insects (Fitzpatrick 1980, Drost et al. 2003). The most common prey items are: true bugs (Hemiptera); flies (Diptera); beetles (Coleoptera); bees, wasps, and ants (Hymenoptera); and leafhoppers (Homoptera, Cicadellidae) (Drost et al. 2003, Durst et al. 2008). Butterflies and moths (Lepidoptera), termites (Isoptera), arachnids, isopods, and dragon- and damselflies (Odonata) also have been reported (Prescott and Middleton 1988, McCabe 1991, Drost et al. 2001, Durst et al. 2008).

Suitable Habitat

"Suitable habitat" for SWFLs contains components necessary for breeding. The Recovery Plan defines suitable habitat as dense, mesic riparian shrub or tree communities > 0.1 ha in size and within a floodplain that has at least 10 m of riparian vegetation perpendicular to the channel (USFWS 2002). Subsequent to publication of the Recovery Plan became available, physical and biological features essential to SWFL conservation ("primary constituent elements," USFWS 2005) have been defined as dense vegetation 2 to 30 m tall (average 4 to 7 m), dense understories 0 to 4 m above the ground, and interspersed patches with small openings (e.g., open water, marsh, seeps, cienegas) (Sogge and Marshall 2000).

Habitat characteristics such as composition of dominant plant species, vertical structure, vegetation height, and size and shape of a habitat patch vary widely among breeding sites (USFWS 2002). Dominant tree species at breeding sites include Goodding's willow (*Salix gooddingii*), coyote or sandbar willow (*Salix exigua*), boxelder (*Acer negundo*), tamarisk or saltcedar (*Tamarix ramosissima*), and Russian olive (*Eleagnus angustifolia*) (USWFS 2002). The majority of breeding sites are dominated by native trees and shrubs, i.e., 43% predominantly native, 28% mixed native (i.e., 50 to 90% native), 22% mixed exotic (i.e., 50 to 90% exotic), and 6% exotic (Durst et al. 2007). Dominant tree species at nests are willow (55%), saltcedar (27%), and boxelder (12%).

In recent years, there is increasing evidence that SWFLs prefer young riparian forest. SWFLs have colonized young forests at Roosevelt Lake in Arizona (Paxton et al. 2007), in the Cliff-Gila Valley in New Mexico (Brodhead et al. 2002), and at Elephant Butte Reservoir in New Mexico (Moore and Ahlers 2008). Native riparian forest more than 3 years old, but less than 10 to 15 years old may be optimum for breeding SWFLs (Paxton et al. 2007); the optimum age of a tamarisk-dominated forest may be less than 21 years old (Paradzick 2005). Mature forests may be important refugia (Paxton et al. 2007, Ellis et al. 2008), particularly in the event that water operations are unfavorable for SWFLs or due to environmental stochasticities. Also, mature forests with the correct structure may provide suitable SWFL habitat, such as in the Cliff-Gila Valley (Stoleson and Finch

1999) and on the South Fork Kern River in California (Sogge and Marshall 2000, Copeland 2004).

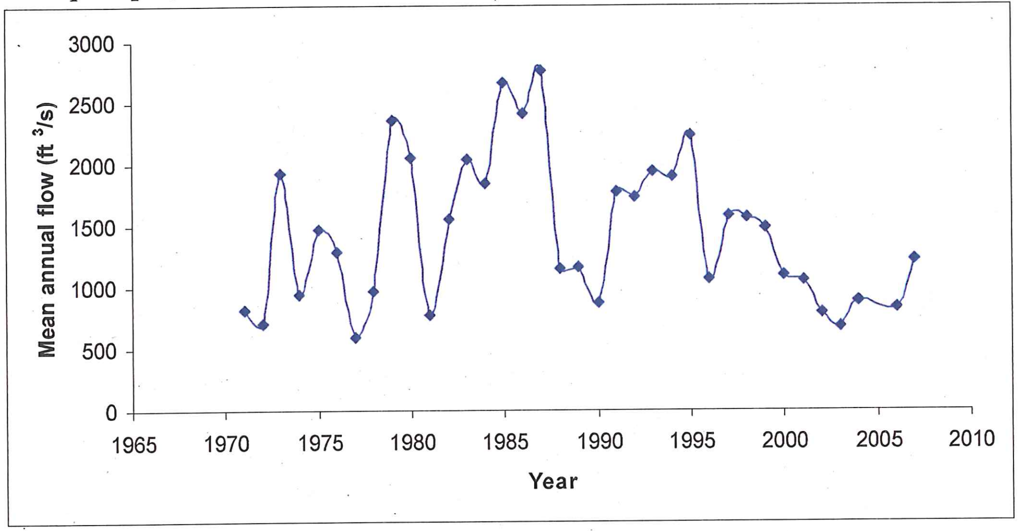
Presence of Water

In the arid Southwest, hydrological conditions can vary dramatically, such as on the MRG (Figure 2). In some areas where SWFLs occur, water or saturated soil may only be present early in the breeding season, particularly during dry years (USFWS 2002, 2005). In other areas, vegetation may be immersed in water during wet years, but during dry years, SWFLs may be hundreds of meters from water. This is particularly true of reservoir sites such as Lake Isabella in California, Roosevelt Lake in Arizona, and Elephant Butte Reservoir in New Mexico (USFWS 2005). Similarly, within riverine systems with natural flood regimes, high flow events can cause channel migration. If tree roots are connected to the groundwater table, habitat can persist, even though the site may be farther from surface water. SWFLs may continue to use the habitat if the structure and other important habitat features (e.g., tree age class, density, and canopy cover) continue to be suitable for nesting (C. Paradzick, pers. obs.). In general, nests are close to water or saturated soils, particularly early in the breeding season (USFWS 2002). The riparian vegetation associated with SWFL breeding sites requires a substantial amount of water (USFWS 2005). Slow-moving or backwater may be important in the production of the arthropod prey base for SWFLs (USFWS 2005).

Southwestern Riparian Areas

Riparian systems are affected by the magnitude, frequency, duration, timing, and rate of change of hydrologic conditions (Poff et al. 1997). Riparian habitat is distributed along a shifting mosaic of patches, which changes over time and in space (Stanford et al. 2005). Flooding, with its cut and fill and channel changes, is the primary process behind habitat formation. High flows from large infrequent floods can remove vegetation, but can also carry woody debris and deposit sediment and nutrients downstream, which are necessary for vegetation establishment. Low flows, little inundation, or shallow groundwater tables are important for growth of many riparian plant species, but few plant species can tolerate long periods of inundation.

Figure 2. Mean annual flow of a large river in the Southwest: the Middle Rio Grande, New Mexico, at Otowi Bridge (USGS Gage Station 8313000), upstream of Albuquerque, 1971–2007 (USGS 2008).



In the Southwest, little precipitation infiltrates the soil surface and percolates to the groundwater table (Ffiolliott et al. 2004). Instead, much of the moisture is lost through evaporation and transpiration as water runs off along the surface toward stream channels. Due to this and the climate, few southwestern streams are perennial. Late winter or early spring flooding, and water receding across the floodplain through the summer, are characteristic of natural flow regimes along southwestern rivers (Mahoney and Rood 1998). Smaller summer floods may temporarily increase water levels. In some instances, groundwater contributes to streamflow via the hyporheic zone, a dynamic exchange of water, nutrients, and oxygen between the stream channel, aquifer, and groundwater (DeBano et al. 2004).

SWFLs breed in a variety of riparian systems, but most territories are below 1,600 m in elevation (Durst et al. 2007). Many breeding sites are along large perennial rivers with slow moving water and broad alluvial floodplains (Graf et al. 2002, DeBano and Schmidt 2004). Typically, SWFLs breed in riparian areas along the low flow channels, but they will use areas in the high flow zone as long as the water table is high enough (Graf et al. 2002). Large perennial rivers with breeding SWFLs include the Santa Ynez in California, San Pedro and Gila rivers in Arizona, and Gila River and Rio Grande in New Mexico. SWFLs also breed in reservoir deltas such as Lake Isabella, California;

Roosevelt Lake, Arizona; and Elephant Butte Reservoir, New Mexico; cienegas or marshes (e.g., Cooks Lake and Bingham Cienegas in Arizona); and agricultural ditches. Plant communities in these different types of riparian systems are tied to the hydrology (i.e., frequency, magnitude, and timing) of flooding.

Woody riparian vegetation in SWFL habitat depends on low flows and surface water or shallow groundwater tables for growth, and occasional floods for establishment (Stromberg et al. 2007a). Fremont cottonwoods (*Populus fremontii*) and Goodding's willow, two common tree species in SWFL habitat, occur in floodplains of low gradient streams (Stromberg 1993). These species and other willows (*Salix* spp.) germinate and establish after spring flood events (Stromberg 1993). They require moist soils for successful establishment and survival (i.e., groundwater tables less than 1 m) (Stromberg et al. 1996). Willows typically occur closer to low flow channels than cottonwoods. Willows germinate later, often after peak flows, and have a higher tolerance for saturation than cottonwoods (Stromberg 1993). In some areas, cottonwoods depend on groundwater (Amlin and Rood 2003) and older cottonwoods (more than 50 years old) may survive in areas with groundwater tables up to 3 m deep (Stromberg et al. 1996). Cottonwoods and willows can survive temporary inundation, but generally cannot survive long-term inundation through the growing season (Gill 1970). Tamarisk is less tolerant of inundation than cottonwoods or willows and occurs in areas that receive less flooding and have deeper groundwater tables (Stromberg et al. 2007b).

Human Alteration of Southwestern Riparian Areas

Humans have altered southwestern riparian areas for at least 12,000 years (Periman and Kelly 2000). By the 20th century, dramatic changes to these areas were evident, including the loss of riparian forests (Periman and Kelly 2000). Many rivers have been altered by dams and other diversion structures, and groundwater pumping. Today, southwestern riparian areas are considered endangered ecosystems (Christensen et al. 1996), but some research has found greater amounts of gallery riparian forest in some southwestern rivers today compared to historical records (Webb and Leake 2006). Loss of riparian vegetation occurs where groundwater use lowers the water table below the root depth of riparian plant species, where base flows are diverted, or both (Webb and Leake 2006).

Dams can store high volumes of water but also have far-reaching impacts on the environment (Nilsson and Berggren 2000). One of the main effects is spatial and temporal reduction in disturbance regimes (i.e., flooding) and simplification of channel and floodplain environments (Stromberg et al. 2004). Upstream of dams, large areas are inundated, resulting in permanent habitat loss of riparian vegetation (Nilsson and Berggren 2000). Fluctuating water levels of reservoirs may result in new shorelines and riparian areas. Upstream of reservoirs, areas may mimic deltas with lower flows and extensive floodplains. Downstream, flow regulation often results in a reduction in magnitude and frequency of flooding (Poff et al. 1997, Nilsson and Berggren 2000). However, the magnitude and impact on riparian forest is system-specific – dams with small storage-to-runoff ratios may have much less impact on forest vegetation than dams that capture multiple years of runoff (Stromberg et al. 2007a). Dams also trap sediments, reducing sediment and nutrient transport and may influence the composition and structure of riparian plant communities (Stromberg et al. 2007a). Farther downstream, flows may be diminished due to water diversions and depletions. Lower flows, in turn, can increase siltation of river channels and result in channel stabilization and narrowing (Poff et al. 1997), which reduces overbank flooding and causes downcutting of channels. Lower flows also may increase evaporative losses, reduce downstream flows, and reduce groundwater recharge and tables (Nilsson and Berggren 2000). Areas with low flows, separated from the floodplain, or where the groundwater table has been lowered, may experience desiccation or mortality of riparian vegetation (Stromberg et al. 1996). Changes in flood frequency and timing, lowering of groundwater tables, and salinization of soils due to reduced overbank flooding can eliminate or reduce the persistence and recruitment of native trees, and favor the exotic species such as tamarisk, which is more drought and salt tolerant than native species (Nilsson and Berggren 2000; Stromberg et al. 2007a, 2007b).

Water managers have several tools for managing riparian habitats. Low flows and peak flows are of particular importance to regeneration and maintenance of healthy riparian forests (Stromberg et al. 2007a) and SWFL habitat (Graf et al. 2002). Increasing flows via agricultural/urban runoff, effluent, irrigation or diversion canal, reservoir or dam release, and regulated flows may result in sufficient water to allow recruitment, growth, or maintenance of riparian vegetation and SWFL habitat, or fulfill other SWFL water needs (USFWS 2002). Large, infrequent floods can be mimicked with timed releases, which may result in vegetation establishment. Longer exposure of previously inundated areas may result in extensive establishment of riparian forests, which may become important SWFL habitat (Graf et al. 2002). Periodic disturbance is necessary to maintain suitable SWFL habitat over time (Paxton et al. 2007).

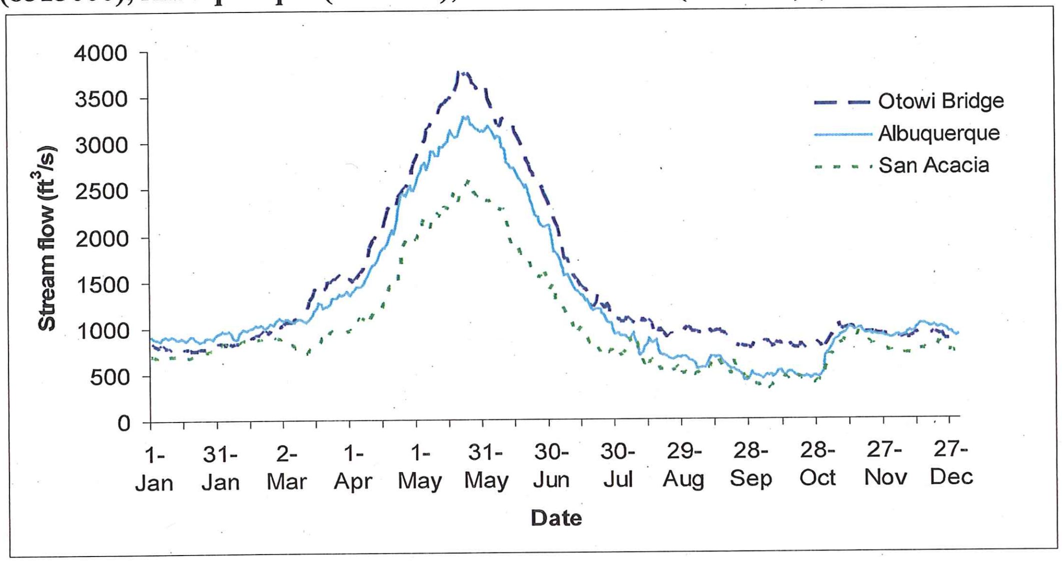
Middle Rio Grande Background

With high annual variation in streamflow, dams and canals were constructed on the MRG for flood control, diversion, and water storage (USFWS 2002), including Cochiti Dam north of Albuquerque and Elephant Butte Dam in southern New Mexico. The Low Flow Conveyance Channel (LFCC) was constructed to move water downstream into Elephant Butte Reservoir without high evaporative and seepage losses (Moore 2005).

Streamflows on the MRG typically peak mid-May to June (Figure 3) as snow melt peaks at higher elevations (Follstad Shah and Dahm 2008). The beginning of the SWFL breeding season coincides with these peak flows. As flows decrease, stored water is used for urban supply and irrigation. Depletions and diversions along with evaporative losses result in diminished flows downstream (Figure 3). Monsoon rains in the summer or fall may temporarily increase flows (Follstad Shah and Dahm 2008).

MRG water users include municipalities, irrigation districts such as the Middle Rio Grande Conservancy District, Indian Pueblos and Tribes, Texas, and Mexico under the Rio Grande Compact (Compact) (Reclamation 2003). The Compact limits depletions when storage is below normal; New Mexico may not store water from the native Rio Grande Basin in reservoirs constructed before 1929, but must release water downstream. This limits the storage capacity upstream of Elephant Butte Reservoir and primarily affects the Middle Rio Grande Conservancy District through the irrigation season. Without upstream storage, the Middle Rio Grande Conservancy District diverts water

Figure 3. Daily average streamflow on the Middle Rio Grande, New Mexico, from 1974–2007 at three USGS gage stations heading downstream: Otowi Bridge (8313000), Albuquerque (8330000), and San Acacia (8354900) (USGS 2008).



directly from the MRG. Irrigation must be curtailed when MRG flows drop to minimal levels. Groundwater usage also affects MRG flows and must be offset (Reclamation 2003).

It is challenging for Reclamation to meet the demands of all MRG water users and maintain habitat for SWFLs and Silvery Minnows. During the drought in the early 2000s, flows were diminished and miles of the MRG and SWFL habitat dried out. As a result, Reclamation was the lead federal agency that consulted with USFWS on flow reductions, changes in reservoir levels, river drying, and potential effects to listed species (Reclamation 2003). Because a substantial portion of SWFLs in the Rio Grande Recovery Unit may have been affected by water operations on the MRG, USFWS issued a Biological Opinion with a Reasonable and Prudent Alternative (RPA) that would avoid "jeopardy" of the SWFL (USFWS 2003). Water Operations Element D of the RPA states that Reclamation is to "ensure that active SWFL territories supported by pumping from the LFCC are provided with surface water or moist soils in the Rio Grande from June 15 to September 1." Furthermore, Water Operations Element G of the RPA states that Reclamation "shall pump from the LFCC as soon as needed to manage river recession," and that "pumping shall continue when it will benefit the flycatcher and its habitats."

Water is important in "maintaining and regenerating essential riparian vegetation for SWFL shelter, feeding, and breeding" (USFWS 2003). However, the extent to which the presence of water is required throughout the breeding season is not clear.

Methods

ERO reviewed literature on hydrology and SWFLs and other WIFLs, focusing on direct relationships with SWFLs. ERO screened peer-reviewed literature on SWFLs and WIFLs in the *Journal of Wildlife Management*, *Auk*, *Condor*, *Studies in Avian Biology*, Conservation Assessment of SWFL (Finch and Stoleson 2000), and the SWFL Recovery Plan (USFWS 2002). ERO consulted with SWFL experts (Appendix 1), screened reports available on the Southwestern Willow Flycatcher Reports and Publications website at http://sbsc.wr.usgs.gov/cprs/research/projects/swwf/reports.asp, and contacted SWFL researchers (Appendix 2) for other pertinent reports. Due to Reclamation's interest in the MRG ecosystem, all reports on SWFLs in New Mexico from Reclamation, Natural Heritage New Mexico, and U.S. Forest Service's Rocky Mountain Research Station were reviewed, along with the Biological Assessment (Reclamation 2003) and Biological Opinion (USFWS 2003) on water operations of the MRG.

Literature with information on relationships between hydrology and SWFL demographics and/or habitat selection was considered pertinent. For each pertinent report, ERO recorded the information source, state and study area drainage, time of year (breeding, migration, or winter), and the number of years that data were collected on demographics and hydrology. Hydrological variables were recorded, including distance to surface water or saturated soil, groundwater depth, reservoir elevation, streamflow, precipitation, floodplain width, and extent of riparian forest, along with methods. The percentage of willow or boxelder compared to the percentage of cottonwoods also was considered due to the increased water requirements of those species (Reed 1988, Stromberg et al. 1996).

Due to the paucity of peer-reviewed literature on relationships between hydrology and SWFL, ERO assessed the quality of gray literature. Criteria were similar to guidelines for reviewers of *Ecological Applications* and *Journal of Wildlife Management* (Chamberlain and Johnson 2008), reviews published in similar journals (i.e., McGarigal and Cushman 2002, Miller et al. 2003), Roberts et al.'s (2006) paper on the reliability of review articles, and Hurlbert's (1984) paper on pseudoreplication. Studies were evaluated for adequate descriptions of methods, experimental design, appropriate use of inferential statistics, pseudoreplication (i.e., lack of replication, lack of independent samples in space or time, or incorrect pooling of data) (Hurlbert 1984), and inference errors. Studies or portions of studies with unrepeatable methods, problematic statistical analyses, and unsupported conclusions were not included in this report.

Results of Focused Literature Review

A total of 92 reports on Willow Flycatchers or associated publications were screened for information on the relationship between hydrology and habitat use or demographics (Appendix 3). Reports from the same study area and with the same methods were grouped. These included annual reports from long-term projects on the MRG, Cliff-Gila Valley, lower Colorado River, Verde River, and summaries on breeding habitats. A total of 71 reports concerned SWFLs and 57 independent studies were retained for further screening. An additional 19 reports describing WIFLs and two on Brown-headed Cowbirds were retained for further screening. Twenty-eight reports were excluded from the focused review (i.e., 18 on SWFLs, 8 on WIFLs, and 2 on Brown-headed Cowbirds), because they addressed other aspects of biology and ecology, such as genetics, physiology, or polygyny (Appendix 4). Of the 48 reports with pertinent information (Appendix 5), 27 described direct relationships between hydrology and SWFLs. The other 10 reports on SWFLs and 11 reports on WIFLs were included in the results due to their relevance on habitat selection, demographics, diet, or riparian vegetation.

Problems Identified with Reviewed Studies

Problems with the reviewed studies included the lack of statistics on relationships between SWFL demographics and hydrology, a focus on comparisons of demographics between native and mixed habitats, as well as differences in the types, timing, and duration of hydrological measurements. Several studies reported demographic data on SWFLs and measured distance to water or other hydrological variables, but did not examine whether demographics were related to hydrology, or only evaluated one demographic variable. Studies examined differences in SWFL demographics, but only made comparisons by habitat type (i.e., native, mixed, or exotic) for potential differences in habitat quality. Other problems were related to hydrological measurements.

Most studies discussed relationships with distance to water, but often no other hydrological variables. Methods for measuring distance to or estimating area of surface water or saturated soils varied, as did the scale of measurements (i.e., plot size and SWFL spatial scale). Several studies used saturated soil as a hydrological variable, yet only one study described how soil saturation was determined and measured soil moisture. Three studies took extensive hydrological measurements and installed piezometers or other probes (Paradzick 2005, McLeod et al. 2007, and Moore and Ahlers 2008).

Some studies described the presence of water and noted when areas dried out. Other studies took hydrological measurements, most commonly distance to surface water or saturated soils, but did not specifically state when the measurements were taken. Only a few studies measured distance to water at the beginning of the breeding season. Differences between used and unused areas may have been more pronounced if measurements were taken early in the season. McLeod et al. 2007 noted when taking measurements only late in the breeding season that differences may be masked between used and unused areas. Few studies measured distance to water early in the season (Copeland 2004, McLeod et al. 2007, Moore and Ahlers 2008). One study measured distance to water in late June, the driest time of year (Paradzick 2005).

Some reports contained descriptions on the duration of water, but these could not be readily related to information on SWFL demographics. Two studies took measurements throughout the breeding season (McLeod et al. 2007, Moore and Ahlers 2008), but only the latter examined the relationship between the duration of water availability and individual nest success. Spatial scale may be important when addressing this question, because water availability may also affect food availability within a SWFL territory where a SWFL forages, not just immediately around a nest site. Also, with annual differences in water availability, and population size affected by other factors, it may be important to examine the relationship between the duration of water and SWFL demographics at several populations and for several years, including a dry year.

Methods varied greatly among studies, making comparisons difficult. Not all studies used inferential statistics and few studies were peer reviewed, or of similar rigor. Studies lacked replication in space and/or time, making interpretations more difficult. To answer future questions on water availability, replication and standardization of measurements (when, how, and scale) may be necessary.

Direct Relationships between Hydrology and Breeding SWFLs

From the 27 studies included in the assessment of direct effects (Table 1), three were strictly narrative, nine only contained descriptive statistics, and 15 used inferential statistics. Twenty-four studies addressed habitat use/selection, 23 studies contained hydrological data, 19 demographic data, but only 11 related SWFL demographics to hydrology. Key papers included studies on the MRG at Elephant Butte (Moore 2005; Moore and Ahlers 2006, 2008) and on the lower Colorado River in Arizona and Nevada (McLeod et al. 2007, 2008) that took extensive hydrological measurements throughout the breeding season and correlated these to SWFL habitat use and demographics. Other important studies included a 10-year synthesis of SWFL demographics at Roosevelt Lake and the San Pedro and Gila rivers in Arizona and modeling predictors for SWFL demographics (Paxton et al. 2007); and a study that related SWFL distribution along the San Pedro and Gila rivers in Arizona to hydrological variables and habitat characteristics, as well as habitat characteristics to hydrology (Paradzick 2005). Another study included SWFL demographic and habitat response to inundation of Roosevelt Lake, Arizona (Ellis et al. 2008).

Table 1. SWFL reports included in the synthesis of direct relationships between water availability and SWFL habitat use and demographics, sorted by type of statistics, with scales of measurement (hydrology, habitat) and demographic variables.

Reference	Type of statistics	Scale* of hydrological measurement	Scale* of habitat use	Scale* of habitat selection	Demographic parameter(s)**	Demographic related to water**
Sogge and Marshall 2000, Sogge et al. 1997	None		N, T			
USFWS 2002	None		N, T		NS	
USFWS 2005	None		N, T		NS	
Brodhead et al. 2002	Descriptive	P			NS, PA, PR, YG	n/a
Dockens and Ashbeck 2005, 2006	Descriptive	P	P		NS, YG	n/a
Farmer et al. 2003	Descriptive	N	N		NS	n/a
Johnson and Smith 2000; Smith and Johnson 2004, 2005, 2006	Descriptive	N	N		NS, PA, PR, YG	n/a
Johnson et al. 1999	Descriptive	N	N		NS	NS[1]
McKernan and Braden 2001a, 2001b	Descriptive	S	S		NS, PA, PR, YG, DE	n/a[1]
Paradzick and Woodward 2003	Descriptive	S	S		n/a	n/a
Smith and Johnson 2007, 2008	Descriptive	N		N	NS, PA, PR, YG	n/a[1]
Whitfield and Enos 1996	Descriptive	N	N		NS, PA, PR, YG	n/a
Allison et al. 2003	Inferential	N		N	n/a	n/a
Brodhead 2005	Inferential	P	(N, P)	P	DE	DE
Brodhead and Finch 2005	Inferential	N, P	N		NS, PA, PR	NS
Brodhead et al. 2007	Inferential	P			NS, PA	PA
Cardinal 2005	Inferential	T		T	n/a	n/a
Copeland 2004	Inferential	N, T, P		N, T	NS, PA, PR, YG	n/a
Copeland unpubl. data	Inferential	S			YG	YG
Ellis et al. 2008	Inferential	N, P	N		NS, PA, PR, YG, DE	NS, PA, PR, YG
Hatten and Paradzick 2003	Inferential	T, P		T, P	DE	DE
McLeod et al. 2007, 2008	Inferential	N, T, P	P	N, T	NS, PA, PR, YG	n/a
Moore 2005; Moore and Ahlers 2006, 2008	Inferential	N, T, P	N		NS, PA, PR, YG	NS, PA, PR, YG
Paradzick 2005	Inferential	P		P	n/a	n/a
Paxton et al. 2007	Inferential	N, P		N, P	NS, PA, PR, YG, DE	NS, YG, DE
Stoleson and Finch 2000a, 2001	Inferential	P		P	NS, PA, PR, YG, DE	NS, DE
Stoleson and Finch 1997, 1999, 2000b, 2003	Inferential	N (P)		N	NS, PA, PR, YG	n/a

* Scale of measurement: N=nest; T=territory; P=patch; S=site/floodplain. Note: Parentheses means that it was not the focus of the study, but mentioned.
** Demographic parameters: DE=density; NS=nest success; PA=parasitism; PR=predation; YG=#young; n/a=not available
[1] Partially excluded for reasons described in Methods.

Temporal and Spatial Variation in Water Availability among SWFL Sites

Climate and hydrology affects water availability at SWFL sites and results in temporal and spatial variation. Surface water and soil saturation may change throughout the breeding season, may differ among territories, patches, or sites within a breeding season, but also may differ between years. Due to the importance of water to SWFL nest selection and the variation in water availability, SWFL nest monitoring protocol (Rourke et al. 1999) includes measuring distance to surface water or saturated soil. However, often distances are measured when nesting is over and soil saturation is often determined visually only. Information on changes in distance to water or saturated soil is rarely summarized in reports and, if so, averaged for a site, not for individual nests. As a result, information is very limited on how important water availability is throughout the breeding season for SWFL reproductive success. Below are descriptions on annual and seasonal differences in water availability at SWFL sites, and a summary of a study that tracked SWFL densities and soil moisture at several sites during three breeding seasons (McLeod et al. 2008). The three studies that compared reproductive success of nests with different levels of water availability (Brodhead and Finch 2005, Ellis et al. 2008, Moore and Ahlers 2008) are discussed in detail under *Influence of Water Availability on SWFL Demographics.*

Annual differences in water availability affect SWFL demographics. Low water availability and earlier drying of soils, such as during dry years, may affect the number of breeding SWFLs (McLeod et al. 2007, 2008) and reproductive success (Johnson et al. 1999, Brodhead et al. 2002, Paxton et al. 2007, Ellis et al. 2008). Of 33 sites with breeding SWFLs along the lower Colorado River from 2003 to 2007, 80% had surface water or saturated soils (McLeod et al. 2008). "Vegetation may be immersed in standing water during a wet year, but be hundreds of meters from surface water in dry years" (USFWS 2002). This may be particularly true at reservoir sites (USFWS 2005). During wet years, SWFLs may move from inundated areas at reservoir sites to areas at higher lake elevations that are not affected by water levels (Dockens and Ashbeck 2006, Ellis et al. 2008). On the MRG, few nest attempts were made by SWFLs during the dry year of 1996 and birds left between mid-June and early July (Johnson et al. 1999). The drought year of 2002 resulted in almost complete reproductive failure and abrupt July departures of SWFLs in the Cliff-Gila Valley (Brodhead et al. 2002) and at Roosevelt Lake (Paxton et al. 2007, Ellis et al. 2008).

Often differences exist in the amount of surface water and moist soils among SWFL territories, and drying may occur at different rates throughout the season (S. Copeland, pers. obs.). Some may dry out in the breeding season as early as June (Whitfield and Enos 1996, McKernan and Braden 2001b) or later (Johnson et al. 1999, Dockens and Ashbeck 2006). Along the lower Colorado River, average soil moisture in areas occupied by SWFLs dropped from the beginning of the season to the end of June, but then increased slightly several times throughout the remainder of the breeding season (McLeod et al. 2008), presumably after monsoon rains. On the South Fork Kern River in California, which is unaffected by monsoon rains, territories always had some water at the beginning of the breeding season, but most areas dried up before young fledged (Whitfield and Enos 1996).

Differences among territories have been reported from the MRG at: the Isleta Pueblo (Smith and Johnson 2007) and at Elephant Butte Reservoir (Moore and Ahlers 2008); along the lower Colorado River (McKernan and Braden 2001b, McLeod et al. 2007); at Horseshoe Lake and on the Verde River (Dockens and Ashbeck 2006); and on the South Fork Kern River, California (Copeland 2004). On the MRG, SWFLs established territories in areas previously occupied, even though the areas were dry in 2006, but then birds moved to wetter areas (Smith and Johnson 2007). On the lower Colorado River, 33% of sites occupied by SWFLs in 2006 were dry mid-May, but 89% of the sites that were still occupied in mid-July had surface water or saturated soils (McLeod et al. 2007). The sites still occupied in mid-July included the wettest sites and still had large areas with saturated soils and some surface water, as well as high densities of SWFLs.

Influence of Water Availability on SWFL Habitat Selection

Descriptions of habitat use and studies on selection were grouped, particularly since results were similar. Whereas habitat use refers to how an animal uses resources in a habitat, habitat selection is a hierarchical process in which an animal makes selections at different spatial scales, from the geographic range of a species to the use of habitat components within its home range (Johnson 1980, Hall et al. 1997). SWFL habitat selection may occur at several spatial scales: from a site or floodplain (> 28 hectares [ha]), to a patch (2.5 – 28 ha), territory (approx. 0.1 – 2 ha), and nest site (< 0.1 ha) (Hatten and Paradzick 2003). Of the 24 studies on habitat use/selection, most were on nest sites. Due to the possible selection for other resources besides a nest site, such as food availability, a larger spatial scale such as territory or patch may be more appropriate to understand relationships between selected characteristics and fitness.

At all spatial scales, SWFLs selected areas close to water or saturated soils and other related hydrological variables (Table 2). Most sites were close to water (McKernan and Braden 2001a, 2001b; Paradzick and Woodward 2003). Of all breeding sites in Arizona over an 8-year period, only 7 of 89 sites were more than 50 m from water (range: 0 to 500 m), but these sites were at reservoirs where water may have been closer earlier in the season (Paradzick and Woodward 2003). Patches were often immediately adjacent to water or saturated soil (Stoleson and Finch 2000a, 2001; Dockens and Ashbeck 2005, 2006), and occupied patches were six times more likely to be next to water than unoccupied patches (Paradzick 2005).

Table 2. Hydrological variables and their effects on SWFL habitat use/selection.

Hydrological Variable	Spatial Scale	Effect on SWFL Habitat Use/Selection†	Habitat Use or Selection	Source
Proximity to water or saturated soils	Site	+	U U	McKernan and Braden 2001a, 2001b Paradzick and Woodward 2003
	Patch	+	U S S	Dockens and Ashbeck 2006 Paradzick 2005 Stoleson and Finch 2000a, 2001
		0	U	McLeod et al. 2007
	Territory	+	S S	Copeland 2004 McLeod et al. 2007
	Nest	+	S U U U S U	Allison et al. 2003 Ellis et al. 2008 Farmer et al. 2003 Moore and Ahlers 2008 Stoleson and Finch 1997, 1999, 2000b, 2003 Whitfield and Enos 1996
		0	U U S U	Johnson and Smith 2000; Smith and Johnson 2004, 2005, 2006‡ Johnson et al. 1999 McLeod et al. 2007 Smith and Johnson 2007, 2008‡
Soil moisture	Territory	+	S	McLeod et al. 2008

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Hydrological Variable	Spatial Scale	Effect on SWFL Habitat Use/Selection†	Habitat Use or Selection	Source
Amount of floodplain	Site	+	S S	Hatten and Paradzick 2003 Paxton et al. 2007
Proximity to river channel	Patch	0	U	Dockens and Ashbeck 2006
	Territory	+	S	Paxton et al. 2007
Percent riparian forest	Patch	+	S S	Brodhead 2005 Paradzick 2005
	Territory	+	S	Cardinal 2005
Percent willow/boxelder	Patch	+	S	Stoleson and Finch 2001
	Territory	+	S	Copeland 2004
	Nest	+	S	Stoleson and Finch 1997, 1999, 2000, 2003
Streamflow in relation to nest distance to channel	Nest	+	U	Brodhead and Finch 2005

† + = positive effect on habitat selection/use; 0 = no effect or no difference detected between used and unused areas.
‡ In some years, used areas were closer to water than unused areas; in other years, unused areas were closer than used areas.

At smaller spatial scales, SWFLs also selected areas with higher water availability. On the lower Colorado River, mean soil moisture was consistently higher in SWFL territories than in unoccupied areas (occupied mean: 776-778 millivolts (mV) vs. unoccupied mean: 577 mV; McLeod et al. 2008). On the scale of territories, used areas were less than 75 m from water or saturated soil and on average more than 20 m closer to water than unused areas (Table 3) (Sogge and Marshall 2000, Copeland 2004, McLeod et al. 2007). Within territories, nest plots were in similar proximity to water as non-nest plots (Copeland 2004, McLeod et al. 2007). Some nest sites were farther from water than areas at larger spatial scales. When comparing nest plots of larger plot sizes with non-nest plots, nest plots were significantly closer to water than non-nest plots (Allison et al. 2003, Stoleson and Finch 2003). Several studies did not find a difference in distance to water or saturated soils between nest and non-nest plots, possibly due to the timing of the measurements or the scale of measurement or plot size. In California, some nests were over water, but others were up to 700 m from the Santa Ynez River, but still within 50 m of standing water (Farmer et al. 2003). At Elephant Butte, 95% of all nests were within 100 m and 91% were within 50 m of water or saturated soil (Moore and Ahlers 2008).

Table 3. Average distance to water or saturated soils at different spatial scales in areas used by SWFLs and unused areas.

Spatial Scale	Average Distance to Water (m)		Statistical Significance†	Source
	Used	Unused		
Site	< 50	---	---	Paradzick and Woodward 2003
Patch	0	---	---	Dockens and Ashbeck 2006
	3.7	26.1	*	Stoleson and Finch 2001
Territory	8.0	29.7	*	Copeland 2004
	6.3-74.8	22.5-124.9	*	McLeod et al. 2007[1]
Nest	66.5	150.7	*	Allison et al. 2003
	16.7	14.2	NS	Copeland 2004
	7.6-70.8	5.7-104.6	NS	McLeod et al. 2007[1]
	< 50	---	---	Moore and Ahlers 2008
	24.7-50.0	41.0	---	Smith and Johnson 2007[2]
	41.2	63.0	*	Stoleson and Finch 2003
	6.9	---	---	Whitfield and Enos 1996

† --- =not available, i.e. no inferential statistics. *=statistical significance, $p < 0.05$. NS= not statistically significant.
[1] Average distances reported are from different sites. Report compared used vs. unused at each site.
[2] Average distances reported are from three years.

At the reservoirs of Horseshoe Lake (Dockens and Ashbeck 2006) and Roosevelt Lake (Paxton et al. 2007), areas occupied by SWFLs were close to the river channel. While proximity to the river channel was a predictor for territory use at Roosevelt Lake, it was not a predictor for use in riverine systems along the San Pedro and Gila rivers in Arizona (Paxton et al. 2007). This may be because at Roosevelt Lake, early successional habitat is closer to the main river channel, whereas in riverine systems, such as the San Pedro and Gila rivers, habitat patches outside of the scour zone may persist longer, or other habitat components (e.g., surface water in form of ponds or agricultural return flows) may be present away from the low flow channel. In the Cliff-Gila Valley, New Mexico, distances of nests from the river channel were positively related to average annual flows (i.e., nests were farther from the main channel in years with higher average flows) (Brodhead and Finch 2005).

Other variables SWFLs selected that were related to hydrology included sites with large floodplains (Hatten and Paradzick 2003, Paxton et al. 2007) and patches with a high percentage of riparian forest (Brodhead 2005, Paradzick 2005) (Table 2). Furthermore, radio tracking showed that SWFLs exclusively used areas within the floodplain (Cardinal 2005). SWFLs also selected areas with: a higher percentage of trees that require higher water tables than other trees: patches and nest sites with boxelder vs. cottonwood in the

Cliff-Gila Valley (Stoleson and Finch 2001, 2003); territories with willow vs. cottonwood on the South Fork Kern River in California (Copeland 2004); and patches dominated by willow vs. tamarisk on the San Pedro River (Paradzick 2005).

Influence of Water Availability on SWFL Demographics

Some studies have examined the relationship of annual differences in water availability on SWFL density and reproductive rates (nest success, productivity, predation, parasitism), but few studies have examined effects of seasonal differences, and no studies have examined the potential influence on survival.

Density

Low and high water years affect SWFL densities. At Bill Williams and on the Virgin River, annual differences in water availability influenced the number of nesting SWFLs at (McLeod et al. 2007). Inundation affected SWFL demographics when habitat availability was reduced (Ellis et al. 2008), but had no effect on demographics when habitat was still available (Dockens and Ashbeck 2006).

Most studies on hydrology and SWFL densities were from models on SWFL distribution (Hatten and Paradzick 2003, Brodhead 2005, Paxton et al. 2007). These studies were based on nest data and remote sensing data (satellite imagery or aerial photography), but not distance to water. Predictions of SWFL densities were based on a high probability of use and not necessarily habitat quality (Van Horne 1983). The amount of floodplain within a site or patch was an important predictor for SWFL use and density (Hatten and Paradzick 2003, Paxton et al. 2007). A high percentage of riparian forest within a patch was also a predictor for SWFL density and patch occupancy (Brodhead 2005, Paradzick 2005). On the Gila River in Arizona, mean cumulative streamflow from the beginning of the monsoon season in July until the beginning of the breeding season in April explained 58% of the annual variation in SWFL densities between 1998 and 2007 (Ellis et al. 2008). For every 100 cubic feet per second (cfs) increase in flow, SWFL density increased by 1.3 territories. However, high flows can also scour and remove vegetation, making areas unsuitable for breeding SWFLs.

Another model that included distance to water/saturated soil to explain differences in patch densities in the Cliff-Gila Valley found that SWFL densities were positively related to the percentage of boxelder in a patch, and, to a lesser extent, floodplain width (Stoleson and Finch 2001).

Reproductive Success

A few studies contained modeling and exploratory analyses on relationships between hydrology and SWFL reproductive success (nest success, parasitism and predation, and productivity) (Brodhead et al. 2002, Paxton et al. 2007, Ellis et al. 2008; S. Copeland, unpubl. data). Most of these studies examined annual variation in reproductive success and its relationship to annual variation of water availability (e.g., reservoir levels, streamflows, and precipitation). A few reports discussed effects of inundation, resultant changes in SWFL distribution, and reproductive success (Dockens and Ashbeck 2006, Ellis et al. 2008). One study compared effects of seasonal water availability at nest sites on SWFL reproductive success (Moore and Ahlers 2008), and two studies compared average SWFL reproductive success among patches (Brodhead and Finch 2005, Ellis et al. 2008). Following in this section, nest success, parasitism and predation rates, and productivity are discussed together, simplifying the synthesis on possible effects of water availability on SWFL reproductive success and demographics, and are broken down into annual and seasonal variation.

Differences in annual precipitation, water levels, and flows affected SWFL reproductive success (Table 4). Drought years, such as 2002, resulted in low nest success and abrupt departures in several SWFL populations (Johnson et al. 1999, Brodhead et al. 2002, Smith and Johnson 2007, Ellis et al. 2008). In Arizona, winter rainfall (January through May) was an important predictor of nest success (Paxton et al. 2007, Ellis et al. 2008). The relationship was nonlinear: nest success was highest at intermediate levels of precipitation (Paxton et al. 2007). Smith and Johnson (2007, 2008) also thought that nest success on the MRG was highest at intermediate water levels and annual precipitation. In Arizona, nest success was also affected by predation (Paxton et al. 2007) and nest height (Ellis et al. 2008).

Table 4. Hydrological variables and their effects on average annual SWFL reproductive success.

Hydrological Variable	Demographic Variable	Effect on SWFL Reproductive Success†	Source
Precipitation	Nest success	* +	Paxton et al. 2007 Ellis et al. 2008
	Parasitism	+[1]	Brodhead et al. 2002 Ellis et al. 2008
Streamflow (Jan-Mar / Jun 29-Jul 2 / Jul 23-Jul 27)	Nest success	+/+/-	Brodhead and Finch 2005
Reservoir level	Productivity	0[2]	Copeland, unpubl. data
Inundation	Nest success	- 0[3]	Ellis et al. 2008 Dockens and Ashbeck 2006
	Productivity	- 0	Ellis et al. 2008 Dockens and Ashbeck 2006
	Parasitism	0	Ellis et al. 2008 Dockens and Ashbeck 2006

† + = positive effect; * = positive effect, but a quadratic relationship (i.e., most positive effect at intermediate levels); - = negative effect; 0 = no effect.

[1] An increase in precipitation may result in an increase in nest success and a decrease in parasitism, possibly due to increased vegetation density and canopy cover, and increased food availability, which may result in increased vigilance by nesting SWFLs.

[2] No relationship was determined with multivariate statistics, but productivity itself was positively related to reservoir levels (see text).

[3] No inferential statistics. Small sample sizes (i.e., number of territories ranged from 17 to 20) from 2004-2006.

When comparing nest success of two riverine sites (San Pedro and Gila rivers) with two reservoir sites (Salt River and Tonto Creek, both inflows of Roosevelt Lake), winter rainfall had a greater effect on nest success of riverine sites than reservoir sites (Ellis et al. 2008). For every inch winter precipitation increased, daily nest survival increased 19 to 20% vs. 4 to 5%, respectively. For example, in 2005, nest success at Roosevelt Lake was not related to winter precipitation, but nest success along the San Pedro and Gila rivers was positively related to winter precipitation. Overall, nest success and productivity at sites in riverine systems were higher than at reservoir sites (Ellis et al. 2008).

On the Gila River in New Mexico, winter streamflows (January to March) between 1997 and 2002 were positively correlated with nest success (Brodhead and Finch 2005). Flows from June 29 to July 2, coinciding with the SWFL nestling stage, were positively correlated with nest success, whereas flows between July 23 and July 27 coinciding with the average fledge date, were negatively correlated with nest success.

Results from Roosevelt Lake before and after 2005, the year that the reservoir was almost at full capacity, indicate that inundation resulting from full reservoirs can negatively affect SWFL demographics if habitat is significantly altered or reduced. Nest success and productivity of nests that were occupied both prior to and after the 2005 inundation were higher prior to the inundation, presumably due to tree mortality and other vegetation changes resulting from the inundation (Ellis et al. 2008), but also due to a tenfold reduction in habitat (Paxton et al. 2007). However, at Horseshoe Lake, changes in 2004 to 2006 reservoir levels, from empty to full to empty, had no apparent effect on the number of breeding SWFLs or reproductive success (Dockens and Ashbeck 2006), but the distribution of SWFLs changed, as it did at Roosevelt Lake (Ellis et al. 2008).

Annual female productivity may vary greatly among sites and years. In Arizona, female productivity ranged from 0.1 young at Roosevelt Lake in 2002 to 2.7 young on the Gila River in 2001 (Paxton et al. 2007). Modeling found no clear relationship between female productivity and variables important in predicting SWFL habitat use or nest success (Paxton et al. 2007). Similarly, no demographic or hydrological variables significantly explained female productivity on the South Fork Kern River between 1989 and 2002 (S. Copeland, unpubl. data). Female productivity was correlated with average annual reservoir levels ($r = 0.60$), but low reservoir levels coincided with low productivity during several years prior to cowbird trapping. When reservoir levels were highest from 1996 to 1998, female productivity ranged widely from 0.97 to 2.0 fledglings per female. Therefore, female productivity is likely affected by factors other than reservoir levels.

In Arizona, parasitism rates of SWFLs varied greatly among years and sites, with most years ranging from 0 to 10%. The drought year of 2002 resulted in a high parasitism rate of 43% at Roosevelt Lake (Ellis et al. 2008). In the Cliff-Gila Valley, parasitism rates were also higher in 2002 compared with other years (Brodhead et al. 2002), possibly due to changes in vegetation density. In contrast, the 2005 inundation at Roosevelt Lake had no effect on annual parasitism rates (Ellis et al. 2008), nor did an increase in reservoir levels at Horseshoe Lake (Dockens and Ashbeck 2006).

Information on seasonal water availability at nest sites and effects on individual reproductive success was limited. One study compared nest success, productivity, and parasitism and predation rates from nests with different levels of water availability throughout the breeding season (Moore and Ahlers 2008). Water levels were categorized as either dry all season, saturated/flooded then dry, saturated all season, or flooded all season. Other studies with pertinent information included a comparison of reproductive success from nests either partially inundated or not inundated at Roosevelt Lake (Ellis et al. 2008), and two studies that compared average patch parasitism rates to patch characteristics (Stoleson and Finch 2001, Brodhead et al. 2007).

Results were conflicting on relationships between hydrology at individual nests and reproductive success. A 4-year demographic study at Elephant Butte found that hydrology did not influence nest success or productivity (Moore and Ahlers 2008). Nests that were saturated or flooded and then dry were not included in the comparisons due to small sample sizes. Earlier in the Moore and Ahlers study (2008), when comparisons were made with 2 years of data, nests saturated or flooded and then dry had the highest nest success, followed by nests that were dry all season, and those that were either saturated or flooded all season long (Moore 2005). At Roosevelt Lake, nest success and productivity did not differ between nests that were partially inundated vs. not inundated (Ellis et al. 2008). When comparing successful nests alone at Elephant Butte from 2004 to 2007, nests that were over water or saturated soils all season produced more fledglings than nests over dry soils all season (2.80 and 2.75 vs. 2.52 young/nest; n = 184, 266, and 108, respectively; $P = 0.02$) (Moore and Ahlers 2008).

There is no indication that nests closer to water or saturated soils experience less parasitism or predation than other nests, but information is limited. Parasitism and predation rates of nests in partially inundated vs. non-inundated areas at Roosevelt Lake did not differ (Ellis et al. 2008), nor did hydrology influence these rates at Elephant Butte (Moore and Ahlers 2008). However, parasitism rates were lower in native vs. mixed or exotic-dominated areas (Moore and Ahlers 2008), possibly due to denser vegetation cover. In the Cliff-Gila Valley, parasitism rates were lower in patches with a higher percentage of boxelder, but nest heights also were greater (Stoleson and Finch 2001).

Indirect Relationships between Hydrology and SWFLs

Riparian Vegetation of SWFL Breeding Sites

Hydrology affects riparian vegetation in areas where SWFLs breed. SWFLs select nest sites with dense understories (Hatten and Paradzick 2003, Stoleson and Finch 2003, Copeland 2004, Paradzick 2005, Paxton et al. 2007), which may be related to territory quality and higher productivity (Copeland 2004). In turn, dense understories are correlated with high water tables (Paradzick 2005). Other selected habitat characteristics related to hydrological conditions include percent wetland forbs and percent cover of boxelder or willow (Stoleson and Finch 2000b, 2003; Copeland 2004), which are trees that require higher soil moistures than cottonwoods. Percent riparian forest, important in SWFL patch selection (Brodhead 2005, Paradzick 2005), also increases with higher water tables. Inundation rates affect patch occupancy and the basal area of young willows (Paradzick 2005), which are important to SWFL habitat selection. On the San Pedro and Gila rivers, SWFLs select areas with a high density of young trees, which depends on hydrological conditions, but differs between native patches and patches dominated by tamarisk (Paradzick 2005). Density of young willows is correlated with shallow groundwater depths and frequent inundation, whereas density of young tamarisk is not related to groundwater depth, but is correlated with a low frequency of inundation. Alternatively, prolonged inundation can result in tree mortality and a decrease in canopy cover (Ellis et al. 2008). Inundation, along with scouring floods along rivers, could be an explanation for the highest riparian vegetation density at intermediate levels of fall and winter rainfall (Paxton et al. 2007).

Food Availability of SWFLs

SWFLs are generalists, feeding on a variety of aquatic and terrestrial insects (Drost et al. 2001, USFWS 2002, Drost et al. 2003, Durst et al. 2008). Aquatic insects spend at least one life stage in aquatic habitats and, therefore, SWFL food availability may be affected by water availability. A diversity of habitats may provide a greater diversity of terrestrial and aquatic insects and higher insect abundance for SWFLs. Insect abundance also may be affected by plant species, including plant species that require higher water tables such as willows and nettle (*Urtica dioca*), compared to cottonwoods and mule fat (*Baccharis salicifolia*) (Williams 1997).

To date, only five studies have examined food availability of SWFLs. Drost et al. (2001, 2003) focused on analyzing fecal samples of SWFLs from the South Fork Kern River and Roosevelt Lake and found differences in diet composition among the two sites. Durst et al. (2008) compared arthropod communities in native, mixed, and exotic habitats at Roosevelt Lake, and found that arthropod community composition differed by habitat type, but arthropod abundance did not. SWFL diets also varied by habitat. Arthropod abundance varied annually and, in 2003, arthropod biomass was five times greater than in 2002, a drought year (Durst et al. 2008). Insect numbers and biomass also vary throughout the season (Whitfield et al. 1999). On the South Fork Kern River, where insects were collected with Malaise traps for three SWFL breeding seasons (1997 to 1999), insect biomass peaked between mid-June and early July (Whitfield et al. 1999). Similarly, insects sampled with sticky traps peaked in biomass mid-July in 2001, but during the drought year of 2002, insect biomass peaked in mid-June (Copeland 2004).

Two studies have examined the effects of food availability on SWFL demographics. In New Mexico, the area with the highest number of arthropods also had the highest SWFL density (DeLay et al. 2002). However, the area with an intermediate number of arthropods had no SWFLs, whereas the area with the lowest number of arthropods had a low density of SWFLs. The other study that examined the relationship between food availability and SWFL demographics was from the South Fork Kern River (Copeland 2004). Territories of higher quality habitat, indicated by higher productivity and habitat characteristics associated with reproductive success, had higher insect abundance and biomass compared to other territories. Insect availability was also related to habitat characteristics around the arthropod sampling sites (i.e., dense understory and horizontal habitat heterogeneity).

Direct Relationships between Hydrology and WIFLs

Hydrology and Breeding WIFLs

WIFLs are closely associated with water. An affinity for moist or wet, shrubby areas, often with standing or running water, has been noted throughout the West (Sedgwick 2000). In Colorado, WIFLs selected territories with wide riparian areas and a high percentage of willows (Sedgwick and Knopf 1992). At smaller scales, WIFLs did not select characteristics related to hydrology. In the Sierra Nevada Mountains, WIFLs selected areas with a greater percent riparian shrub cover at several spatial scales, although occupied meadows had a higher percent of standing water or saturated soils than territories (Bombay et al. 2003). A higher percent riparian shrub cover also had a positive effect on density and reproductive success. In the Willamette Valley in Oregon, nest success was positively related to proximity to water (Altman et al. 2003).

Hydrology and WIFL Winter Ecology

In the winter, similar to SWFL selection of breeding habitat, WIFLs are found in areas that are inundated during the rainy season – coinciding with arrival of WIFLs – and often dry out during the dry season (Lynn et al. 2003, Koronkiewicz et al. 2006, Nishida and Whitfield 2006, Schuetz et al. 2007). In Mexico and Ecuador, all sites that were occupied by WIFLs were near water and/or had been inundated during the rainy season (Nishida and Whitfield 2006). In El Salvador, Costa Rica, and Panama, all sites with WIFLs had standing or slow-moving freshwater and/or saturated soils, and patches and/or stringers of trees, woody shrubs, and open areas (Lynn et al. 2003). Interestingly, WIFLs exhibited a high degree of territoriality on the wintering grounds, possibly due to defense of resources (Koronkiewicz et al. 2006).

Summary

Water availability varies among SWFL sites. Most sites have surface water or saturated soils, but in some instances SWFLs will occupy dry sites as long as suitable vegetation structure and vegetation density are present. Water availability also varies annually, seasonally, and among territories. During drought years or years with high flows or high reservoir levels, SWFLs are less likely to occupy a site and SWFL density and reproductive success may be negatively affected. Water availability is important to SWFL habitat selection and use. This is evident in the selection at several spatial scales for areas near water or saturated soils, and other variables related to water availability. During the breeding season, some areas with SWFLs may dry out, consistent with WIFL wintering ecology.

Reproductive success is affected by annual differences in water availability (i.e., winter streamflow and winter precipitation), with intermediate levels of water resulting in the highest reproductive success. However, nest height and predation rates are other variables that explain differences in reproductive success. Conversely, annual differences in female productivity in terms of the number of young fledged could not be explained by hydrological variables, indicating that other factors influence productivity. To date, few studies have examined the influence of water availability through the season on individual nest success, and results are inconclusive.

Water availability also affects SWFLs indirectly via vegetation characteristics that are important to SWFL habitat selection and nest success (i.e., dense understory, percentage of riparian forest, and plant species that require high soil moisture). Water availability and vegetation species and structure also may affect SWFL food availability. During drought years, abundance and biomass may be significantly reduced and peak biomass may occur earlier in the season.

Discussion

Influence of Water Availability on SWFL Habitat Selection

Water availability is important to SWFL habitat selection on several spatial scales, which is consistent with studies on breeding WIFLs, as well as those on the wintering grounds. Some areas may dry up during the season (breeding and winter), while other areas may contain surface water or saturated soils all season. Some vegetation characteristics important to SWFL habitat selection are also related to water availability, such as dense understories. Food availability of SWFLs may be related to water availability, although this correlation has not been measured directly.

SWFLs typically occur in areas with surface water and/or saturated soils, but some SWFLs may establish territories and build nests in areas without available water adjacent to the nest tree or patch of habitat. Surface water may be hundreds of meters away, but water availability is sufficient for suitable riparian vegetation and structure, and possibly insect abundance. Greater distances to surface water are particularly evident during dry years or in areas with channel changes. Other factors likely affect SWFL habitat selection besides water availability and habitat structure (USFWS 2002, Paxton et al. 2007), including habitat availability, proximity to other SWFLs (semicolonialism; USFWS 2002), philopatry (Paxton et al. 2007), and previous reproductive success

(Paxton et al. 2007). Territorial behavior also affects selection (USFWS 2002, Copeland 2004), consistent with ideal preemptive distribution, where dominant individuals may preempt others from occupying optimal habitat (Pulliam and Danielson 1991).

Given the dynamic nature of riparian habitats in the Southwest, SWFLs are likely adapted to respond to some changes in habitat availability. However, due to the high fidelity to their breeding sites (Paxton et al. 2007), SWFLs are more likely respond to habitat changes if suitable habitat is present within 30 to 40 km of the same drainage (Paxton et al. 2007). SWFLs are capable of finding and colonizing new breeding sites in the event of habitat desiccation and degradation or inundation (Dockens and Ashbeck 2006, Paxton et al. 2007, Ellis et al. 2008), or natural aging of trees within existing breeding patches and establishment of new cohorts of younger and more suitable riparian trees within the same drainage (Paradzick and Woodward 2003; C. Paradzick, pers. obs.). Movement during the breeding season is uncommon, particularly once nesting has begun (average distance 7.5 km); territory switching is the least common (Paxton et al. 2007). However, there are observations of individuals moving during dry years from dry to wetter areas (Johnson et al. 1999, Smith and Johnson 2007).

Questions remain on how water availability and associated features may benefit SWFL fitness. Water availability affects understory density, which in turn affects SWFL reproductive success (Uyehara and Whitfield 1999, Copeland 2004). Water availability also affects SWFL food availability, which may be important in habitat selection and affect SWFL density and reproductive success. Arthropod biomass is important in territory selection of Acadian flycatchers (*Empdionax virescens*) (Bakermans and Rodewald 2006) and other avian insectivores (Smith and Shugart 1987, Petit and Petit 1996, Burke and Nol 1998). Side channels, wetlands, and backwaters, typically associated with lentic water and broad floodplains, have higher insect diversity and production than main river channels (Malmqvist 2002). Wide floodplains also may have more diverse habitats, as well as high water tables and plant species associated with them. Some of these plant species also have more insects than other plant species (Williams 1997). Water availability also may affect predator access (Cain et al. 2003). Therefore, various characteristics associated with water availability may affect SWFL fitness and play a role in habitat selection.

Influence of Water Availability on SWFL Demographics

Given the diversity and dynamic nature of southwestern riparian areas, understanding how important water availability is throughout the breeding season may shed light on the mechanisms of SWFL habitat selection and reproduction. Are nests with water available throughout the breeding season more successful or productive than other nests, and does water availability affect where and whether birds renest? Unfortunately, due to lack of information, these questions cannot be definitively answered at this time.

Studies addressing how seasonal water availability affects SWFL reproductive success are limited, but some related information exists, suggesting possible relationships. It is common for SWFLs to construct nests in areas that have surface water or saturated soils early in the season, but these areas often dry out during the breeding season, in July, or even as early as June. In the Cliff-Gila Valley, reproductive success was positively correlated with streamflows in late June, but in mid- to late-July was negatively correlated with streamflow. This finding is consistent with hydrology of southwestern rivers under natural flow regimes where standing water or saturated soils across a floodplain throughout the summer is unexpected. Water peaks from late winter/spring floods, recedes through the summer, decreasing water distribution across the floodplain and into the main low flow channel until occasional summer floods occur (Mahoney and Rood 1998). However, it is possible that territories with more water available through the season have denser vegetation and more insects (Copeland 2004), and more favorable microclimates (McLeod et al. 2007), all of which have positive effects on reproductive success. None of these studies have been replicated in other populations or other SWFL sites with different hydrological conditions.

SWFLs and WIFLs are territorial and defend resources during the breeding season, as well as on the wintering grounds (Koronkiewicz et al. 2006). Several authors have hypothesized that prey is an important resource for SWFLs and may affect habitat quality and productivity (USFWS 2002, Copeland 2004, Brodhead and Finch 2005, Koronkiewicz et al. 2006, Paxton et al. 2007). "SWFL food availability may be largely influenced by the density and species of vegetation, proximity and presence of water, saturated soil levels, and microclimate features such as temperature and humidity" (USFWS 2002). Reduced nest success and number of nesting attempts have been related to reduced arthropod biomass resulting from weather (Rodenhouse and Holmes 1992, Durst et al. 2008, Ellis et al. 2008). Differences in arthropod biomass among territories also affect reproductive success of SWFLs (Copeland 2004), Acadian Flycatchers (Bakermans and Rodewald 2006), and Black-throated Blue Warblers (*Dendroica caerulescens*) (Nagy and Holmes 2005).

Birds have evolved to synchronize peak needs during the nesting cycle with peak resource availability (Gill 1990). Peak needs for WIFLs is during the nestling stage (McCabe 1991). On the South Fork Kern River, arthropod biomass peaked between mid-June and mid-July (Whitfield et al. 1999, Copeland 2004), coinciding with the nestling stage. It is not known whether seasonal or annual differences in arthropod biomass are related to hydrologic conditions. In Kansas, insect emergence and biomass peaked 3 weeks after water levels decreased (Gray 1993). In Nebraska, peak insect biomass was highest at a site with an intermediate hydroperiod (i.e., wet 81% of the year), with the longest dry period being 48 days (Whiles and Goldowitz 2001). These studies are consistent with the intermediate disturbance hypothesis, i.e., diversity is highest in systems with intermediate levels of disturbance (Connell 1978), such as areas that receive intermediate levels of flooding (Ward and Stanford 1983). Invertebrate species richness of streams has also been related to the intermediate disturbance hypothesis (Townsend et al. 1997). Climatic and hydrological conditions (Malmqvist 2002), as well as site conditions, such as plant species composition (Williams 1997) and proximity to an edge (Whitaker et al. 2000) may affect arthropod diversity and abundance. Different hydrological regimes may result in different insect emergence patterns (Whiles and Goldowitz 2001).

Climate and hydrology also affect riparian vegetation growth and maintenance. Prolonged inundation of habitat can result in tree mortality, and has been observed at several SWFL breeding locations (i.e., on the South Fork Kern River (USFWS 2000, Copeland 2004), Horseshoe Lake (Dockens and Ahsbeck 2006), and Roosevelt Lake

(Ellis et al. 2008)). Desiccation and mortality of trees due to salinization or hydrologic separations or changes (e.g., receding reservoir levels, reduced overbank flooding, and channel changes) have been documented at Elephant Butte (Moore and Ahlers 2008) and in Arizona (Ellis et al. 2008). The amount of available surface and groundwater also affects vegetation density and rigor (Paradzick 2005, Paxton et al. 2007, Ellis et al. 2008). These relationships have been studied extensively (Stromberg et al. 1996, Sher et al. 2000, Horton and Clark 2001, Vandersande et al. 2001, Karrenberg et al. 2002, Tallent-Hassell and Walker 2002, Lite and Stromberg 2005, Stromberg et al. 2007a), but are beyond the scope of this review.

Conclusions

SWFLs are adapted to patch dynamics, characteristic of southwestern riparian areas (Paxton et al. 2007). At larger spatial scales (i.e. patch or site), the riparian vegetation SWFLs use for breeding depends on disturbance (i.e., magnitude and frequency of flooding) for creation of habitat patches. After several years, these patches can become optimal habitat (3 to10 years for native habitat (Paradzick 2005, Paxton et al. 2007), and less than 21 years for tamarisk-dominant habitat (Paradzick 2005)). Over the long term, shallow groundwater depths are important for maintenance and vigor of plant growth. Drought, water diversions, groundwater pumping, and salinization can result in desiccation and eventual mortality of trees in the riparian area. Long-term inundation may also harm riparian vegetation, killing vegetation and even trees such as willows, which can tolerate some inundation. With the loss of habitat, mature riparian forests may become refugia until other suitable habitat is available.

At a smaller scale, presence of surface water or saturated soils early in the breeding season is important in SWFL habitat selection (i.e., patch, territory, and nest). The average distance to surface water within a patch is often less than 10 m. On average, territories are closer to water than nest sites (Copeland 2004, McLeod et al. 2007), but nest sites are generally less than 75 m from water. Evidence of selection is stronger at the patch and territory scales than at the scale of nest sites. This is consistent with other studies on WIFL habitat selection (Sedgwick and Knopf 1992, Bombay et al. 2003). Other important resources besides the actual nest site may depend on hydrology, such as food availability and vegetation structure. SWFLs may key in on these resources by the presence of water.

Climate and hydrological conditions affect food availability and riparian vegetation, which are both likely annual and seasonal determinants of SWFL densities and reproductive success. Other factors that may affect SWFL occupancy and nest success include parasitism, predation, vegetative cover and structure, and microclimate. Evidence exists that food availability of birds is related to hydrology. Vegetation density is positively related to water availability and has also been related to parasitism rates (Uyehara and Whitfield 1999, Brodhead et al. 2007).

Annual differences in water availability due to climate and water management affect SWFL demographics (density and reproductive success). Both low water availability (drought and drop in water tables) and high water availability (inundation and high flows) have negative effects on SWFL densities and reproductive success. Intermediate levels (in terms of annual variation) of water availability result in the highest reproductive success. These findings suggest there may be an optimum range of annual water availability for SWFL demographics where SWFLs can reproduce successfully. Below the optimum range, vegetation density and rigor is reduced, affecting cover and nest microclimate; and food availability is reduced, resulting in possible reproductive failure. Above the optimum range, vegetation may die and have reduced cover, resulting in reduced reproductive success. McLeod et al. (2008) recommend a mean seasonal soil moisture of 752 mV in areas with breeding SWFLs, with a range between 600 and 800 mV. The thresholds may vary by climate, vegetation communities, hydrology, and fluvial geomorphology.

Seasonal variation of water availability and differences in water availability among territories affect individual reproductive success. SWFLs may adapt to low or high water availability early in the season by shifting territories. During the breeding season, many territories dry out, which is characteristic of natural flow regimes of southwestern rivers. The amount of surface water or saturated soils necessary at various times in the breeding season that may result in reproductive success is not known at this time. Methods and scale of measurements differed among the few studies that attempted to address this question and the mechanism behind the relationship of water availability and reproductive success is unclear.

The literature review and questions raised above identified knowledge gaps on SWFL demographics and its relationship to hydrology. Past studies have focused on nest site and patch selection, distribution, nest success, parasitism, predation, survival, and movement. These studies are important to conservation of SWFLs by defining breeding habitat, predicting distribution and use, and understanding differences in demographics and movement among populations. Several studies have focused on whether exotic habitats are lower quality than native habitats. Even though exotic habitats are associated with less flooding and lower water tables than native habitats (Stromberg et al. 2007b), there is no evidence that exotic habitats have a negative effect on SWFL physiology (Owen et al. 2005) or their food availability (Durst et al. 2008). Furthermore, nest success is not lower in exotic vs. native habitats (Sogge et al. 2005, Moore and Ahlers 2008), but productivity may (Moore and Ahlers 2008) or may not be (Sogge et al. 2005) lower than in native habitats. To date, few studies have examined how habitat quality may affect reproductive success, and which habitat characteristics are related to quality. Populations may be limited by available habitat, predators, and cowbirds, but may also be limited by quality habitat (Stoleson and Finch 2001, Copeland 2004). Considering that habitat quality may affect SWFL demographics, this may be a fruitful area of research, particularly seasonal differences in water availability and food availability on the scale of territories and effects on reproductive success. Due to defended resources within territories, including food availability, territories are the most appropriate scale to measure and compare fitness (Bombay et al. 2003, Copeland 2004).

Based on the problems discussed, the following gaps in knowledge were identified:

- Importance of the amount of wet area in a territory on selection and reproductive success
- Importance of duration of water on reproductive success (nest success, productivity, and breeding season female productivity)
- Importance of duration of water for nest selection for late nests and renests
- Relationship between groundwater tables, soil moisture, and the duration of water throughout the breeding season

- Relationship between food availability and reproductive success
- Relationship between food availability and water availability, annually and throughout the breeding season
- Relationship between water availability and the duration of water on survival

To address some of Reclamation's unanswered questions, ERO suggests standardizing methods, developing rigorous study designs of peer-reviewed studies, and replicating studies. To assess water availability, methods of taking measurements need to be standardized. At a minimum, distance to surface water should be measured twice—when a nest is found and at the end of the breeding season. Also, the definition of saturated soils needs to be clarified because visual estimates may miss areas with saturated soils. In addition, the amount of area inundated or with saturated soils within a territory may be important to SWFLs, which would require mapping approximate territory boundaries; however, caution must be taken to avoid disturbing nesting SWFLs. The use of piezometers for groundwater levels may be a useful measure because vegetation density and vigor, for example, are related to groundwater levels. Ideally, these measurements of water availability should be taken at the scale of the question being asked (e.g., individual nest success, territory quality, and average reproductive success within a patch). Researchers should also give careful consideration to the hydrological variables to be measured, particularly since soil moisture and groundwater levels may not be correlated, possibly due to soil texture (McLeod et al. 2007)

Due to differences in hydrology, climate, and the effects on SWFL site conditions, studies should be replicated using similar methods to help with future management decisions. The two studies to date that have taken the most extensive hydrological measurements and examined relationships between hydrology and SWFL demographics (McLeod et al. 2008; Moore and Ahlers 2008) have taken some similar measurements, but scales of measurements and types of analyses have differed, making comparisons difficult. Differences in annual and seasonal water availability probably exist among SWFL territories at Elephant Butte. By focusing research on these potential differences, the question of how much moisture throughout the season is needed for SWFLs to reproduce successfully could be answered, although the research should be replicated at another site. Evaluating seasonal abundance of insects and differences among territories, and relating these findings to hydrology may help understand the mechanism behind selection for areas with water availability and effects on reproductive success.

One of the great challenges of this century is to "achieve a more effective and sustainable balance between human and ecological needs for fresh water" (Poff et al. 2003). In 2004, the Middle Rio Grande Endangered Species Act Collaborative Program (MRGESACP) was created to "to protect and improve the status of endangered species along the Middle Rio Grande in New Mexico while simultaneously protecting existing and future regional water uses" (MRGESACP 2007). This literature review and the MRGESACP can help direct future research that may minimize water management conflicts. In light of climate change and the increased likelihood of low water years in the future, research on the importance of water availability will help with SWFL management and conservation.

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APPENDICES

APPENDIX 1. AUTHOR BIOSKETCHES.

Ron Beane, is a Principal and Senior Wildlife Biologist at ERO Resources. He has a B.S. in Wildlife Biology from Colorado State University and a M.A. in Biology from the University of Colorado. Ron has over 25 years of professional experience as an ecologist and wildlife biologist, specializing in threatened and endangered species and environmental planning. Ron has surveyed for southwestern willow flycatchers (SWFL) in southern Utah and the San Luis Valley of Colorado. He has also been involved in the preparation of a multi-species habitat conservation plan (HCP) focusing on the SWFL for the Verde River in Arizona and is a Project Manager preparing an HCP for SWFLs in the San Luis Valley.

Sylvia Copeland is a Wildlife Biologist with ERO Resources. She has a B.S. in Biology from the University of Massachusetts at Amherst and a M.S. in Wildlife Science from Virginia Polytechnic Institute and State University. Since completing her Master's on "Habitat Selection, Food Availability, and Reproductive Success of Southwestern Willow Flycatchers on the South Fork Kern River, California", she has worked for federal and state agencies. Sylvia's experience with federally and state-listed threatened, endangered, and sensitive species includes conducting field studies, writing and reviewing biological assessments, and conducting consultations for environmental compliance. She has authored technical reports, including a literature review for the U.S. Army Corps of Engineers' "Nest Predation of Passerines and Predator Control Studies: A Review with Implications for the Southwestern Willow Flycatcher" (Schmidt 2001). Sylvia currently conducts natural resource investigations and environmental planning in the Intermountain West.

Chuck Paradzick is a Senior Ecologist for the Salt River Project, and served as third-part, technical/peer review on this project. Chuck obtained his B.S. in Wildlife Conservation Biology and Masters in Natural Science from Arizona State University. As a Wildlife Specialist for the Arizona Game and Fish Department Nongame Branch, he served as SWFL field supervisor, and compiled and analyzed project field data. Chuck's Master's research focused on "Characterizing Southwestern Willow Flycatcher Habitat along the Lower San Pedro and Gila Rivers, Arizona: Vegetation and Hydrogeomorphic Considerations". He has also published in peer-reviewed journals. Since 2002, he has been working for the Salt River Project, where his primary responsibility has been to develop and implement the Verde River HCP for operation and maintenance of Horseshoe and Bartlett Dams. The HCP covers SWFL and 12 other listed and sensitive species.

Craig Sommers, is the President of ERO and a Water Resource Specialist. He received a B.S. in Soil and Water Science and a M.S. in Agricultural Economics with an emphasis on Water Resources, both from the University of California at Davis. Craig has almost 30 years of experience in natural resource investigations and water resource surveys. As project manager on the Roosevelt Lake natural resource investigation for the Salt River Project in Arizona, he was responsible for the preparation of an incidental take application and HCP for the continued operation of the reservoir and the effect on SWFLs. He developed a similar HCP and EIS for the Horseshoe and Bartlett Reservoirs for the Salt River Project. Work on the HCP and EIS included hydrological and biological modeling, impact assessments, and habitat mapping and analysis. Craig also has extensive experience with the hydrology and biological issues involving the Rio Grande River in New Mexico resulting from consulting projects with the New Mexico Office of the State Engineer and Interstate Stream Commission since 1984.

APPENDIX 2. LETTER SENT TO SWFL RESEARCHERS SOLICITING ADDITIONAL INFORMATION ON SWFL WATER REQUIREMENTS.

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May 13, 2008

To: Greg Beatty, USFWS
Mark Sogge, USGS Flagstaff
Chasa O'Brien, AZGFD
Tom Koronkiewicz, SWCA
Scott Durst, EcoPlan Associates
Susan Sferra, BOR Phoenix
Dave Moore, BOR Denver
Robert Doster, BOR Albuquerque
Deborah Finch, USFS RMRS, Albuquerque
Barbara Kus, USGS San Diego
Mary Whitfield, Southern Sierra Research Station
Robert McKernan, San Bernardino County Museum
Heather Mathewson, University of Reno
Helen Bombay Loffland

RE: Literature Review on Water Requirements of Southwestern Willow Flycatchers

In February 2008, ERO Resources (ERO) was awarded a contract from Bureau of Reclamation (BOR) to conduct a literature review on the water needs of southwestern willow flycatchers (SWFL) as it relates to territory establishment, nest site selection, and nest success. In the last few years, several studies have taken hydrological measurements in areas (or in close proximity) where SWFLs occur and breed. To ensure that we are including all pertinent information in our review, we are soliciting input on unpublished data or reports that have examined relationships between hydrology and SWFL's. We are assuming that most habitat studies and nest monitoring reports include information on distance to water or saturated soils, and therefore, are not asking for that information, unless these contain analyses on the availability of water throughout the season and how this relates to SWFL demographics. The hydrological variables that we are specifically interested in and how these relate to SWFL demographics include groundwater depth, stream flow, reservoir levels, and precipitation data. Any additional information would be greatly appreciated. Thank you for your time and cooperation.

Regards,

Sylvia Copeland

Sylvia Copeland
Wildlife Biologist

Consultants in
Natural Resources
and the Environment

APPENDIX 3. PEER-REVIEWED AND GRAY LITERATURE SCREENED FOR INCLUSION IN THE FOCUSED LITERATURE REVIEW ON SWFL WATER NEEDS.

Reference	Species	State	Type of study	Journal	Focus of study	Incl. in Rpt	Direct Rel. Hydro-SWFL
Allison et al. 2003	SWFL	NM	peer-reviewed	Studies in Avian Biology	HU	Y	Y
Boucher et al. 2003	SWFL	NM	peer-reviewed	Studies in Avian Biology	RE	N	N
Brodhead 2005	SWFL	NM	thesis		HU	Y	Y
Brodhead and Finch 2005	SWFL	NM	annual report		NS, PM, HY	Y	Y
Brodhead et al. 2002	SWFL	NM	annual report		NS, PM, HY	Y	Y
Brodhead et al. 2007	SWFL	NM	peer-reviewed	Auk	NS, PA, GR	Y	Y
Busch et al. 2000	SWFL	range	peer-reviewed	Auk	GE	N	N
Cardinal 2005	SWFL	AZ	thesis		HU, HR	Y	Y
Copeland 2004	SWFL	CA	thesis		HU, NS, PM, FA	Y	Y
Copeland unpubl. data	SWFL	CA	annual report		PM, HY	Y	Y
Davidson and Allison 2003	SWFL	AZ	peer-reviewed	Studies in Avian Biology	NS, MS	N	N
DeLay et al. 2002	SWFL	NM	annual report		FA	Y	N
Dockens and Ashbeck 2005, 2006	SWFL	AZ	annual report		NS, PM	Y	Y
Drost et al. 2001	SWFL	AZ/CA	research report	USGS	FA	Y	N
Drost et al. 2003	SWFL	CA	peer-reviewed	Studies in Avian Biology	FA	Y	N
Durst 2004	SWFL	AZ	thesis		FA	Y	N
Durst et al. 2007	SWFL	range	annual report		HU, PM	Y	N
Durst et al. 2008	SWFL	AZ	peer-reviewed	Journal of Wildlife Management	FA	Y	N
Ellis et al. 2008	SWFL	AZ	research report	AZGFD	HU, NS, PM, HY	Y	Y
Farmer et al. 2003	SWFL	CA	peer-reviewed	Studies in Avian Biology	HU, NS	Y	Y
Finch et al. 2000a	SWFL	range	peer-reviewed	Conservation Assessment	MR, SU	N	N
Graf et al. 2002	SWFL	range	peer-reviewed	Geomorphology	HU, HY, SU	Y	N
Hatten and Paradzick 2003	SWFL	AZ	peer-reviewed	Journal of Wildlife Management	HU	Y	Y
Hatten and Sogge 2007	SWFL	NM	research report	USGS	HU	N	N
Johnson and Smith 2000, Smith and Johnson 2004, 2005, 2006	SWFL	NM	annual report		NS, PM	Y	Y
Johnson et al. 1999	SWFL	NM	peer-reviewed	Southwestern Naturalist	NS, HY	Y	Y
Kus et al. 2003	SWFL	CA	peer-reviewed	Studies in Avian Biology	HU	N	N
Marshall 2000	SWFL	range	peer-reviewed	Conservation Assessment	PM, SU	N	N

Reference	Species	State	Type of study	Journal	Focus of study	Incl. in Rpt	Direct Rel. Hydro-SWFL
Marshall and Stoleson 2000	SWFL	range	peer-reviewed	Conservation Assessment	HY, SU	Y	N
McKernan and Braden 2001a, 2001b	SWFL	AZ/CA	annual report		HU, NS, PM, HY	Y	Y
McLeod et al. 2007, 2008	SWFL	AZ/CA	annual report		HU, NS, PM, HY	Y	Y
Moore 2005, Moore and Ahlers 2006, 2008	SWFL	NM	annual report		NS, PM, HY	Y	Y
Moore 2006	SWFL	NM	annual report		NS, GR	N	N
Mora et al. 2003	SWFL	AZ	peer-reviewed	Studies in Avian Biology	CO	N	N
Owen et al. 2005	SWFL	AZ/NM	peer-reviewed	Auk	PH	Y	N
Paradzick 2005	SWFL	AZ	thesis		HU, HY	Y	Y
Paradzick and Woodward 2003	SWFL	AZ	peer-reviewed	Studies in Avian Biology	HU	Y	Y
Paxton et al. 2007	SWFL	AZ	research report	USGS	HU, NS, PM, SV, HY	Y	Y
Pearson et al. 2006	SWFL	CA	peer-reviewed	Condor	NS, MS	N	N
Rothstein et al. 2003	SWFL	range	peer-reviewed	Studies in Avian Biology	MR, SU	N	N
Rourke et al. 1999	SWFL	range	peer-reviewed	USGS	HU, NS, PM, HU	Y	N
Shook et al. 2003	SWFL	NM	peer-reviewed	Studies in Avian Biology	SI	N	N
Smith and Johnson 2007, 2008	SWFL	NM	annual report		NS, PM, HY	Y	Y
Sogge 2000	SWFL	range	peer-reviewed	Conservation Assessment	HU, SU	Y	N
Sogge and Marshall 2000, Sogge et al. 1997	SWFL	range	peer-reviewed	Conservation Assessment	HU, SU	Y	Y
Sogge et al. 2003	SWFL	range	peer-reviewed	Studies in Avian Biology	HU, SU	Y	N
Sogge et al. 2005	SWFL	range	peer-reviewed	Conference Proceedings	NS, SU	Y	N
Stoleson and Finch 2000a, 2001	SWFL	NM	annual report		HU, NS	Y	Y
Stoleson and Finch 1997, 1999, 2000b	SWFL	NM	annual report		HU, NS, PM	Y	Y
Stoleson and Finch 2003	SWFL	NM	peer-reviewed	Studies in Avian Biology	HU	Y	Y
Stoleson et al. 2000a	SWFL	range	peer-reviewed	Conservation Assessment	MR, SU	N	N
Stoleson et al. 2000b	SWFL	range	peer-reviewed	Conservation Assessment	PM	N	N
Stumpf et al. 2007	SWFL	AZ/CA	peer-reviewed	TWS Mtg	NS	N	N
USFWS 2002	SWFL	range	peer-reviewed	USFWS	HU, NS, SU	Y	Y
USFWS 2005	SWFL	range	peer-reviewed	USFWS	HU, HY, SU	Y	Y
Whitfield and Enos 1996	SWFL	CA	annual report		HU, NS, PA	Y	Y
Whitfield and Sogge 1999	SWFL	range	peer-reviewed	Studies in Avian Biology	NS, PA	N	N
Whitfield et al. 1999a	SWFL	CA	peer-reviewed	Studies in Avian Biology	NS, PA	N	N
Yard and Brown 2003	SWFL	AZ	peer-reviewed	Studies in Avian Biology	MS, SI	N	N

Reference	Species	State	Type of study	Journal	Focus of study	Incl. in Rpt	Direct Rel. Hydro-SWFL
Altman et al. 2003	WIFL	OR	peer-reviewed	Studies in Avian Biology	HU, NS, PM	Y	N
Bombay et al. 2003	WIFL	CA	peer-reviewed	Studies in Avian Biology	HU, NS, PM	Y	N
Finch et al. 2000b	WIFL	NM	peer-reviewed	Conservation Assessment	HU, MI, WE	N	N
Fitzpatrick 1980	WIFL				FA	Y	N
Haas and Hargrove 2003	WIFL	OR, CA, AZ	peer-reviewed	Studies in Avian Biology	MI	N	N
King and King 2003	WIFL	CA	peer-reviewed	Studies in Avian Biology	HU, NS, PM	N	N
Koronkiewicz et al. 2006	WIFL	Central America	peer-reviewed	Condor	HU, WE	Y	N
Kulba and McGillivray 2003	WIFL	Alberta	peer-reviewed	Studies in Avian Biology	HU, HY	N	N
Lynn et al. 2003	WIFL	Central America	peer-reviewed	Studies in Avian Biology	HU, WE	Y	N
McCabe 1991	WIFL	MidWest	book		HU, NS, FA	Y	N
Nishida and Whitfield 2006	WIFL	Central America	annual report		HU, WE	Y	N
Paxton et al. 2003	WIFL	UT	peer-reviewed	Studies in Avian Biology	HR	N	N
Prescott 1986	WIFL	MidWest	peer-reviewed	Condor	MS	N	N
Prescott and Middleton 1988	WIFL	MidWest	peer-reviewed	Auk	FA	Y	N
Ralph and Hollinger 2003	WIFL	CA/OR	peer-reviewed	Studies in Avian Biology	MI	N	N
Schuetz et al. 2007	WIFL	Central America	annual report		HU, WE	Y	N
Sedgwick 2000	WIFL	range	peer-reviewed	Birds of North America	SU	Y	N
Sedgwick and Knopf 1989	WIFL		peer-reviewed	Condor	MS	N	N
Sedgwick and Knopf 1992	WIFL	CO	peer-reviewed	Condor	HU	Y	N
Sechrist and Ahlers 2003	BHCO	NM	peer-reviewed	Studies in Avian Biology	NS, PA, GR	N	N
Tisdale-Hein and Knight 2003	BHCO	NM	peer-reviewed	Studies in Avian Biology	PA, GR	N	N

* CO=contaminants; FA=diet/food availability; GE=genetics; GR=grazing; HU=habitat use; HR=home range; HY=hydro; MI=migration; MR=management recommendations; MS=mating strategy; NS=Nest success; PA=parasitism; PH=physiology; PM=population monitoring; RE=restoration; SI=singing; SU=survival; SV=survival; WE=winter ecology.

APPENDIX 4. REPORTS SCREENED, BUT EXCLUDED FROM THE REPORT.

Boucher, P. F., S. H. Stoleson, R. S. Shook, R. D. Pope, and J. Monzingo. 2003. Riparian restoration on the Gila River, New Mexico, creates breeding habitat for Southwestern Willow Flycatcher. Studies in Avian Biology 26:136-142.

Busch, J. D., M. P. Miller, E. H. Paxton, M. K. Sogge, and P. Keim. 2000. Genetic variation in the endangered Southwestern Willow Flycatcher. Auk 117:586-595.

Davidson, R. F. and L. J. Allison. 2003. Effects of monogamy and polygyny on reproductive success in Southwestern Willow Flycatchers (*Empidonax traillii extimus*) in Arizona. Studies in Avian Biology 26:118-124.

Finch, D. M., J. Agyagos, T. D. McCarthey, R. M. Marshall, S. H. Stoleson, and M. J. Whitfield. 2000a. Management recommendations, p. 107-118. *In*: D. M. Finch and S. H. Stoleson (Eds.). Status, ecology, and conservation of the Southwestern Willow Flycatcher. Gen. Tech. Rep. RMRS-GTR-60. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT.

Finch, D. M., J. F. Kelly, and J.-L. E. Cartron. 2000b. Migration and winter ecology, p. 71-82. *In*: D. M. Finch and S. H. Stoleson (Eds.). Status, ecology, and conservation of the Southwestern Willow Flycatcher. Gen. Tech. Rep. RMRS-GTR-60. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT.

Haas, W. E. and L. Hargrove. 2003. A solution to leg band injuries in Willow Flycatchers. Studies in Avian Biology 26:180-184.

Hatten, J. R. and M. K. Sogge. 2007. Using a remote sensing/GIS model to predict Southwestern Willow Flycatcher breeding habitat along the Rio Grande, New Mexico. Prepared for the Bureau of Reclamation, Upper Colorado River Region.

King, A. M. and J. R. King. 2003. Willow Flycatchers in Warner Valley, Plumas County, California. Studies in Avian Biology 26:56-59.

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Kus, B. E., P. P. Beck, and J. M. Wells. 2003. Southwestern Willow Flycatcher populations in California: distribution, abundance, and potential for conservation. Studies in Avian Biology 26:5-11.

Marshall, R. M. 2000. Population status on breeding grounds, p. 3-12. *In*: D. M. Finch and S. H. Stoleson (Eds.). Status, ecology, and conservation of the Southwestern Willow Flycatcher. Gen. Tech. Rep. RMRS-GTR-60. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT.

Moore, D. 2006. Riparian obligate nesting success as related to cowbird abundance and vegetation characteristics along the Middle Rio Grande, New Mexico. U.S. Bureau of Reclamation, Albuquerque, NM.

Mora, M. A., J. Rourke, S. J. Sferra, and K. King. 2003. Environmental contaminants in surrogate birds and insects inhabiting southwestern willow flycatcher habitat in Arizona. Studies in Avian Biology 26:168-176.

Paxton, E. H., S. N. Cardinal, and T. J. Koronkiewicz. 2003. Using radiotelemetry to determine home range size, habitat use, and movement patterns of Willow Flycatchers. Studies in Avian Biology 26:185-189.

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Rothstein, S. I., B. E. Kus, M. J. Whitfield, and S. J. Sferra. 2003. Recommendations for cowbird management in recovery efforts for the Southwestern Willow Flycatcher. Studies in Avian Biology 26:157-167.

Sechrist, J. D. and D. D. Ahlers. 2003. Movements and home-range estimates for female Brown-headed Cowbirds along the Rio Grande, New Mexico. Studies in Avian Biology 26:143-151.

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Stoleson, S. H., J. Agyagos, D. M. Finch, T. McCarthey, J. Uyehara, and M. J. Whitfield. 2000a. Research needs, p. 119-128. *In*: D. M. Finch and S. H. Stoleson [Eds.]. Status, ecology, and conservation of the Southwestern Willow Flycatcher. Gen. Tech. Rep. RMRS-GTR-60. USDA Forest Service, Rocky Mountain Research Station. Ogden, UT.

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Whitfield, M. J. and M. K. Sogge. 1999. Range-wide impact of Brown-headed Cowbird parasitism on the Southwestern Willow Flycatcher (*Empidonax traillii extimus*). Studies in Avian Biology 18:182-190.

Yard, H. K. and B. T. Brown. 2003. Singing behavior of Southwestern Willow Flycatchers in Arizona. Studies in Avian Biology 26:125-130.

Appendix 5. Reports included in the focused literature review on SWFL water needs, and their content on hydrology, as well as other pertinent WIFL reports.

Reference	State	Drainage	Hydro/ SWFL	DomVeg/ SWFL*	Hydro/ Veg	No hydro	Incl. Direct SWFL	Incl. other than SWFL breeding
Allison et al. 2003	NM	Roos Lake, Gila, San Pedro	X				Y	
Brodhead 2005	NM	Cliff-Gila	X				Y	
Brodhead and Finch 2005	NM	Cliff-Gila	X				Y	
Brodhead et al. 2002	NM	Middle Rio Grande	X				Y	
Brodhead et al. 2007	NM	Cliff-Gila	X				Y	
Cardinal 2005	AZ	Roos Lake	X	X			Y	
Copeland 2004	CA	South Fork Kern	X				Y	
Copeland unpubl. data	CA	South Fork Kern	X				Y	
Dockens and Ashbeck 2005, 2006	AZ	Verde River	X				Y	
Ellis et al. 2008	AZ	Roos Lake, Gila, San Pedro	X	X			Y	
Farmer et al. 2003	CA	Santa Ynez	X				Y	
Hatten and Paradzick 2003	AZ	Roos Lake, Gila, San Pedro	X				Y	
Johnson and Smith 2000; Smith and Johnson 2004, 2005, 2006	NM	Middle Rio Grande	X	X			Y	
Johnson et al. 1999	NM	Middle Rio Grande	X				Y	
McKernan and Braden 2001a, 2001b	AZ/CA	Lower Colorado	X				Y	
McLeod et al. 2007, 2008	AZ/CA	Lower Colorado	X	X			Y	
Moore 2005; Moore and Ahlers 2006, 2008	NM	Middle Rio Grande	X	X			Y	
Paradzick 2005	AZ	Gila, San Pedro	X	X			Y	
Paradzick and Woodward 2003	AZ	all	X	X			Y	
Paxton et al. 2007	AZ	Roos Lake, Gila, San Pedro	X	X			Y	
Smith and Johnson 2007, 2008	NM	Middle Rio Grande	X	X			Y	
Sogge and Marshall 2000, Sogge et al. 1997	range	all	X	X			Y	
Stoleson and Finch 2000a, 2001	NM	Cliff-Gila	X				Y	
Stoleson and Finch 1997, 1999, 2000b, 2003	NM	Cliff-Gila	X				Y	
USFWS 2002	range	all	X	X	X		Y	
USFWS 2005	range	all	X	X			Y	
Whitfield and Enos 1996	CA	South Fork Kern	X				Y	

Reference	State	Drainage	Hydro/ SWFL	DomVeg/ SWFL*	Hydro/ Veg	No hydro	Incl. Direct SWFL	Incl. other than SWFL breeding
DeLay et al. 2002	NM	Cliff-Gila					N	Diet
Drost et al. 2001	AZ/CA	South Fork Kern, Roos Lake		X			N	Diet
Drost et al. 2003	CA	South Fork Kern				X	N	Diet
Durst 2004, Durst et al. 2008	AZ	Roosevelt Lake		X			N	Diet
Graf et al. 2002	range	all			X		N	Hydro/veg
Marshall and Stoleson 2000	range	all			X		N	Hydro/veg
Owen et al. 2005	AZ/NM	Cliff-Gila, Gila, Roosevelt Lake, San Pedro		X			N	Veg/fitness
Sogge 2000	range	all		X			N	Hydro/veg
Sogge et al. 2005	AZ	Roosevelt Lake		X			N	Veg/fitness
Whitfield et al. 1999b	CA	South Fork Kern				X	N	Diet
Altman et al. 2003	OR	Willamette Valley	WIFL				N	Hydro/WIFL
Bombay et al. 2003	CA	Sierra Nevada	WIFL				N	Hydro/WIFL
Fitzpatrick 1980							N	WIFL Diet
Koronkiewicz et al. 2006	Costa Rica		WIFL				N	Winter
Lynn et al. 2003	El Salvador, Costa Rica, Panama		WIFL				N	Winter
McCabe 1991	MidWest		WIFL				N	Diet
Nishida and Whitfield 2006	Mexico, Ecuador		WIFL				N	Winter
Prescott and Middleton 1988	MidWest						N	WIFL Diet
Schuetz et al. 2007	Guatemala, Mexico		WIFL				N	Winter
Sedgwick 2000	range		WIFL				N	Habitat
Sedgwick and Knopf 1992	CO		WIFL				N	Habitat

* DomVeg = dominant vegetation community (i.e., native, mixed native, mixed exotic, or exotic).