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RECOMMENDATIONS FOR COWBIRD MANAGEMENT IN RECOVERY EFFORTS FOR THE SOUTHWESTERN WILLOW FLYCATCHER

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Abstract. The incidence of Brown-headed Cowbird (*Molothrus ater*) parasitism of Southwestern Willow Flycatchers (*Empidonax traillii extimus*) is highly variable, ranging from less than 10% at some sites to over 50% at others. Parasitism usually results in complete loss of flycatcher reproductive output because most parasitized nests are deserted or fledge only a cowbird, although birds that desert often renest. Despite the reduced reproductive output from individual flycatcher nests, it is not clear that cowbird parasitism affects Southwestern Willow Flycatcher population sizes. Cowbird control reduces parasitism rates and increases the reproductive output of Southwestern Willow Flycatchers, but there is no firm evidence yet that it has resulted in any increases of flycatcher populations or forestalled declines, suggesting that populations may be limited by other factors, such as habitat. Cowbird control may nevertheless be an appropriate management option because some populations may benefit and there may be benefits that have not been detected. However, cowbird control efforts should: (a) be applied cautiously and when baseline data indicate serious impacts, because control is expensive and has a number of potentially negative aspects; (b) be geared towards critical assessments of the efficacy of the control, with increases in flycatcher population sizes being the ultimate measure of efficacy; and (c) be regarded as a short term measure, not a permanent management activity.

Key Words: brood parasitism, cowbird, cowbird management, cowbird control, *Empidonax traillii extimus*, endangered species, *Molothrus ater*, Southwestern Willow Flycatcher, Willow Flycatcher.

Many factors can lower the reproductive output of passerines (Martin 1992), including predation of eggs and nestlings, poor food resources due to marginal habitat or inclement weather, anthropogenic toxins, and brood parasitism. This paper addresses the ways in which cowbird (*Molothrus* spp.) parasitism affects the endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*). Key issues considered are whether cowbird parasitism affects host population growth or regulation, whether population level effects on hosts are sufficient to warrant management action, and the most appropriate actions that land managers can take if cowbird management is warranted.

These are complicated issues because cowbirds are native songbirds and because impacts to individual Willow Flycatchers that are parasitized, no matter how severe, may have little or no effect on flycatcher populations. Furthermore, cowbird management consumes large amounts of limited management funds. Approximately a million dollars is spent annually in California alone (Hall and Rothstein 1999), primarily to protect the endangered Least Bell's Vireo (*Vireo bellii pusillus*). On the other hand, even small reductions in Southwestern Willow Flycatcher reproductive success due to cowbirds could make the difference between a declining population and a stable or growing one if a population is experiencing other difficulties.

We limit this paper to consideration of only the Brown-headed Cowbird (*M. ater*). The Bronzed Cowbird (*M. aeneus*) is sympatric with the Southwestern Willow Flycatcher but only two cases of parasitism are known (Skaggs 1996; Arizona Game and Fish Department., unpubl. data). Given its preference for moderate to large passerines (Friedmann and Kiff 1985, Lowther 1995), it is unlikely that the Bronzed Cowbird will ever pose a threat to flycatcher populations.

IMPACTS OF COWBIRD PARASITISM

Most parasitic bird species specialize on one or a few host species (Johnsgard 1997, Ortega 1998, Rothstein and Robinson 1998a,b; Davies 2000), but Brown-headed Cowbirds are known to have parasitized at least 220 bird species (although at greatly varying intensities) and to have been raised by 144 of these (Lowther 1993). Even individual female cowbirds do not usually specialize on a single host species (Friedmann 1963, Fleischer 1985, Hahn et al. 1999; Alderson and Gibbs 1999a,b). Therefore, parasitism can drive a rare host species to extinction because there is no feedback process that lowers cowbird numbers, and thus parasitism rates, when a rare and heavily impacted host species declines (Rothstein 1975a, Mayfield 1977; Grzybowski and Pease 1999, 2000). Common host species can maintain high cowbird populations even as a rare host is pushed to extinction by parasitism.

Another aspect of cowbird biology that raises the potential of major effects on host populations is the high laying rate of female cowbirds.

Females lay on about 70% of the days during their breeding season (Rothstein et al. 1986, Fleischer et al. 1987), i.e., 42 eggs for a two-month breeding season. However, many and perhaps most of these eggs have little or no effect on host productivity because they are laid in nests lost to predation, in nests of host species that eject them (Rothstein 1977, Robinson et al. 1995a, Hahn et al. 1999), or in the nests of hosts that desert and then renest (Hosoi and Rothstein 2000).

Although nestling cowbirds take no direct action against host young (see Hoffman [1929] in Ahlers and Tisdale [1998a] and Dearborn [1996] for possible rare exceptions), hosts divert parental care from their own offspring to cowbird nestlings and nearly always experience some reduction in their own reproductive output (Pease and Grzybowski 1995, Ortega 1998, Payne 1998). Cowbird nestlings often out-compete host nestlings for food because they usually hatch first (Briskie and Sealy 1990, McMaster and Sealy 1998), and are usually larger (Friedmann 1963, Lowther 1993). Host losses are also due to female cowbirds removing one or more host eggs from nests they parasitize (Sealy 1992) and to host eggs damaged by adult cowbirds (Peer and Sealy 1999). Robinson et al. (1993, 1995a), Ortega (1998), Morrison et al. (1999b) and Smith et al. (2000) provide comprehensive reviews of cowbird biology, impacts, and management.

Cowbird eggs hatch after 11 days of incubation (Lowther 1993) and small hosts with long incubation periods such as the Willow Flycatcher, whose eggs hatch in 12–15 days (Sogge 2000b), experience the greatest losses, usually losing all of their own young if a cowbird egg hatches (Sedgwick and Iko 1999, Whitfield 2000). For Southwestern Willow Flycatchers, only 14% of 133 and 13% of 31 parasitized nests in California in Arizona, respectively, produced any host young, compared to 54% of 190 and 60% of 133 unparasitized nests in these two states (Whitfield and Sogge 1999).

Arcese et al. (1996) have hypothesized that cowbirds depredate unparasitized nests to cause renesting by hosts with nests too advanced to be parasitized, but evidence for this hypothesis is mixed. There are published observations of cowbirds removing nestlings and eggs and therefore acting as predators (Tate 1967, Scott and McKinney 1994, Sheppard 1996, Elliott 1999), but such anecdotal reports do not mean that cowbird nest predation is common. Similar acts of predation have also been documented for other passerines not regularly thought to be predators such as Red-winged Blackbirds (*Agelaius phoeniceus*), Yellow-headed Blackbirds (*Xanthocephalus xanthocephalus*), Yellow-breasted Chats (*Icteria virens*), and Gray Catbirds (*Dumetella carolinensis*) (Belles-Isles and Picman 1986, Sealy 1994, Cimprich and Moore 1995, Paradzick et al. 2000). Cowbirds were responsible for only one of 25 video-taped predation events of two frequently parasitized host species at a Missouri study site where cowbirds were abundant (Thompson et al. 1999).

If cowbirds preferentially depredate unparasitized nests to cause renesting, unparasitized nests should have higher predation rates than parasitized nests, but no such overall trend has been found (Rothstein 1975b, Kus 1999, Whitfield et al. 1999b). If cowbirds are frequent agents of nest predation, predation should decline when host populations are protected by cowbird removal programs. No such decline is evident for Southwestern Willow Flycatchers, either among years with versus without cowbird removal (Whitfield et al. 1999b), or within the same year between areas with and without cowbird removal (Whitfield 2000). There was also no marked change in predation of Kirtland's Warbler (*Dendroica kirtlandii*) nests after a cowbird removal program began (Walkinshaw 1983). Similarly, Stutchbury (1997) reported that removal of cowbirds had a large effect on parasitism rates of Hooded Warblers (*Wilsonia citrina*), but no effect on reproductive success because nest predation was high in areas with reduced cowbird numbers. The presently available data do not indicate that cowbirds depredate unparasitized nests regularly enough to make this a management concern but additional research is needed. The critical issue is not whether cowbird predation occurs but whether such predation is common enough to significantly impact host populations.

Reductions in reproductive output of individual hosts do not necessarily impact host populations or entire species because density dependent processes, such as habitat availability, may limit passerine birds (Sherry and Holmes 1995). If there is insufficient habitat, decreases in a host's reproductive output due to cowbird parasitism may simply mean that fewer excess individuals die without producing young. Determining whether cowbird parasitism has an impact at the level of a host population or species is the most significant challenge facing conservation biologists concerned with cowbirds and their hosts. Even if parasitism is shown to limit a host species, one must still decide whether that limitation is a cause for concern because every population must ultimately be limited by some factor. Unless population limitation due to parasitism is a recent situation brought about by anthropogenic factors, it is as natural as limitation by competition, habitat, nest predation, or disease.

On the other hand, any factor that limits a rare species or subspecies is a source of concern and may require management action. If parasitism is the reason for a taxon's rarity, then long-term reduction of cowbird impacts may be needed. However, all endangered passerines that appear to be impacted at the population level by parasitism also suffer from a severe scarcity or degradation of habitat due to anthropogenic factors (Rothstein and Cook 2000). It is possible that all of these endangered birds would be able to coexist with cowbirds if their habitat problems were remedied.

HOST DEFENSES AGAINST COWBIRD PARASITISM

About 25 North American passerine species remove cowbird eggs from their nests nearly 100% of the time. Unlike these "rejecter species," the majority of species, including the Willow Flycatcher, are "accepters" and show no egg recognition (Rothstein 1975a, Ortega 1998) and a small number of species have low to moderate levels of egg rejection (Burhans and Freeman 1997). Although accepters do not eject cowbird eggs, they often desert naturally parasitized nests and renest (Friedmann 1963, Rothstein 1975a, Graham 1988). Desertion is primarily or completely a response to detection of adult cowbirds near or at nests (Burhans 2000) and not a response to cowbird eggs, because it is very rare after nests are experimentally parasitized (Rothstein 1975a,b). Parasitized nests are most likely to be deserted by species that have broad habitat overlap with cowbirds and that experience high losses when they accept parasitism (Hosoi and Rothstein 2000), as is the case for Willow Flycatchers.

Southwestern Willow Flycatchers desert about 35–57% of parasitized nests (Table 1). Because small passerines that desert parasitized nests often renest and successfully rear their own young in unparasitized nests (Graham 1988, Hosoi and Rothstein 2000), declines in Willow Flycatcher reproductive output due to cowbird parasitism are much less than the parasitism rate. Increased reproductive effort could theoretically make the costs of renesting significant through adverse effects on adult condition or survival, but such costs have not been detected in Willow Flycatchers (Sedgwick and Iko 1999).

In addition to nest desertion as a host defense, many hosts, including Southwestern Willow Flycatchers (Uyehara and Narins 1995), recognize cowbirds as special threats and attack them or sit tightly on nests to keep cowbirds from laying (reviewed in Sealy et al. 1998). However, such tactics are not very effective, especially for small hosts, which are often parasitized at high rates despite their responses to adult cowbirds because they are unable to drive cowbirds away.

INDICATORS OF IMPACTS AT THE POPULATION LEVEL

A critical issue in assessing population level impacts is the parasitism rate (% of nests parasitized). Breeding season timing is an important determinant of parasitism rate. In some regions, cowbirds begin to breed later than some of their major hosts and because early nests tend to have the greatest potential productivity, early breeding host species may experience little or no impact at the population level even if late nests suffer high rates of parasitism. However, Southwestern Willow Flycatchers are among the last passerines to breed (Whitfield 2000) and may experience high parasitism levels of their earliest and potentially most productive nests. Willow Flycatchers may also sometimes be subject to unusually high rates of parasitism due to the

TABLE 1. DESERTION RATES OF PARASITIZED WILLOW FLYCATCHERS IN DIFFERENT REGIONS

Subspecies	Region	New contact?[a]	Parasitism rate (N[b])	Desertion rate (N[c])	Reference
extimus	Arizona	No	7% (203[d])	36% (14)	Paradzick et al. 1999
extimus	California	Yes	68% (19)	57% (14)	Harris 1991
extimus	California	Yes	63% (60)	45% (38)	Whitfield 1990
extimus	New Mexico	No	22% (129)	35% (26)	Stoleson & Finch 1999
trailii	Colorado	?[e]	45% (27)	82% (11)	Sedgwick & Knopf 1988
trailii	Michigan	Yes	10% (325)	27% (33)	Berger 1967
trailii	Ohio	Yes	9% (88)	63% (8)	Holcomb 1972

[a] Populations noted as "yes" under New Contact were allopatric with respect to cowbirds in pre-Columbian times.
[b] N reflects number of nests for which parasitism status (parasitized or unparasitized) could be determined.
[c] N reflects number of parasitized nests for which desertion status (deserted or not deserted) could be determined.
[d] Most nests were protected by cowbird trapping but within the total sample, parasitism at two sites with no trapping was 0 of 8 nests (Alamo Lake) and 6 of 16 nests (Camp Verde).
[e] Sedgwick and Knopf (1988) thought this high elevation population was only recently exposed to parasitism but it is close to the cowbird's center of abundance in the Great Plains; Chace and Cruz (1998) suggest that cowbirds occurred in the region in the 1800s before bison were nearly extirpated.

TABLE 2. Geographic Variation in Cowbird Parasitism Rates (in the Absence of Cowbird Control) of Southwestern Willow Flycatchers from Different Regions (Data Are from Whitfield and Sogge (1999) Unless Noted Otherwise)

Locality	Years	Number of nests	Parasitism rate
San Pedro River, AZ	1995–1996	61	3%
Tonto Creek, AZ	2001	33	6%[a]
Gila River, NM	1995, 1997	49	18%
Gila River, NM	1997–1999	>129	18%[b]
Roosevelt Lake, AZ	1995	17	18%
White Mtns., AZ	1993–1996	36	19%
Virgin River delta, NV	1997	14	21%
Santa Ynez River, CA	1995–1997	17	29%[c]
Verde River, AZ	1998	16	38%[d]
various sites, NM	1995	10	40%
Verde River, AZ	1996	13	46%
Grand Canyon, AZ	1982–1986, 1992–1996	25	48%
South Fork Kern River, CA	1987, 1989–1992	163	66%

[a] Data from Smith et al. 2002. There was cowbird control at this site in years preceding 2001.
[b] Data from Stoleson and Finch (1999a) and S. Stoleson (pers. comm.). There were 129 nests in 1997–98 and sample size for 1999 nests was not available; hence number of nests is given as >129.
[c] Data from Farmer (1999a). Parasitism rate is an overall one, not a mean of the rate for each separate year covered.
[d] Data from Paradzick et al. (1999).

scarcity of other host species nesting late in the season. Thus cowbird impacts on Willow Flycatcher populations are potentially greater than on most host species. However, late Willow Flycatcher nests are likely to escape parasitism completely because the cowbird laying season generally ends in early to mid-July (Rothstein et al. 1980, Stafford and Valentine 1985, Lowther 1993), although exceptional eggs have been laid into early August (Friedmann et al. 1977:47).

As with all host species (Robinson et al. 1995a), parasitism rates on Willow Flycatchers are highly variable in space and time. Even populations separated by only a few km may experience markedly different parasitism rates (Sedgwick and Iko 1999). In the absence of cowbird control, parasitism of Southwestern Willow Flycatchers ranged from 29% to 66% for California sites, and from 3% to 48% for Arizona sites (Table 2). Because of this large range, baseline studies need to be done on each population to determine whether cowbird parasitism is a serious problem (Whitfield and Sogge 1999). Some populations that incur parasitism may be doing well even without cowbird management efforts. For example, the large Southwestern Willow Flycatcher population in the Cliff-Gila Valley of New Mexico grew despite parasitism rates of 11% in 1997 and 27% in 1998 (Stoleson and Finch 1999a; S. H. Stoleson, pers. comm.).

Given the temporal variability in the frequency of cowbird parasitism (Sedgwick and Iko 1999, Whitfield and Sogge 1999), baseline studies to assess degree of risk due to cowbirds should usually include at least two and preferably more years of data collection before cowbird management is considered. However, a first year of data collection showing a rate of parasitism of >30% may alone warrant cowbird control management (U.S. Fish and Wildlife Service 2001). Impacts of parasitism can be reduced during baseline studies by removing cowbird eggs from accessible parasitized nests (if authorized by the U.S. Fish and Wildlife Service) or by addling them, as a cowbird egg in a nest may reduce the chances of subsequent parasitism (Ortega et al. 1994). Such manipulations have proven effective with another endangered cowbird host (Kus 1999).

RECENT ECOLOGICAL CHANGES THAT MAY HAVE INCREASED COWBIRD IMPACTS

Cowbird fossils from California, Florida, Virginia, New Mexico, and Texas date from 10,000 to 500,000 years ago (Lowther 1993), and DNA sequence data indicate that cowbirds have been in North America for at least 800,000 years (Rothstein et al. 2002). Thus cowbirds are an ancient component of the North American fauna, so impacts on endangered host species are likely to be due to major ecological changes such as a loss or deterioration of breeding habitat, something well recognized as the major cause of the decline of the Southwestern Willow Flycatcher (Unitt 1987; U.S. Fish and Wildlife Service 1995, 2001) and other endangered species impacted by cowbirds (Rothstein and Cook 2000). Another possible ecological change that could perturb stable cowbird-host interactions is an increase in the abundance and distribution of cowbirds. Host populations that have only begun to experience parasitism due to recent cowbird range extensions might be especially likely to decline if they are deficient in evolved host defenses. Given these considerations, trends in cowbird numbers and range extensions are important issues.

The first available historical records show the presence of cowbirds in the mid-1800s throughout the Southwest as far west as the Colorado River (Rothstein 1994). Cowbirds colonized southern California and all of the area west of the Sierra Nevada and Cascades since 1900. Thus parasitism is a new pressure only for Southwestern Willow Flycatchers in California. However, cowbirds might be more common and more widespread today than under original conditions, even within their historical range. Some early pre-1920s visitors to the cowbird's original range in the Southwest reported that cowbirds were uncommon, while others reported them to be common in habitats used by Southwestern Willow Flycatchers (Whitfield and Sogge 1999, Periman and Kelly 2000). Parasitism rates of Southwestern Willow Flycatchers showed large increases after the early 1900s when data for California and Arizona were lumped (Whitfield and Sogge 1999). However, it is unclear if the same temporal trend would occur if analysis were restricted to only data for the original contact areas in Arizona.

Although there is uncertainty concerning cowbird population trends over the last century, Breeding Bird Survey (BBS) data provide reliable indicators of recent population trends. Averaged across North America, cowbirds have shown a statistically significant ($P < 0.01$) decline of 1.0% per year since the inception of the Survey in 1966 (Sauer et al. 2000). Focusing on the states that contain the largest numbers of Southwestern Willow Flycatchers, cowbirds declined moderately in Arizona and California and increased moderately in New Mexico (all trends statistically nonsignificant) from 1966 to 1999. Even if cowbirds have not increased since the 1800s, Willow Flycatchers and other riparian species have decreased due to habitat loss. Thus increasing cowbird-to-host ratios may have resulted in escalated rates of parasitism even in areas of historical sympatry between cowbirds and Southwestern Willow Flycatchers. Increased cowbird impacts in the absence of increased cowbird numbers may be especially likely in riparian habitats because cowbirds show a distinct preference for riparian habitats in the West (Farmer 1999b, Tewksbury et al. 1999).

CAN SOUTHWESTERN WILLOW FLYCATCHERS AND COWBIRDS COEXIST?

It is clear that most Southwestern Willow Flycatcher populations are viable even when exposed to cowbird parasitism, at least under primeval conditions, because cowbirds have long occurred over most of the flycatcher's range. Southwestern Willow Flycatchers in southern California only recently exposed to cowbird parasitism might not be viable in the presence of cowbirds, because they lack evolved defenses against cowbirds, as proposed for the Least Bell's Vireo (U.S. Fish and Wildlife Service 1998). However, desertion and renesting after parasitism is as frequent in southern California flycatchers as in populations further east with longer histories of parasitism (Table 1). The occurrence of high nest desertion tendencies in California Willow Flycatchers is likely due to retention of host defenses that evolved in ancestral populations that experienced cowbird parasitism (Hosoi and Rothstein 2000) and/or gene flow from parasitized populations. Thus available evidence indicates that newly exposed populations can coexist with cowbirds, unless they are experiencing a marginal existence due to other stresses such as loss of habitat, high levels of nest predation, or low levels of juvenile and adult survival.

A demographic analysis of the Southwestern Willow Flycatcher population along the Kern River indicated that under current conditions, this population cannot grow unless parasitism is about 10% or less (Uyehara et al. 2000). A population that cannot sustain itself in the presence of such a low parasitism rate is probably endangered by factors other than cowbird parasitism. This same population was able to remain stable and possibly even grow from 1982–1989 (Whitfield 1990, 2000) despite a 68% parasitism rate in 1987 (Harris 1991), the only year this rate was determined. Thus it is likely that some critical variable has changed in recent years. In short, available data indicate that Southwestern Willow Flycatchers in all regions can co-exist with cowbirds unless they also experience some new pressure such as severe habitat losses.

DOES COWBIRD PARASITISM NECESSITATE MANAGEMENT ACTIONS?

As described above, cowbird parasitism per se does not necessarily warrant management action. Parasitism is a naturally occurring process and may have little or no effect on the size of host breeding populations, even if it causes major reductions in host breeding success. Cowbirds are native birds and as such are important to biodiversity. They may even affect overall avifaunas in complex and unexpected ways, by, for example, limiting the numbers of some common species and thereby allowing the persistence of other species that might otherwise be out-competed, as is the case for some predators that enhance biodiversity (Simberloff 1998).

Nevertheless, there are some circumstances in which it may be prudent to employ management actions to deter cowbird parasitism. The circumstances that should trigger cowbird management may differ from site to site because of site-specific factors such as a host population's current size, recent population trend, parasitism rate, amount of suitable habitat, and the extent of the losses attributable to cowbird parasitism. These and other factors are discussed in greater detail below, but management actions are constrained by what is possible to achieve. For example, no amount of cowbird management will result in growth of a flycatcher population that is limited by habitat. Furthermore, if such a population is small, it would contribute negligible numbers of individuals that might disperse to other populations. So first we review the range of management actions that may be available.

POTENTIAL APPROACHES TO COWBIRD MANAGEMENT

Cowbird distribution and abundance may be reduced by landscape-wide measures that limit anthropogenic influences that benefit this species. Cowbirds typically feed in areas with short grass (Friedmann 1929, Morris and Thompson 1998) and in the presence of ungulates such as bison and domesticated livestock. Cowbirds also often feed at campgrounds, suburban areas with lawns and bird feeders, and golf courses. It is unclear whether cowbirds always require anthropogenic food sources or native ungulates (Goguen and Mathews 1999) but reductions in the former might reduce cowbird numbers over large regions.

Attempts to limit cowbird numbers on landscape scales should consider the cowbird's commuting behavior (Rothstein et al. 1984, Thompson 1994, Ahlers and Tisdale 1999a, Curson et al. 2000, Sechrist and Ahlers *this volume*, Tisdale-Hein and Knight *this volume*). In many regions, cowbirds spend the morning dispersed over host-rich areas such as forest edges or riparian strips. They typically leave these breeding ranges by late morning to early afternoon and commute to feeding sites, where groups may feed on concentrated food sources. If cowbirds are to be reduced by removing anthropogenic food sources, these removals need to be done over spatial scales that exceed the distances over which most local cowbirds commute. Although maximum commuting distances of 7 km (Rothstein et al. 1984) and 14 km or more (Curson et al. 2000) have been reported, most individuals commute shorter distances, as cowbird abundance declines over distances as short as 2–4 km from anthropogenic food sources (Verner and Rothstein 1988, Tewksbury et al. 1999, Curson et al. 2000, Sechrist and Ahlers *this volume*). Given the pervasiveness of human influence, and the lack of commuting behavior in areas with widespread feeding opportunities for cowbirds, there may be few instances in which landscape-level management measures can completely eliminate local cowbird populations. However, cowbird abundance may at least be reduced by landscape-level actions, although this may not provide sufficient protection if a flycatcher population is severely impacted by cowbirds. Furthermore, landscape-level measures may be costly and time consuming if activities and facilities such as grazing and golf courses are curtailed. In addition, land managers should stress reductions in anthropogenic food sources only if the sources subject to their regulatory action are the major food sources in an area. For example, if there are feeding sites for cowbirds that will remain after regulatory actions, there may be little justification for limiting cattle grazing, although the direct impacts of cattle will often warrant their removal from riparian habitats (Belsky et al. 1999a).

Parasitism rates and cowbird densities may decline with increases in vegetation density (Larison et al. 1998, Averill-Murray et al. 1999; Farmer 1999a,b; Spautz 1999, Staab and Morrison 1999; but see Barber and Martin 1997), because nests may be more difficult to find in dense vegetation. Thus cowbird parasitism might be reduced by measures that result in denser riparian vegetation. Furthermore, managers should also vigorously pursue long term efforts to augment habitat because habitat loss or degradation is probably the ultimate cause of decline for all endangered hosts (Rothstein and Cook 2000), including the flycatcher (U.S. Fish and Wildlife 2001). However, attempts to increase and improve habitat, for example by increased water flows, are fraught with economic and political constraints that can delay changes for years. Unfortunately, flycatcher populations threatened by parasitism may require actions that produce benefits more quickly. Therefore, although land managers should have long range goals that augment the quality and extent of habitat and that address landscape-level actions in regions where parasitism is a threat, cowbird control will often be the most effective action if cowbird impacts justify management intervention.

Cowbirds are highly social (Rothstein et al. 1986) and are attracted to decoy traps, which can remove most individuals from large areas (Eckrich et al. 1999, DeCapita 2000, Griffith and Griffith 2000). Shooting cowbirds attracted to playback of female calls (Rothstein et al. 2000) can be a valuable supplemental way to reduce cowbird numbers (Eckrich et al. 1999). Removing or addling cowbird eggs from parasitized nests can further reduce host losses (Ortega et al. 1994, Hall and Rothstein 1999). Although trapping is usually the most effective means of cowbird control, shooting cowbirds and removing/addling cowbird eggs may be more cost effective and practical if cowbird and/or local host numbers are low and where the set-up and servicing of traps is difficult (Winter and McKelvey 1999).

EFFECTIVENESS OF COWBIRD CONTROL

Cowbird trapping efforts are typically highly successful in reducing parasitism rates and increasing host reproductive output. Cowbird trapping along the South Fork of the Kern River increased the mean number of young each female Southwestern Willow Flycatcher fledged per season from 1.04 before control to 1.88 afterwards (Whitfield et al. 1999a). Cowbird control has resulted in similar productivity increases with three other endangered species: Black-capped Vireo (*Vireo atricapillus*; Eckrich et al. 1999, Hayden et al. 2000), Least Bell's Vireo (Griffith and Griffith 2000), and Kirtland's Warbler (DeCapita 2000). However, the efficacy of cowbird control efforts for Southwestern Willow Flycatchers can not be assessed in some cases in California and Arizona because baseline data on parasitism rates and host nesting success were not collected before control began (Winter and McKelvey 1999).

Despite its effects on the productivity of host nests, cowbird control has a mixed record when it comes to increases in host breeding populations (Rothstein and Cook 2000). The Least Bell's Vireo and Black-capped Vireo have generally increased markedly since cowbird control began (Eckrich et al. 1999, Griffith and Griffith 2000), although little attempt has been made to assess the extent to which other management actions, such as improved and expanded habitat, have contributed to the increases. On the other hand, Kirtland's Warbler and Southwestern Willow Flycatchers at the Kern River did not increase after cowbird trapping; trapping may have forestalled further declines in these species (DeCapita 2000; Whitfield et al. 1999a, 2000) but Rothstein and Cook (2000) argue that the evidence for such effects is far from conclusive.

Focusing on the Willow Flycatcher, the Kern River Valley population has declined from 34 pairs in 1993 to 12 pairs in 2000 despite cowbird trapping since 1993. Cowbirds have been controlled at Camp Pendleton since 1983 to aid recovery of the Least Bell's Vireo (Griffith and Griffith 2000). Despite a report of a modest increase in Willow Flycatchers as of 1991 (Griffith and Griffith 1994), there has been no marked increase in flycatchers as of 2000 after 18 years of cowbird control, even though there appears to be suitable habitat that remains unoccupied. Because it is designed to protect Least Bell's Vireos, cowbird trapping at Pendleton ends well before the Willow Flycatcher breeding season ends. However, only minimal numbers of cowbirds remain when Willow Flycatcher breeding begins in June (Griffith and Griffith 2000) and no parasitism of flycatchers has been detected since nest monitoring began in 1999 (B. Kus, pers. obs.). As with Camp Pendleton, long term cowbird trapping to protect Least Bell's Vireos at another southern California site, the Prado Basin, has not resulted in an increase in the small number of flycatchers (three to seven territories per year) that breed there (Pike et al. 1997).

Trapping programs to protect flycatchers began in 1996 and 1997 in Arizona (Table 3). No baseline data on parasitism rates were collected and local flycatcher habitat was not completely surveyed at some sites before trapping began. A critical assessment of the efficacy of cowbird control for these Arizona populations can only be done after compensating for changes in survey effort and in habitat area and quality; unfortunately, available data do not allow such compensations. The best overall assessment by field workers familiar with these populations is that increases at the Roosevelt Lake, Salt River inflow site reflect the effects of increased survey effort and increased habitat but may also be partially attributable to cowbird control. It is worth noting that there may have been population increases at other sites (e.g., Gila sites) before control began and that the Greer/Alpine site declined after control began, although it may have already been at dangerously low levels (Table 3).

Data from San Marcial, along the Rio Grande in New Mexico, show no clear benefits of cowbird trapping. This site had six flycatcher nests in 1995 when there was no cowbird control. Control occurred in 1996, 1997, and 1998 when there were one, two, and two nests, respectively (Robertson 1997; Ahlers and Tisdale 1998b, 1999b). At present no conclusive results arise from these Arizona and New Mexico data but it seems clear that there has not been a rapid increase in any flycatcher population soon after cowbird control began, unlike the increases in

TABLE 3. NUMBERS OF SOUTHWESTERN WILLOW FLYCATCHER PAIRS COUNTED AT ARIZONA SITES BEFORE AND AFTER COWBIRD CONTROL BEGAN

Site/Area	1993	1994	1995	1996	1997	1998	1999	2000	2001
Alamo Lake	0	0	2	4	6	9	**21**[a]	**20**	**15**
Alpine/Greer	7	10	10	13	**7**	**7**	**5**	**3**	**2**
Gila River sites	0	0	0	3	**30**	**46**	**58**	**48**	**40**[b]
Roosevelt Lake, Salt River inflow	1	15	9	**18**	**17**[a]	**20**	**52**[c]	**80**	**106**
Roosevelt Lake, Tonto Creek inflow	1	7	8	**11**[a]	**18**	**23**	**22**	**25**	**25**
San Pedro River	3	30	26	27	**40**[a]	**38**	**61**[c]	**59**	**67**

Notes: Data underlined and in bold denote years with cowbird control. Inferences concerning numerical trends after cowbird control began are complicated by changes in habitat extent and quality, survey intensity and amount of area surveyed (see text). Data are from Arizona Game and Fish Department, and White and Best (1999).

[a] Higher numbers of birds are likely due to increased survey effort not to an actual increase in the population.

[b] Cowbird control has occurred at only one of several sites.

[c] Higher numbers of birds in these and subsequent years are likely to reflect actual increases in populations due to increases in amount and/or quality of habitat.

Least Bell's Vireos immediately after cowbird control (see Griffith and Griffith 2000).

Even if it results in the growth of a host's breeding population, cowbird control is a stop-gap measure (U.S. Fish and Wildlife Service 1995) that must be done for a number of years if a host population is to continue growing. This continued effort is needed because all cowbird control programs show that control either has no effect on cowbird numbers in subsequent years (Eckrich et al. 1999, DeCapita 2000, Ahlers and Tisdale 1999b, Griffith and Griffith 2000) or too small an effect to reduce parasitism to negligible levels (Whitfield et al. 1999a). Although intensive cowbird trapping efforts do not negate the need for trapping in subsequent years, it is possible that trapping may not be needed as a permanent solution. If a small host population grows and becomes large as a result of cowbird trapping and possibly other measures, it may experience reduced parasitism rates as increased host numbers lower the per capita risk of parasitism. These lower rates of parasitism might have no significant impacts on host population dynamics. Stopping cowbird control after a local host population has increased greatly would reveal whether parasitism rates are lower than when the population was much smaller. It could also have high management value because considerable resources would be saved if parasitism rates were so low that yearly cowbird control is no longer necessary. For these reasons, it is premature to conclude that an endangered host will require cowbird control in "perpetuity" as is done in the draft recovery plan for the Least Bell's Vireo (U.S. Fish and Wildlife Service 1998). Nevertheless, if cowbird parasitism is indeed a limiting factor given the amount of currently available habitat, agencies may have to commit to a decade or more of cowbird trapping. But the most critical question facing mangers is whether cowbird management is likely to produce significant benefits and whether the funds used for such management might produce greater benefits if expended on other measures, such as habitat augmentation.

REASONS FOR CAREFUL DELIBERATION IN THE INITIATION OF COWBIRD CONTROL PROGRAMS

Managers need to be flexible in their approaches and should not assume that cowbird control is one of the very first things that should be done when parasitism of a population of any endangered species is documented. Similarly, managers should not adopt cowbird control just because funding becomes available, and regulators should not earmark management funds to cowbird control simply because this is an easily executed action. An endangered host may benefit more in the long run by first using funds to monitor the extent and impacts of parasitism, as data may show that funding will be of more benefit if applied to management actions unrelated to cowbirds.

We suggest some caution in initiating cowbird control programs for two reasons. First, while cowbird control typically increases reproductive output, evidence to date indicates that it does not usually result in increases in flycatcher breeding populations. The extra birds that are produced may not be recruited into the breeding population because flycatchers may be limited by breeding, wintering, or migration habitat (see papers in Finch and Stoleson [2000]). Nevertheless, cowbird control may yet prove to boost some flycatcher populations to which it is applied. Moreover, it is possible that the extra flycatchers produced by flycatcher populations protected by cowbird control may disperse to other populations. Indeed, determining whether such dispersal occurs and benefits overall metapopulations is a major research need.

Our second reason for urging caution arises from a series of potential problems associated with cowbird control. A cowbird control program with little prospect of producing significant benefits uses funds that could likely produce greater benefits for flycatchers if spent in another manner. Besides using limited resources in a less than optimal way, ineffective control programs may deter attention from other management needs. In a worst case scenario, cowbird control might be used to legitimize harmful activities. For example, cowbird control may be done to mitigate livestock grazing on public lands, when in fact the real harm is habitat damage due to overgrazing rather than cowbird attraction. Benefits of cowbird control might be insignificant because pre-control levels of parasitism were low, because a remote habitat patch has too little habitat to support more flycatchers, or for other reasons. A cowbird control program that has little prospect of producing important benefits is especially unfortunate because it may waste resources for many years, as control programs tend to continue indefinitely.

Control programs typically continue indefinitely because control in one year usually has little effect on cowbird numbers in subsequent years. In fact, cowbird control programs often take on a life of their own, perhaps because they can be highlighted as proactive management, with the numbers of cowbirds killed becoming a numerical indicator of a positive benefit. For example, intense cowbird control continues for Least Bell's Vireo management at Camp Pendleton after almost 20 years despite a 20 fold increase in vireos (Griffith and Griffith 2000) and for Kirtland's Warbler management in Michigan after over 30 years despite a five fold increase in warblers (DeCapita 2000). In both cases, managers show little interest in reducing cowbird trapping efforts to determine whether intensive control is still needed (S. Rothstein, pers. obs.). Management actions that would produce long-term benefits and reduce or eliminate the need for yearly actions are clearly preferable but may not be enacted because of conflict with special interest groups. An example is grazing and the cowbird control program to protect the Black-headed Vireo at Fort Hood, Texas. Experimental reduction of cattle numbers on large parts of this army base has been shown to reduce cowbird numbers (Cook et al. 1998, Koloszar and Horne 2000) leading Cook et al. (1998) to conclude that "The need for [cowbird] trapping is largely a result of a continuous and loosely regulated grazing system on the installation." Nevertheless, managers have opted to continue extensive cowbird trapping and intense grazing even though cowbird attraction is not the only impact grazing has on the base's natural resources (Sanchez and Batchelor 2000). Finally, an important issue associated with cowbird control is whether a species can legally or logically be removed from the endangered species list as long as human intervention (i.e., cowbird control) continues.

Because the ultimate value of cowbird control is not known, control should never be the sole mitigation measure to compensate for habitat destruction of any endangered species. This is especially true if cowbird control is initiated with insufficient baseline data on the extent of parasitism. In the absence of baseline data, huge sums of scarce management funds may be spent for no good purpose and cowbird control is indeed expensive, with contractors generally charging around $2000 per season for each trap. If cowbird control is adopted as a mitigation for habitat loss, there would in fact be no mitigation if parasitism had little effect on the population impacted by habitat loss.

Cowbird trapping is often done by private consulting firms, which raises the issues of profit incentives and consultant advocacy becoming the impetus for such programs. While there is nothing inherently wrong with profiting from such work, managers and regulators should base cowbird control decisions on the work of researchers who do not profit from control. Another reason for initiating control programs only when well justified is the need to show that native animals are being killed only when there is a good reason to do so. Killing large numbers of a native songbird, such as the cowbird, when there is no basis for expecting significant benefits is ethically questionable and could create a public opinion backlash that jeopardizes control programs that are worthwhile. Likewise, capturing non-target species is of concern. Griffith and Griffith (1994), for example, reported 8453 captures of about 1500 individuals of non-target species during a single year of cowbird trapping at Camp Pendleton. Species other than cowbirds have higher mortality rates in traps and may suffer breeding failure due to time spent away from their nests.

RECOMMENDATIONS FOR THE INITIATION AND DESIGN OF COWBIRD CONTROL PROGRAMS

Cowbird control to aid local Willow Flycatcher populations should be instituted after baseline data show parasitism rates to be above a critical level (U.S. Fish and Wildlife Service 2001), as also proposed in recovery plans for other endangered southwestern hosts such as the Golden-cheeked Warbler (*Dendroica chrysoparia*) and Black-capped Vireo (U.S. Fish and Wildlife Service 1991, 1992). In a review of cowbird management for hosts in general, Smith (1999) recommended that management should only be considered if parasitism is >60% for two or more years, but listed a number of considerations that dictate raising or lowering this threshold. In particular, he recommended that the critical parasitism level for management considerations be lowered to >50% for species listed as threatened or endangered.

Given the Southwestern Willow Flycatcher's low numbers (Sogge et al. *this volume*), we recommend that cowbird control should be considered if parasitism exceeds 20–30% after collection of two or more years of baseline data (see also U.S. Fish and Wildlife Service 2001). But this guideline should be applied with flexibility that gives weight to available data on local populations, such as current population trends. For example, there has been a decline in flycatchers at the South Fork Kern River since cowbird control began, despite a reduction in parasitism rates from 65% to 11–20% from 1994–1999 (Whitfield et al. 1999b; M. Whitfield, unpubl. data); intensified control that reduces parasitism even further might be suitable for this population. However, the large Cliff-Gila site in New Mexico grew between 1997–99 despite parasitism rates of 11–27%; rates of 30% or even higher may not warrant cowbird control for this population.

Monitoring nests to collect baseline data on parasitism rates can be costly, but could save funds in the long run if it shows that control is not necessary. Although available resources may make it unrealistic to monitor nests in all small populations, populations with more than five territories should be monitored. If available funds allow attention only to some small populations, managers should give higher priority for both control and nest monitoring to populations that do not appear to be limited by habitat availability. Cowbird eggs should be removed or addled during years when nests are monitored, unless a population is part of an experiment designed to test whether cowbird trapping alters flycatcher population trends (next paragraph).

If a cowbird control program is initiated, we recommend development of an initial statement of goals that define conditions that will end the control program and periodic (3–5 year) peer reviews that judge the program's efficacy. Because current cowbird control programs have not yet resulted in clear increases in Southwestern Willow Flycatchers, we also recommend that overall control programs should be designed as experiments that have the potential for critical assessments of the efficacy of control. To accomplish this, populations with cowbird control should be compared with a limited number of comparable populations that have no cowbird control. We also advise that managers should re-evaluate the need for continued cowbird control if a flycatcher population has grown to be large, because enlarged host populations may experience lowered levels of parasitism, even in the absence of cowbird control.

In addition, we remind managers that the goal of cowbird control is to aid impacted host populations, not to maximize the number of cowbirds killed. Although the number of cowbirds killed can be increased by trapping at cowbird feeding sites and at times other than a host's breeding season, managers need to determine whether these trapping policies provide increased protection for endangered hosts. There is little justification for trapping outside of an endangered host's breeding season if this trapping results in killing large numbers of migratory cowbirds. Trapping from 1 May to 31 July should provide maximal protection for Southwestern Willow Flycatchers. Trapping in host breeding habitat is likely to be the best strategy in most situations as this removes the cowbirds that may put hosts at risk. However, conditions in some local landscapes may make trapping at cowbird feeding sites worthwhile. Because no single control protocol is best for all situations, managers should consult a range of published, peer-reviewed accounts of cowbird control programs (e.g., Eckrich et al. 1999; Whitfield et al. 1999b, 2000; Winter and McKelvey 1999, DeCapita 2000, Griffith and Griffith 2000) for information on the design, number, placement, and visit schedule for traps, on humane euthanasia methods, and on activities that may supplement trapping.

Managers also need to ensure that impacts on non-target species are minimized, e.g., by adjusting the sizes of trap openings to reduce captures of other species, and by visiting traps once or more per day to release all non-target birds as quickly as possible. However, reasonable levels of unavoidable negative impacts on common, non-target species should not deter cowbird trapping if control is well justified. Impacts on non-target species are an undesirable but unavoidable consequence of trapping programs that benefit endangered hosts.

Lastly, managers should initiate public education programs to inform the public about the justification for controlling cowbirds and about other measures that can reduce cowbird numbers such as suspending bird feeding activities during the passerine breeding season. If cowbird control elicits complaints that it is wrong to kill one native bird to help another, managers should explain that control is viewed as a short-term management tool necessitated by increased rates of parasitism and/or drastically reduced host populations that are threatened by loss of reproductive potential. Managers should explain that action against one native bird to aid another reflects no value judgment as to the worth of one species over another but instead reflects society's commitment to conserve endangered species and maintain levels of biodiversity.

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ENVIRONMENTAL CONTAMINANTS IN SURROGATE BIRDS AND INSECTS INHABITING SOUTHWESTERN WILLOW FLYCATCHER HABITAT IN ARIZONA

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Abstract. Several deformed Southwestern Willow Flycatchers (*Empidonax traillii extimus*) were reported in Arizona during the last few years. Environmental contaminants, particularly persistent bioaccumulative pollutants, have been associated with deformities in other birds from diverse areas of the United States. One objective of this study was to determine if environmental contaminants could be linked to deformities of the Southwestern Willow Flycatcher in Arizona. We measured levels of selected inorganic and organic contaminants in potential insect prey of the Willow Flycatcher and in avian surrogate species at selected sites within the San Pedro River and in Roosevelt Lake. DDE and PCBs were the only organochlorine compounds quantified above detection limits in all samples. None of the mean concentrations of DDE and PCBs in eggs, nestlings, or adult birds were near or above the threshold for potential detrimental effects on the birds themselves or on predators that may feed on them. Also, none of the concentrations of metals and metalloids in eggs, nestlings, and adults were at levels known to affect reproduction or that have been associated with deformities. Selenium was relatively elevated in bird samples (up to 5.8 μg/g dry mass); however, these levels were still below those that have been associated with deformities in birds. We detected high concentrations of Sr (up to 450 μg/g dry mass) in whole eggs of Yellow-breasted Chats (*Icteria virens*) that could affect eggshell strength, but more research is needed. Overall, the contaminants reported in this study are not likely to be implicated in the deformities observed in Southwestern Willow Flycatchers in the Lower San Pedro River and Roosevelt Lake.

Key Words: Arizona, contaminants, DDE, *Empidonax traillii extimus*, inorganic elements, insectivorous birds, PCBs, Southwestern Willow Flycatcher.

The lower San Pedro River, including adjacent downstream reaches of the Gila River (San Pedro-Gila rivers) and Roosevelt Lake in Arizona provide important nesting habitat for many passerine birds, including the federally endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*). Environmental contaminants such as polychlorinated biphenyls (PCBs), polychlorinated dibenzo-dioxins, polychlorinated dibenzo-furans, and selenium have been associated with deformities in birds from diverse areas of the United States (Ohlendorf et al. 1986, Giesy et al. 1994). Some of the most common deformities are crossed bills, small or missing eyes, and clubbed feet, but other types of deformities also occur (Gilbertson et al. 1991). Although fish-eating birds and birds at the top of the food chain are usually the most affected by persistent bioaccumulative toxicants (Hoffman et al. 1996), insectivorous birds may also be affected (McCarty and Secord 2000). Terrestrial and emerging aquatic insects in the lower San Pedro River and Roosevelt Lake may accumulate toxicants from agricultural pesticides, mining by-products, and wastewater treatment effluent. Therefore, insectivorous birds breeding on riparian corridors in both regions may accumulate toxicants from feeding on insects or other diets.

Between 1996 and 2000, 12 adult, one fledgling, and two nestling Willow Flycatchers were found with bill or eye deformities in Arizona, Colorado, and New Mexico (Sogge and Paxton 2000). The mandible and beak deformities were characteristic of those observed in fish-eating birds from the Great Lakes, which have been attributed primarily to dioxins and PCBs (Giesy et al. 1994). Because environmental contaminants may be affecting the Willow Flycatcher and other wildlife of the lower San Pedro River, it is important to evaluate environmental contaminants to determine if there is a connection with flycatcher deformities in Arizona.

The objectives of this study were to determine levels of selected inorganic and organic contaminants in potential insect prey of the Southwestern Willow Flycatcher and in avian surrogate species at potentially impacted sites within the San Pedro River riparian zone and Roosevelt Lake. Specifically, we determined concentrations of persistent environmental contaminants to provide useful insights for evaluating causes of deformities in Willow Flycatchers in Arizona. We selected surrogate species that occupy the same habitat and have diets similar to those of the Willow Flycatcher in Arizona (Drost et al. 1998, Yard 1998). Therefore, we expected that contaminant burdens in adults, nestlings, and eggs of surrogate species should reflect those of the Willow Flycatcher. We analyzed for contaminants in adults, nestlings, eggs, and insects in order to establish the chemical dynamics from

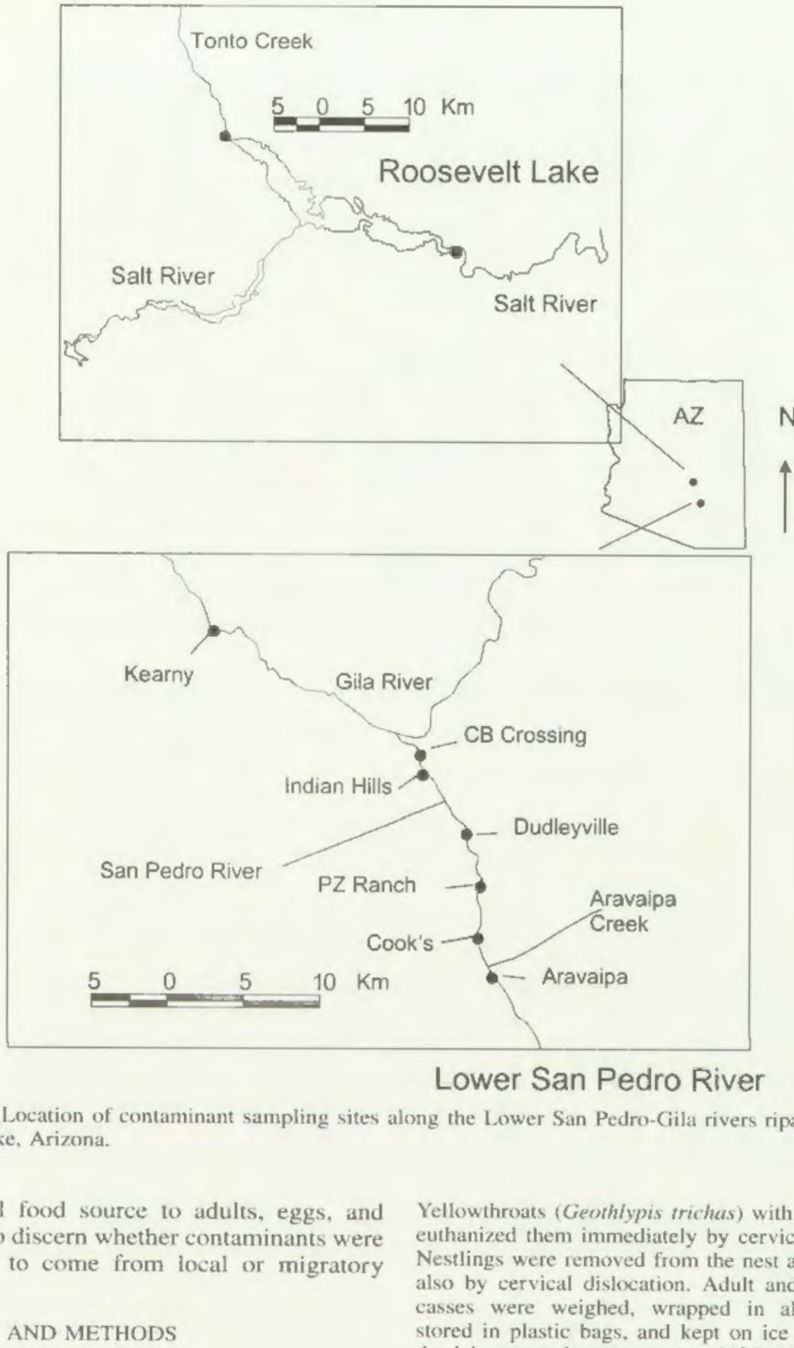

FIGURE 1. Location of contaminant sampling sites along the Lower San Pedro-Gila rivers riparian zone and Roosevelt Lake, Arizona.

the potential food source to adults, eggs, and young and to discern whether contaminants were more likely to come from local or migratory routes.

MATERIALS AND METHODS

STUDY AREAS AND SAMPLE COLLECTION

We collected 62 samples consisting of insects, carcasses, and eggs of surrogate bird species in the summer 1999 from several Willow Flycatcher nesting locations within the riparian zone at the San Pedro-Gila rivers (Pinal County), and from Roosevelt Lake (Gila County) in central Arizona (Fig. 1; Table 1). We captured adult Yellow Warblers (*Dendroica petechia*), Yellow-breasted Chats (*Icteria virens*), and Common Yellowthroats (*Geothlypis trichas*) with mist nets and euthanized them immediately by cervical dislocation. Nestlings were removed from the nest and euthanized also by cervical dislocation. Adult and nestling carcasses were weighed, wrapped in aluminum foil, stored in plastic bags, and kept on ice until taken to the laboratory for storage at −20°C. Yellow-breasted Chat eggs were collected from nests (mostly full clutches), wrapped in aluminum foil, and stored in a commercial refrigerator until further processing (some broken eggs were stored in glass jars at −20°C).

Approximately 2–5 g of insects (flies, bees, wasps, true bugs, leafhoppers, and dragonflies, among others) were collected from Cooks Lake, Indian Hills, and Kearny in the lower San Pedro River and from Roosevelt Lake, with malaise traps containing a killing jar

TABLE 1. MEAN DDE AND PCBs (μG/G WET MASS) IN EGGS AND CARCASSES OF NESTLING AND ADULT INSECTIVOROUS BIRDS AND INSECTS FROM ARIZONA, 1999 (RANGE IN PARENTHESES)

Class	Species	Location	N	4,4'DDE	PCBs
Adults	Yellow-breasted Chat	Cooks Lake	3	0.034 (0.019–0.051)	0.016 (0.014–0.018)
		Indian Hills	7	0.126 (0.020–0.250)	0.021 (0.012–0.050)
		Kearny	1	0.023	0.040
		Roosevelt	5	0.031 (0.017–0.061)	0.012 (0.006–0.021)
	Yellow Warbler	Cooks Lake	2	0.090 (0.055–0.125)	0.019 (0.016–0.022)
		Indian Hills	1	0.056	0.039
		Kearny	8	0.143 (0.024–0.269)	0.141 (0.037–0.311)
	Common Yellowthroat	Cooks Lake	3	0.125 (0.073–0.215)	0.025 (0.020–0.031)
Nestlings	Yellow-breasted Chat	Cooks Lake	1	0.016	0.014
		Indian Hills	2	0.034 (0.025–0.044)	0.013 (0.008–0.017)
		Roosevelt	2	0.017 (0.014–0.020)	0.007 (0.003–0.012)
	Yellow Warbler	Cooks Lake	1	0.180	0.022
		Kearny	2	0.058 (0.051–0.064)	0.161 (0.139–0.183)
Eggs	Yellow-breasted Chat	Cooks Lake	1	0.034	0.017
		Indian Hills	3	0.165 (0.019–0.355)	0.033 (0.010–0.067)
		Dudleyville	3	0.035 (0.019–0.060)	0.033 (0.015–0.064)
		GRS-12	3	0.084 (0.078–0.093)	0.032 (0.023–0.048)
		PZ Ranch	3	0.099 (0.049–0.161)	0.186 (0.024–0.491)
		Roosevelt	6	0.027 (0.017–0.041)	0.026 (0.011–0.056)
Insects	Several	Cooks Lake	1	0.026	0.224
		Indian Hills	1	0.102	0.387
		Kearny	1	0.024	0.237
		Kearny	1	0.003	0.026
		Roosevelt	1	0.042	0.258

with a cloth soaked in acetone at the top. The traps were placed near the sites where the birds were collected and were left for one or more days until enough insect biomass was gathered. After collection, the insects were transferred to chemically cleaned glass jars and kept at −20°C until chemical analysis.

CHEMICAL ANALYSIS

Bird carcasses, eggs, and insects were analyzed for organochlorine contaminants and inorganic elements. The carcasses were obtained by plucking feathers, removing head, legs, beak, and stomach contents. Eggs were analyzed whole (including eggshells) because some eggs were broken and frozen prior to separation of the eggshells. This occurred because eggs had to be carried around for several hours while searching for more nests. We also analyzed the whole egg to determine total depuration of contaminants from the adult female to the egg. Contaminant concentrations were not adjusted for possible moisture loss. After homogenization, about 2 g of sample were used for each analysis. The samples were analyzed at the Geochemical and Environmental Research Group (GERG), Texas A&M University.

ORGANOCHLORINE COMPOUNDS

We analyzed the following organochlorine compounds: polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), hexachlorocyclohexane (α, β, γ, and δ-HCH) chlordane (α and γ isomers), cis-nonachlor, trans-nonachlor, dieldrin, endrin, heptachlor epoxide, mirex, oxychlordane, toxaphene, DDT [1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane], DDE [1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene], and DDD [1,1-dichloro-2,2-bis(p-chlorophenyl)ethane]. Approximately 2 g of sample homogenate were mixed with anhydrous sodium sulfate and extracted with hexane. The samples were extracted following the NOAA status and trends method (McLeod et al. 1985) with some modifications (Brooks et al. 1989). The extracts were purified by silica/alumina column chromatography and with HPLC. Residues were quantitated by gas chromatography and electron capture detector, GC-ECD (^{63}Ni) in splitless mode, with a DB-5 (30 × 0.25 mm ID) fused-silica capillary column (Sericano et al. 1990). Ten percent of the samples were confirmed by second injection on a DB-17 capillary column or by GC-MS. Spike recoveries were above 80% in all cases; variation between duplicates remained within 15%. The lowest detection limit for organochlorine compounds was approximately 1 ng/g wet mass (ww).

Heavy Metals and Metalloids

We quantified the following heavy metals and metalloids: aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se), and strontium (Sr). Approximately 0.5 g of sample was digested with nitric and perchloric acids. The digest was analyzed for most elements with a Perkin Elmer, Model ELAN 5000, inductively-coupled plasma-mass spectrometer (ICP-MS). Arsenic and Se were analyzed with a Varian VGA-76 hydride generation accessory mounted to an atomic absorption spectrophotometer, AA Perkin Elmer, Model 3030. Mercury was analyzed by the standard cold vapor atomic absorption method. The lowest detection limits for trace elements varied between 0.006 μg/g dw for Cd and 2 μg/g dw for Al. Percent recoveries of spiked samples and certified reference materials were above 90% in most cases. Mean relative percent differences between duplicates were <10%.

Statistical Analyses

Yellow-breasted Chats were the main species collected from most locations; therefore, most comparisons among locations were performed only with chat data. We used the GLM procedure on ranked data (SAS Institute 1987) to test for differences in mean concentrations of organic and inorganic elements among all sites (within San Pedro and Roosevelt). The Tukey multiple comparisons procedure was used to determine which means were significantly different. We compared concentrations of organochlorine and inorganic compounds in adult chats with data from three locations and in eggs with data from five locations. We compared inorganic element concentrations among adults, nestlings, and eggs with data from Roosevelt and Indian Hills and all locations combined. We also compared concentrations of inorganic elements among species with combined data for adults from several locations. We tested for differences in mean concentrations of organochlorines between locations (San Pedro vs Roosevelt) and between species (chats vs. warblers) by two-sample comparison procedures. The level of significance was set *a priori* at $P < 0.05$.

Accumulation Factors for Metals and Metalloids

We estimated the proportion of inorganic contaminants that birds acquired through the diet, assuming that they were feeding on insects similar to those sampled in our study. We used mean inorganic element concentrations from Yellow-breasted Chats from specific locations (Indian Hills and Roosevelt) and from all locations to obtain accumulation ratios from insects to adults and nestlings, adults to eggs, and eggs to nestlings. The accumulation factor represents the ratio of the concentration in a given compartment (e.g., carcass) divided by the concentration in another compartment (e.g., insects). The accumulation factor indicates whether a contaminant ingested in the food is potentially accumulated in adults, the proportion that is depurated by the female through the egg (including deposition in the eggshell), and accumulation in nestlings. A ratio ≤ 1 suggests no bioaccumulation, whereas a ratio > 1 indicates bioaccumulation.

RESULTS

Organochlorines

DDE and PCBs were the only organochlorine compounds detected in all samples (Table 1). DDE concentrations were low (range 0.003–0.355 μg/g ww) but were somewhat higher in adult birds and eggs than in insects and nestlings. Polychlorinated biphenyl concentrations also were low (range 0.006–0.491 μg/g ww); however, PCBs were higher in insects and much lower in adults and nestlings. There were no significant differences (GLM of ranked data, $P > 0.05$) in concentrations of DDE and PCBs among adult chats from Cooks Lake, Indian Hills, and Roosevelt Lake. DDE and PCB concentrations also were not significantly different (GLM of ranked data, $P > 0.05$) among chat eggs from Dudleyville, Indian Hills, GRS-12 (by CB Crossing), and PZ Ranch, in the lower San Pedro River, and Roosevelt Lake. DDE and PCBs were not significantly different (t-test, $P > 0.05$) between chat eggs or carcasses from the lower San Pedro River and Roosevelt Lake. DDE concentrations also were similar (t-test, $P > 0.05$) between carcasses of adult chats and Yellow Warblers from the lower San Pedro River; however, concentrations of PCBs were significantly greater (t-test, $P < 0.01$) in Yellow Warblers than in chats from the same locations.

Metals and Metalloids

Insects had proportionally higher concentrations of Cr, As, Cd, and Ni than bird carcasses and eggs (Table 2). Mean concentrations of Cr, As, Cd, Ni, Sr, and Al were similar (GLM of ranked data, $P > 0.05$) in adult chats from Cooks Lake, Indian Hills, and Roosevelt Lake. However, concentrations of Pb and Se were significantly higher (GLM of ranked data, $P < 0.05$) in adult chats from Indian Hills than in adults from Roosevelt Lake, but were similar to chats from Cooks Lake. Copper concentrations were significantly higher (GLM of ranked data, $P < 0.05$) in adult chats from Cooks Lake than in those from Indian Hills and Roosevelt Lake. Concentrations of Hg were significantly higher

TABLE 2. MEAN INORGANIC ELEMENT CONCENTRATIONS AND RANGES (µG/G DRY MASS) IN EGGS AND CARCASSES OF NESTLING AND ADULT BIRDS AND INSECTS FROM ARIZONA, 1999

Age Class	Species	Location	N	Cr	As	Cd	Pb	Se	Hg	Cu	Ni	Sr	Al
Adult	Yellow-breasted Chat	Cooks Lake	3	0.83 (0.53–1)	0.17 (0.10–0.22)	1.11 (0.83–1.40)	0.34 (0.13–0.46)	1.79 (1.31–2.1)	0.11 (0.1–0.12)	14.0 (10.6–19.6)	0.22 (0.15–0.27)	44 (39.4–51)	21 (18–20)
		Indian Hills	7	0.71 (0.32–1.9)	0.23 (0.11–0.35)	0.50 (0.26–0.64)	0.51 (0.28–1.04)	1.90 (1.1–2.4)	0.14 (0.1–0.23)	7.6 (5.2–10.4)	0.72 (0.01–3)	29 (15–46)	30 (12–58)
		Kearny	1	1.35	0.26	1.15	0.52	2.08	0.48	10.6	0.35	21	21
		Roosevelt	5	0.79 (0.53–1.25)	0.18 (0.1–0.24)	0.49 (0.17–1.3)	0.18 (0.13–0.26)	1.04 (0.87–1.24)	0.36 (0.24–0.4)	7.2 (6.3–7.8)	0.15 (0.05–0.41)	21 (12.4–28)	20 (14.4–26.7)
	Yellow Warbler	Cooks Lake	2	0.36 (0.27–0.44)	0.20 (0.12–0.27)	0.26 (0.23–0.29)	0.49 (0.30–0.67)	3.07 (2.91–3.23)	0.19 (0.17–0.21)	8.9 (8.6–9.2)	0.40 (0.26–0.53)	22 (16.2–28.7)	25 (19–32)
		Indian Hills	1	0.50	0.36	0.21	3.85	5.87	0.14	20.8	0.46	15	39
		Kearny	8	0.90 (0.5–1.7)	0.17 (0.11–0.23)	0.20 (0.07–0.63)	0.57 (0.42–0.8)	5.10 (2.1–6.6)	0.21 (0.13–0.31)	11.9 (10.1–15.9)	0.24 (0.05–0.54)	15 (10.3–22.4)	26 (13.2–42.4)
	Common Yellowthroat	Cooks Lake	3	0.78 (0.27–1.18)	0.36 (0.09–0.81)	0.17 (0.1–0.21)	0.22 (0.16–0.26)	1.73 (1.41–2.05)	0.25 (0.13–0.32)	9.0 (8.7–9.2)	0.20 (0.08–0.46)	15 (12.8–15.9)	15 (13–17)
Nestling	Yellow-breasted Chat	Cooks Lake	1	0.27		0.17	0.09	1.09	0.13	8.2	0.17	45	30
		Indian Hills	2	0.95 (0.84–1.05)	0.27 (0.23–0.31)	0.60 (0.11–1.09)	0.42 (0.35–0.50)	1.23 (1.17–1.29)	0.02	69.5 (19–120)	0.43 (0.11–0.75)	52 (23–81)	456 (231–682)
		Roosevelt	2	2.61 (0.9–4.3)	0.25 (0.12–0.38)	0.18 (0.18–0.18)	0.10 (0.01–0.18)	0.24 (0.16–0.32)	0.27 (0.19–0.35)	13.9 (12.1–15.7)	0.24 (0.12–0.35)	22 (17–28)	161 (43–279)
	Yellow Warbler	Cooks Lake	1	0.54	0.10	0.13	0.02	1.32	0.83	9.7	0.40	37	7
		Kearny	2	1.14 (0.96–1.32)	0.16 (0.15–0.17)	0.04 (0.04–0.04)	0.18 (0.11–0.26)	4.84 (4.55–5.14)	0.07 (0.06–0.07)	8.7 (8.3–9.05)	0.79 (0.72–0.85)	50 (38–63)	16 (14.8–16.8)
Eggs	Yellow-breasted Chat	Cooks Lake	1	0.16	0.54		0.17	3.53	0.02	2.3	1.65	257	28
		Indian Hills	3	0.30 (0.21–0.42)	1.00 (0.6–1.3)	0.02 (0.01–0.03)	0.17 (0.02–0.28)	3.90 (3.4–4.3)	0.02	2.2 (1.9–2.9)	0.71 (0.24–1)	313 (266–395)	10 (5.3–12.4)
		Dudleyville	3	0.30 (0.16–0.57)	1.27 (1–1.43)	0.01	0.19 (0.05–0.39)	3.80 (3.2–5)	0.02	3.0 (2.3–4.1)	0.50 (0.28–0.80)	450 (324–579)	59 (2–149)
		GRS-12	3	0.38 (0.18–0.62)	0.82 (0.72–0.98)		0.12 (0.03–0.19)	4.51 (3.46–5.2)	0.02	3.4 (2.5–4.2)	1.30 (0.8–1.9)	243 (145–363)	14 (0.33–35.6)
		PZ Ranch	3	0.11 (0.09–0.14)	0.88 (0.61–1.1)		0.26 (0.18–0.33)	2.70 (1.3–3.9)	0.12 (0.02–0.32)	2.7 (2.1–3.2)	0.33 (0.03–0.75)	396 (283–545)	27 (12–64)
		Roosevelt	6	0.56 (0.03–1.45)	0.94 (0.7–1.2)	0.01 (0–0.02)	0.14 (0.04–0.28)	4.80 (2.7–6.7)	0.02	2.8 (1.8–3.8)	1.11 (0.02–2.8)	168 (99–233)	19 (7–38)

TABLE 2. CONTINUED

Age Class	Species	Location	N	Cr	As	Cd	Pb	Se	Hg	Cu	Ni	Sr	Al
Insect	Various Species	Cooks Lake	1	0.91	0.38	0.81	0.62	1.33	0.07	29.1	10.80	9	89
		Indian Hills	1	3.91	1.04	1.60	0.89	0.96	0.16	37.4	2.75	8	123
		Kearny	1	13.71	0.31	0.38	1.07	1.21	0.09	27.9	0.22	13	185
		Kearny	1	0.55	0.88	1.18	0.57	1.39	0.12	44.6	0.08	117	46
		Roosevelt	1	2.25	1.98	0.70	0.77	0.12	0.16	27.1	2.55	8	141

($P < 0.05$) in adult chats from Roosevelt than in those from Indian Hills and Cooks Lake.

Concentrations of Cr, As, Cd, Pb, Se, Cu, Ni, and Al were similar in chat eggs from five locations in the lower San Pedro River and Roosevelt Lake (GLM of ranked data, $P > 0.05$). Concentrations of Sr, however, were significantly higher (GLM of ranked data, $P < 0.05$) in chat eggs from Dudleyville and PZ Ranch in the lower San Pedro River than in Roosevelt Lake. Mercury was near detection limits in chat eggs.

Concentrations of Cr, As, Cd, Pb, Se, Hg, Ni, and Sr were similar between adults and nestling chats but differed significantly from concentrations in eggs (GLM of ranked data, see below). Concentrations of As, Se, Ni, and Sr were significantly higher (GLM of ranked data, $P < 0.05$) in whole eggs than in adults or nestling chats; however, concentrations of Cr, Cd, Pb, and Hg were significantly lower (GLM of ranked data, $P < 0.05$). Copper concentrations were significantly higher in nestlings than in adults or eggs (GLM of ranked data, $P < 0.05$).

Concentrations of Cr, As, Hg, Ni, and Al were similar among carcasses of chats, warblers, and yellowthroats (GLM of ranked data, $P > 0.05$). Cadmium and Sr were significantly higher (GLM of ranked data, $P < 0.05$) in chat carcasses than in other two species. Copper and Hg were significantly higher (GLM of ranked data, $P < 0.05$) in Yellow Warblers than in chats, but were similar to Common Yellowthroats.

METAL AND METALLOID ACCUMULATION FACTORS

Table 3 provides mean accumulation factors of metals and metalloids from insects to birds, nestlings, and eggs. The accumulation factor was >1 in the following cases: from insects to adults for Se, Hg, and Sr; from adults to eggs for As, Se, Ni, and Sr; from insects to nestlings for Se, Hg, Cu, Sr, and Al; and from eggs to nestlings for Cr, Cd, Pb, Hg, Cu, and Al.

DISCUSSION

CONTAMINANT PATTERNS AND HAZARD ASSESSMENT

DDE concentrations in birds from Arizona were similar to those found in other insectivorous species collected recently in Big Bend National Park, but were about 30 times lower than the DDE residues found in Cliff Swallows (*Petrochelidon pyrrhonota*) collected along the Rio Grande near El Paso, Texas, during the same year (M. Mora, unpubl. data). None of the mean DDE concentrations in eggs, nestlings, and adult birds were near or above the threshold for potential detrimental effects on the birds themselves or on predators that may feed on them. Based on available studies, the Brown Pelican

TABLE 3. MEAN ACCUMULATION FACTORS (RANGES IN PARENTHESES) FOR METALS AND METALLOIDS BASED ON CONCENTRATIONS IN YELLOW-BREASTED CHATS AND INSECTS FROM ARIZONA

Category	Cr	As	Cd	Pb	Se	Hg	Cu	Ni	Sr	Al
Adult/Insect	0.24	0.18	0.57	0.43	4.08	1.68	0.25	0.16	2.42	0.20
	(0.18–0.35)	(0.09–0.22)	(0.31–0.70)	(0.23–0.57)	(1.61–8.65)	(0.90–2.26)	(0.20–0.27)	(0.08–0.26)	(0.93–3.56)	(0.14–0.24)
Egg/Adult	0.53	4.80	0.02	0.53	3.06	0.12	0.33	2.72	9.59	0.78
	(0.42–0.71)	(4.36–5.34)	(0.01–0.03)	(0.33–0.79)	(2.05–4.63)	(0.06–0.16)	(0.30–0.38)	(0.98–5.19)	(7.85–10.9)	(0.33–1.03)
Nestling/Insect	0.58	0.20	0.33	0.30	1.36	1.01	1.14	0.11	3.54	2.35
	(0.24–1.16)	(0.13–0.26)	(0.26–0.37)	(0.12–0.48)	(0.8–2)	(0.13–1.70)	(0.51–1.86)	(0.09–0.16)	(1.26–6.46)	(1.15–3.72)
Nestling/egg	3.98	0.25	37.86	1.50	0.19	6.16	16.21	0.39	0.15	21.94
	(3.15–4.66)	(0.22–0.27)	(27–51)	(0.68–2.5)	(0.09–0.32)	(1–13.5)	(5.02–31)	(0.21–0.61)	(0.13–0.17)	(8.48–47.1)

(*Pelecanus occidentalis*) has been one of the most sensitive bird species to the eggshell thinning effects of DDE; levels of approximately 3 μg/g ww in eggs increased egg breakage and decreased productivity. However, there is much variation in sensitivity to DDE among species (Blus 1996). The low levels of DDE in adult birds, nestlings, and insects suggested little, if any, accumulation along migratory routes; rather, they indicate possible accumulation from local sources.

Polychlorinated biphenyl concentrations also were very low. PCBs were higher in insects and much lower in adults and nestlings, also suggesting local sources rather than acquisition during migration or in wintering grounds. PCBs were greater in warblers than in chats from Kearny probably because warblers were feeding closer to the Kearny sewage ponds, the most likely source of PCBs in the area. The lowest concentrations of PCBs that have been associated with deformities in birds are approximately 3.5 μg/g ww in eggs of Double-crested Cormorants (*Phalacrocorax auritus*; Yamashita et al. 1993). All PCB values in eggs, nestlings, and adult birds collected in Arizona were less than 1 μg/g ww; thus, it is unlikely that PCBs are associated with deformities that have appeared in flycatchers in the area.

Most concentrations of metals and metalloids in eggs and carcasses of the three bird species also were not of concern for biological effects such as deformities in birds. None of the concentrations of Cr, As, Cd, Pb, Hg, Cu, Ni, and Al in eggs, nestlings, and adults were at levels known to affect reproduction or that have been associated with deformities (Heinz 1979; Eisler 1985a, 1986, 1987, 1988, 1998; Whitworth et al. 1991, Miles et al. 1993, McIlveen and Negusanti 1994). Additionally, some inorganic elements were retained in the eggshell since the eggs and eggshells were analyzed together; therefore, some elements were less likely to affect the embryos. Recent analyses indicate that except for Cu, Mn, Se, and Zn, concentrations of inorganic elements were 2–35 times greater in eggshells than in eggs (Mora in press). However, Burger (1994) found that concentrations of Pb and Cr were higher in egg contents than in eggsbells of Herring Gulls (*Larus argentatus*) and Roseate Terns (*Sterna dougallii*). Thus, species differences in deposition of inorganic elements in eggs and eggshells need to be considered.

A concentration of 0.4 μg/g dw total Hg in the diet of fish-eating birds has been suggested as the threshold value at which no negative effects are known to occur (Eisler 1987). The mean concentration of total Hg in insects in the Lower San Pedro River and Roosevelt Dam was below 0.15 μg/g dw, about 1/3 the maximum recommended level to protect wildlife. Insects from the same area also had Cu levels ranging from 27–45 μg/g dw. No data on toxicity of Cu to wildlife are available; however, poultry studies indicate that adverse effects could occur when chickens are fed diets containing 350 μg/g ww Cu for 25 days (Eisler 1998). Of the few studies with Ni, Outridge and Scheuhammer (1993) observed that a diet of 300 μg/g ww caused reduced growth in newly hatched chickens. Nickel concentrations in insects from Arizona were all below 11 μg/g dw. Aluminum concentrations in insects and nestlings from Arizona were somewhat high; however, dietary concentrations of Al of 200, 1000, and 5000 μg/g ww administered to European Starlings (*Sturnus vulgaris*) did not affect their growth, reproduction, or survival (Miles et al. 1993).

Selenium, derived primarily from irrigation drainage of areas with marine sedimentary rocks of Late Cretaceous age (Seiler 1997), was relatively elevated in bird samples (up to 5.8 μg/g dw); however, these levels were still below those that have been associated with deformities in birds (13–24 μg/g dw; Skorupa and Ohlendorf 1991). Although Se may not be lethal or teratogenic at such levels, dietary concentrations of Se >3 μg/g dw may have negative effects on fish and wildlife (Lemly 1996). Concentrations of Se <5 μg/g dw in the diet of adult Screech Owls (*Otus asio*) resulted in oxidative stress in their nestlings (Wiemeyer and Hoffman 1996). Thus, raptorial birds feeding on songbirds or insectivore species along the San Pedro River and the Roosevelt Lake area could be affected by high concentrations of Se in their prey.

One important finding of this study was the elevated levels of Sr (up to 450 μg/g dw) in eggs of chats from two locations on the San Pedro River. The unusually high concentrations of Sr, however, were present mostly in the eggshell (Mora in press) with little potential for association with deformities in birds. Notwithstanding, Sr mobilization is closely associated with Ca metabolism; thus, it is possible that a high deposition of Sr in the eggshell could affect eggshell strength and increase egg breakage (Mraz et al. 1967), but this deserves further documentation. The distribution of Sr in the environment is associated with potassium- or calcium-rich rocks. Some areas in Arizona south of the study area have been reported with high concentrations of Sr in stream sediments (Theobald and Barton 1988). Our findings point out the potential for accumulation of high concentrations of Sr in eggshells of passerine birds nesting in some regions of Arizona.

Except for Sr, which showed some geographic differences in concentrations among samples from the San Pedro River, concentrations of most inorganic elements were similar between the lower San Pedro River and Roosevelt Lake. This suggests that the sources of inorganic contaminants are distributed somewhat uniformly throughout the nesting habitat in these two regions. This is also supported by similar concentrations of Cr, As, Hg, Ni, and Al among the three bird species from the lower San Pedro River. Additional collection of samples from other Willow Flycatcher locations would allow for increased sample sizes and more robust comparisons to better determine contaminant patterns and potential impacts on nesting insectivorous birds.

Metal Dynamics Among Biotic Compartments

Analysis of the accumulation factors suggests that of all the inorganic elements, only Se, Hg, and Sr (ratio > 1) bioaccumulated from insects to adults. However, the presence of high concentrations of metals in insects suggested acquisition of other metals through the diet. The accumulation factors also indicate that adult birds deposited greater concentrations of As, Se, Ni, and Sr than other metals in eggs, relative to their body burdens. From insects to adults and then from adults to eggs, bioaccumulation factors were 12.5 for Se, and 23.2 for Sr (Table 3). As indicated earlier most Sr is deposited in the eggshell, whereas most Se absorbs directly in the egg contents (Mora in press). This study documents the significance of the eggshell for deposition of Sr by the laying female. The accumulation factors of metals from insects to nestlings were quite similar to those from insects to adults suggesting that the possible source of inorganic contaminants was local rather than from a distant source. These considerations assume that the insect samples analyzed represent the food source for the birds collected in the area and that the metal concentrations observed were average concentrations for the area.

CONCLUSIONS AND RECOMMENDATIONS

Overall, DDE, PCBs, metals, and metalloid concentrations reported in this study are not likely to be implicated in the deformities observed in Southwestern Willow Flycatchers in the Lower San Pedro River and Roosevelt Lake. Local Willow Flycatcher deformities may be due to other factors or to exposure to other contaminants to which the surrogate species were not exposed or that were not detected in our analysis. Southwestern Willow Flycatcher deformities appear to be occurring throughout their breeding range (Sogge and Paxton 2000); therefore, sampling of surrogate species from other areas in Arizona and New Mexico should be conducted to determine differences and similarities in contaminants among sites. Environmental contaminants such as metals, organochlorines, and other persistent chemicals would be expected to exert their toxic and teratogenic effects on the developing embryo or young rather than on adults; therefore, we should be able to document mortality rates and deformities in young to better assess exposure and effects of contaminants on the Southwestern Willow Flycatcher. Additionally, the effects of high concentrations of Sr on eggshell strength and potential increase in egg breakage in insectivorous birds should be investigated.

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A FIELD EVALUATION OF THE SOUTHWESTERN WILLOW FLYCATCHER SURVEY PROTOCOL

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Abstract. Establishing the presence of birds, determining their breeding status, and providing consistent, standardized data constitute the rationale behind accepted protocols for monitoring populations of *Empidonax traillii extimus*. During 1999 and 2000, we compared results from inexperienced flycatcher surveyors with those from an experienced surveyor on the same (well-studied) site along the Gila River in southwestern New Mexico. We compared these survey results with the best composite estimate based on all available data. Both experienced and inexperienced surveyors detected the species during both summers; however a pronounced difference in estimated numbers of breeding territories existed between the two groups in both years. The experienced surveyor detected pairs by the use of the soft *whitt* call, while the inexperienced persons relied on the *fitz-bew* call. Data obtained show that the field application of the prescribed protocol can lead to errors in estimating the actual numbers of existing territories.

Key Words: Empidonax traillii extimus; observer experience; Southwestern Willow Flycatcher; survey techniques; vocalizations.

Following the listing of the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) as an endangered species by the U.S. Fish and Wildlife Service in 1995 (USFWS 1995), it became imperative to identify and monitor potential breeding areas for the occurrence of this species. Hence, a survey protocol was developed and implemented as a method to assist in the effective management and conservation of this species (Tibbitts et al. 1994, Sogge et al. 1997a). The primary stated objectives of this protocol are "to provide a standardized survey technique to detect southwestern willow flycatchers, and determine breeding status, and provide consistent and standardized data reporting" (Sogge et al. 1997a:17). The protocol consists of using tape playback of Willow Flycatcher songs (*fitz-bew*) to elicit responses from flycatchers. Surveys are conducted at least once in each of three survey periods (15–31 May, 1–21 June, and 22 June–17 July).

The current protocol was primarily designed to determine presence/absence, rather than an accurate count of flycatchers at any given site (Sogge et al. 1997a). However, an important secondary application of the procedure was to estimate population size, as indicated by several of the authors' statements (Sogge et al. 1997a: pp. 17, 23, 25): "Surveys conducted by qualified personnel in a consistent and standardized manner will enable continued monitoring of general population trends at or between sites . . . . Extra visits provide a greater confidence about presence or absence of flycatchers at a site, as well as help in estimating the number of breeding territories or pairs. . . . Given sufficient time, effort and observation, it is usually possible to approximate the number of territories and pairs." The use of survey results to estimate flycatcher numbers is also promoted by the official protocol data form, which instructs surveyors to estimate the number of pairs and territories detected for each survey period. The protocol thus becomes the primary source of population estimates for *E. t. extimus* for most locations. For example, in 2000, survey crews from the Arizona Game and Fish Department surveyed 197 sites although more intensive monitoring occurred at only 13 (Paradzick et al. 2001).

Prior to the present study, no field evaluation of the efficacy of this protocol existed. Braden and McKernan (1998) argued that the current protocol is inadequate even for detecting flycatcher presence. Their arguments were problematic for several reasons delineated by Sogge et al. (1999) and did not constitute a true field test.

The purpose of this study is not to criticize the current protocol but to evaluate with a field test its efficacy, and how closely surveyors are actually following the protocol. As additional information on a species is made available through scientific studies, protocols can and should be modified accordingly. Indeed the current protocol evolved from the first version by Tibbitts et al. (1994). Our objectives were to evaluate the ability of the protocol to detect flycatcher presence and to assess the effect of observer experience on the ability to estimate the number of breeding pairs.

METHODS

The study plot, approximately 11 ha known to be occupied by Southwestern Willow Flycatchers (hereafter "Willow Flycatchers"), was adjacent to the Gila River, approximately 50 km northwest of Silver City, Grant County, New Mexico, at an elevation of 1366

m. The site supported deciduous woods, extending in a mainly north-south direction along the east bank of the river, characterized by boxelder (*Acer negundo*), velvet ash (*Fraxinus velutina*), Goodding's willow (*Salix gooddingii*) and Fremont's cottonwood (*Populus fremontii*).

Each summer (1999 and 2000) we chose two different persons with no experience in surveying flycatchers to participate in the study. We also selected an additional participant (the same in both years) who had surveyed the species in the Gila Valley from 1995 to 1998. Each surveyor in this study had some previous exposure to bird identification either through a college course in ornithology or from extensive field training involving local birds. Prior to the study, all participants attended a Southwestern Willow Flycatcher survey training workshop, which consisted of presentations on the status and distribution, habitats, biology, cowbird impact, field identification, vocalizations, protocol and data sheets, and permitting issues relating to this species. At the conclusion of the classroom presentations, participants traveled to a site previously occupied by Willow Flycatchers to gain additional field experience. Participants in the workshop exhibited a wide range of experience, physical abilities, and field identification skills. At the workshop, no attempt was made to assess these skills.

To evaluate how accurately individuals with workshop training followed the protocol, each individual, before censusing flycatchers, was introduced to the boundaries of the study plot and instructed to "follow the protocol." Surveyors were given a field map and required to plot their route through the study area for each survey, noting the positions of all Willow Flycatchers detected and the manner of detection (sight or vocalization). Participants were not allowed to discuss among themselves or with others any aspect of the study for the duration of each breeding season. At the conclusion of the field season, surveyors were interviewed about the methods and procedures they used to survey flycatchers.

During both seasons, a field crew from the Rocky Mountain Research Station not associated with the actual surveys periodically visited the study area to locate breeding territories, conduct nest searches, and monitor nests of Willow Flycatchers. Criteria used to designate a breeding pair were presence of an active nest or fledglings, or observations of nest-building or copulation. We then compared the resulting data to those compiled by all surveyors, and a final composite estimate of breeding pairs was based on both experienced and inexperienced surveyor estimates, known nests, and breeding territories.

RESULTS

Little difference in survey effort was found between the inexperienced and experienced surveyors. During the three survey periods prescribed by the protocol, each survey required approximately 2.2 hours to complete. Survey results did not appear to be influenced by amount of time spent surveying.

During the 1999 breeding season, both groups identified up to two individuals by *fitz-bew* calls per survey (Table 1). In 2000, both groups detected more birds by *fitz-bew* calls per survey, with more detections made by the inexperienced surveyors (Table 1), suggesting that more Willow Flycatchers were present on the study site that year. Only one of the four inexperienced observers noted "soft" *whitt* calls in either year, whereas the experienced observer based most of his flycatcher detections on soft *whitts*.

Data from nest searches confirmed a population increase from 11 breeding pairs in 1999 to 16 in 2000 (based on 63 and 165 person-hours of search effort, respectively). Estimated population numbers each year, based on composite estimates from all sources, are presented in Table 1. Compared to these estimates, inexperienced surveyors detected 8–40% of breeding pairs present, whereas the experienced observer recorded 83–100% of breeding pairs.

TABLE 1. NUMBER OF SOUTHWESTERN WILLOW FLYCATCHERS DETECTED BY INEXPERIENCED (S1 AND S2) AND EXPERIENCED (S3) OBSERVERS VIA *FITZ-BEW* VERSUS SOFT *WHITT* CALLS

	1999[a]			2000[a]		
	S1	S2	S3	S1	S2	S3
Detected by *fitz-bew*						
Survey period 1	1	2	1	4	8	3
Survey period 2	2	0	1	6	7	4
Survey period 3	0	1	1	0	6	2
Detected by *soft whitt*						
Survey period 1	0	1	0	0	0	8
Survey period 2	0	2	10	0	0	20
Survey period 3	0	1	10	0	0	12

[a] Composite estimates of the number of breeding pairs within the patch = 12 pairs in 1999, and 20 pairs in 2000.

DISCUSSION

Results of this study indicate that both inexperienced and experienced surveyors detected flycatchers at the study site during both 1999 and 2000; however, surveyors differed in their estimates of flycatcher abundance. This in itself is not a surprising finding, given that observer experience and training are well known sources of variability in avian survey protocols (Ralph and Scott 1981). However, the current Southwestern Willow Flycatcher survey protocol was developed with the intent that it could be effectively used—after a structured training workshop—by relatively inexperienced surveyors (M. Sogge, pers. comm.). Therefore, it is important to determine the degree to which survey results are influenced by use of inexperienced surveyors, and to identify ways in which the protocol could be made more effective.

The first survey of a given season is intended to coincide with the period of highest singing rates of newly arrived males (Sogge et al. 1997). Field work during this period is important in identifying potential Willow Flycatcher habitat, but may not indicate resident pairs, as not all breeding birds have yet arrived on territory, and locally singing birds may be either migrants or unpaired males. Impressions gained over several summers along the Gila River indicate that Willow Flycatchers do not respond consistently to tape playback of *fitz-bew* calls during the second and third survey periods when pairs are actively breeding. Therefore, the possibility exists that reliance on the standard protocol may overlook numerous flycatcher pairs.

Willow Flycatchers are known to give a variety of vocalizations in addition to the *fitz-bew* call (Sedgwick 2000). Owing to difficulty in separating these calls from similar vocalizations of other species, the protocol precludes their use in confirming the presence of Willow Flycatchers (Sogge et al. 1997a:24). A *whitt* note is well known in this species (Sedgwick 2000), but we believe the situation is more complex, with this species producing a "soft" *whitt* that differs in intensity from a "hard" *whitt*, a distinction not made in Sogge et al. (1997a). The hard *whitt* is remarkably similar to calls of Brown-crested (*Myiarchus tyrannulus*) and Ash-throated (*Myiarchus cinerascens*) Flycatchers, and is used as an alarm call by all three species. The soft *whitt*, unique in this location to Willow Flycatchers, seems to function as a contact call between members of a pair (see Barlow and McGillivray 1983, as cited in Sedgwick 2000; Rourke et al. 1999). The soft *whitt*, easily distinguished from the more forceful hard note with practice, is useful in detecting Willow Flycatcher pairs in the field. However, we noted a difference in the detection abilities of inexperienced and experienced surveyors during both summers (Table 1), the experienced individual relying more on detecting flycatchers through soft *whitt* notes.

CONCLUSIONS

The small sample sizes in this study preclude statistical analyses. We recommend that our experiment be replicated elsewhere, particularly in other habitats as habitat structure may influence detectability of Willow Flycatchers. The following conclusions should therefore be considered tentative.

The Willow Flycatcher survey protocol appears to be an effective method of detecting the presence of flycatchers by both experienced and inexperienced surveyors, although the potential exists for missing flycatchers when solely the *fitz-bew* call is relied upon. Based upon the interpretation of all data, however, the protocol is not effective in estimating the number of breeding pairs by inexperienced surveyors or those relying only on *fitz-bew* calls. Sogge et al. (1997a) strongly encourage additional follow-up visits to confirm Willow Flycatcher presence (by *fitz-bew*) when *whitt*s are heard in the field, as those authors do not consider the *whitt*s to be diagnostic for that species (Sogge et al. 1997a: 20, 24). Such follow-ups are not mandated in the protocol, however, and our results, based upon post-survey interviews, suggest that follow-up visits are not carried out in the field.

The experienced surveyor in 2000 had the benefit of site familiarity and knowledge of previous bird locations, both of which would increase the ability to detect Willow Flycatchers. We were not able in this study to quantify the effect of site familiarity on ability to locate birds. However, we did note differences, based upon post-survey interviews, in the methods used by experienced and inexperienced surveyors that might explain why inexperienced surveyors detected fewer flycatchers. The experienced surveyor played the taped *fitz-bew* call less while listening more for soft *whitt*s. The failure of inexperienced surveyors to detect Willow Flycatchers by soft *whitt*s is probably a function of the protocol's emphasis on the *fitz-bew* vocalization and a lack of recognition of soft *whitt*s by these individuals.

The soft *whitt* can be an important tool in estimating the number of breeding pairs, especially in the latter two seasonal survey periods. Observers unfamiliar with this vocalization appeared to consistently underestimate the number of flycatchers within the survey area. Incorporation of the soft *whitt* calls—and perhaps other distinctive vocalizations, such as the *wheeo* call (see Rourke et al. 1999)—into future versions of survey protocol and training sessions may increase the reliability of population estimates derived from future surveys.

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A SOLUTION TO LEG BAND INJURIES IN WILLOW FLYCATCHERS

WILLIAM E. HAAS AND LORI HARGROVE

Abstract. Leg injuries caused by colored plastic leg bands have been reported in Willow Flycatchers (*Empidonax traillii*) in Oregon, California, and Arizona. Based on a five-year banding study of Southwestern Willow Flycatchers (*E.t. extimus*) in southern California, our observed band injury rates were lower than those reported elsewhere. We believe our injury rates were lower because we used modified celluloid bands that were: (a) resized to better fit the flycatcher's tarsus and to avoid slipping over the tarsometatarsal joint; (b) smoothed around the upper and lower edges to minimize abrasion; and (c) sealed to additionally reduce the amount of potentially abrasive surface and to maintain a prescribed inside diameter. Our overall observed injury rate was 2.9%, and declined to 0% over the last three years of the study after we switched from four bands to two bands per individual and eliminated the use of certain bands. We believe that the rate of band-related leg injuries is related to the number of bands applied, physical condition of bands, and use of improperly sized bands. Even the smallest commercially available celluloid leg bands are too large for Southwestern Willow Flycatchers. Moreover, we found that inside diameter of plastic bands varied widely, and were typically larger than advertised. To minimize band-caused leg injury, we recommend using a band of 2.0 mm ± 0.1 inside diameter for Southwestern Willow Flycatchers. Unaltered "0A" and "0" bands from the U.S. Geological Survey Bird Banding Lab are suitably sized and have physical characteristics appropriate for use on Willow Flycatchers; plastic color bands, if correctly modified, are also suitable. Banders must take the responsibility to examine the propriety of bands they apply to live specimens, and to attempt recapture and treatment of injured individuals.

Key Words: banding; color bands; *Empidonax traillii extimus;* injury; Southwestern Willow Flycatchers

Comparative data on band-related injuries in birds are limited and vary widely. Published studies report band-related injury rates ranging from 0.4% (Gratto-Trevor 1994) to 50% (Salzert and Schelshorn 1979). However, much of the literature on band injuries comes from studies of shorebirds and may have limited application to passerines. Nevertheless, it appears that band type, size, and application technique may contribute significantly to injury rates in a host of species (Amat 1999, Bailey et al. 1987, Nisbet 1991, Rothstein 1979). Sedgwick and Klus (1997) recorded an overall leg injury rate of 9.6% in a long-term band and recapture study of Willow Flycatchers (*Empidonax traillii*). Similar injuries have been noted in some Southwestern Willow Flycatcher (*E.t. extimus*) banding studies in Arizona (M. Sogge, pers. comm.) and California (M. Whitfield, pers. comm.); injuries in *E.t. extimus* are of particular concern due to the endangered status of this subspecies.

During the course of a five-year Southwestern Willow Flycatcher research project, we noted a plastic band-related leg injury rate lower than that reported by Sedgwick and Klus (1997). This led us to investigate the level and nature of band-related injuries in our banded population, and the factors that may contribute to these injuries. We hypothesized that band-related injury may be the result of application of improperly sized bands and/or bands with physical characteristics conducive to abrading flycatcher tarsi or constriction of the foot. It is also possible that the weight of more than one band per leg further exacerbates the potential for leg injury. To determine if improper band size or physical characteristics may contribute to injuries, we compared measurements of Willow Flycatcher lower tarsometatarsus diameter (tarsus) and distal tarsometatarsal joint (distal joint) width to the inside diameters of federal aluminum bands and commercially available plastic color bands.

METHODS

BAND MEASUREMENTS

Celluloid bands are produced in a variety of colors and three primary color schemes: solid (uniform color throughout), two-colored narrow striped, and two-colored broad striped. We used a dial caliper (with 0.05 mm resolution) to measure the inside diameter and wall thickness (gauge) of 100 size XF plastic color bands (manufactured by A. C. Hughes). We randomly selected and measured inside diameter and gauge of 40 solid color bands from a population of 400, 20 two-colored narrow striped bands from a population of 200, and 40 two-colored broad striped bands from a population of 400. We also measured the inside diameter and gauge of 100 size 0 and 100 size 0A federal numbered aluminum bands.

WILLOW FLYCATCHER CAPTURE, BANDING, AND LEG MEASUREMENTS

We conducted our field study from 1996 to 2000 on a breeding population of Willow Flycatchers along the upper San Luis Rey River (San Diego Co., California), approximately 1 km downstream of Lake Henshaw.

TABLE 1. BAND-RELATED INJURIES IN SOUTHWESTERN WILLOW FLYCATCHERS (1997 TO 2001) AT THE UPPER SAN LUIS REY RIVER, SAN DIEGO COUNTY, CA

Year banded	Year and age recaptured	Sex	Injury/symptoms	Treatment/outcome
1996	1997 Third year	Female	Celluloid band (thin-striped) slipped over distal joint of left foot; joint slightly abraded; loss of foot use	Removed plastic bands from left leg; treated with povidone-iodine and released. Observed on territory for remainder of breeding season, use of foot restored. Individual not observed in following years.
1996	1998 Fourth year	Male	Severe abrasion: raw, swollen tissue below bands on left leg	Removed plastic bands from left leg, treated with povidone-iodine; released. Recaptured June 1999, minimal evidence of injury (slight scarring observed with 10-power hand lens).
1996	1998 Third year	Male	Raw, swollen tissue at joints above and below bands (thin-striped) on left leg	Removed plastic bands from left leg, treated with povidone-iodine; released. Remained on territory through season; not observed in subsequent years.
1997	1999 Fourth year	Male	Raw, swollen tissue at joints above and below bands on right and left legs	Removed all bands, treated with 10% povidone-iodine; released. Remained on territory through season. Unknown if observed in subsequent years.

Note: All birds were originally banded with two bands per leg.

We used mist-nets to capture summer resident flycatchers, and banded each individual with a numbered size 0A federal aluminum band and from one (1998–2000) to three (1996–1997) plastic colored leg bands; the size XF celluloid bands were re-sized and modified to a 2.0 mm ± 0.1 inside diameter (details below). For this study we used a dial caliper (with 0.05 mm resolution) to measure the maximum diameter of the tarsus and width of the distal joint in 65 live adult (≥ second year) flycatchers.

DETERMINATION OF LEG INJURIES

We derived our band injury data from banding, recapture, and resighting data of birds banded between 1996 and 2000 (N = 168) and re-sighted and/or recaptured at least one year later (i.e., 1997 to 2001, N = 139). We thoroughly inspected the tarsi of each newly captured and recaptured flycatcher, and visually inspected (through binoculars) the leg condition of each flycatcher that was resighted.

RESULTS AND DISCUSSION

TARSAL MEASUREMENTS

Tarsal diameter of 65 Southwestern Willow flycatchers ranged from 1.65 to 1.90 mm (mean = 1.80 mm, SD = 0.04). Diameter (maximum width) of the distal joint ranged from 2.05 mm to 2.45 mm (mean = 2.20 mm, SD = 0.07).

BAND MEASUREMENTS

Advertised as having an inside diameter of 2.30 mm, celluloid XF color band inside diameter ranged from 2.35 to 2.65 mm (mean = 2.45 ± 0.06 SD). Because all Willow Flycatchers we measured had distal joints of 2.05 mm or larger, bands of 2.00 mm inside diameter are unlikely to slip over the distal joint. Forty of the 65 flycatchers had distal joint widths of 2.30 mm or less; thus, unmodified plastic XF bands had the potential to slide over the distal joint of more than 60% of the flycatchers.

Size 0A and 0 aluminum bands were more consistent in dimensions than were all other bands we measured. Mean inside diameter of size 0A bands was 2.05 mm (SD = 0.05, range = 1.90–2.15). Mean inside diameter of size 0 aluminum bands was 2.1 mm (SD = 0.06, range = 2.05–2.30). Therefore, all size 0A bands were large enough to fit around the flycatcher tarsi and small enough to avoid slipping over the distal joint. Size 0 bands had smaller inside diameters than the distal joints of 57 (88%) of the flycatchers we measured; however, there is potential for slippage over some flycatcher distal joints (8 of 65 flycatchers had a distal joint width less than 2.15 mm).

BAND-RELATED INJURY RATES

We banded 168 Southwestern Willow Flycatchers between 1996 and 2000, and recaptured/resighted 139 (not including birds re-sighted within the season in which they were banded). We have detected four (2.9%) band-related injuries (Table 1). Injuries included tarsal abrasions above and/or below the plastic bands (N = 3) and plastic band slippage over the distal tarsal joint (N = 1). All four injuries occurred to birds on which we had placed four bands (two bands per leg), two (50%) of the four injuries involved birds with thin-striped color bands adjacent to the distal joint. Of 168 birds banded, only 17 (10%) had thin-striped bands in the position directly above the distal joint. Thus, 50% of our injuries occurred in a small subset of banded individuals (i.e., the thin-striped group), yielding in this small sample an observed injury rate of approximately 12%. We observed no leg injuries in birds with one band per leg; however, none of these had been banded with thin-striped bands. Our observed injury rates declined to 0% over the last three years of the study after we switched from four bands to two bands per individual and eliminated the use of thin-striped bands.

Although our injury rates were lower than those reported by Sedgwick and Klus (1997), the nature of injuries was similar and a potential cause for concern. Because there is a paucity of published data on leg injury rates in passerines, it is difficult to determine whether the Willow Flycatcher is particularly susceptible to band-related injury as compared to other species. Band-related injuries have been reported in other *Empidonax* and some *Contopus* flycatchers (M. Gustafson, pers. comm.), which may suggest that the tarsi of these genera may be susceptible to abrasion injuries, at least with improperly sized or physically unrefined bands. Injury data reflect only evidence from birds that were injured but survived long enough to be recaptured and re-sighted. It is probable that band-related injury rates are actually higher than can be observed and therefore reported, especially for more serious injuries that prevent a banded individual from surviving between breeding seasons.

Possible Mechanisms for Injury

Sedgwick and Klus (1997) describe a potential route for abrasive injury to flycatcher tarsi: sharp edges on the rims of color bands irritate the tarsus, leading to open wounds that become infected. Predicating that bands are not affixed too tightly, we believe that there are two additional injury mechanisms: (a) oversized bands may slip over the flycatcher distal joint, and (b) sharp lower edges and offset corners where the plastic band is split may cut into the fleshy flycatcher distal joint. Therefore we believe that some leg injuries may be related to the use of improperly sized and/or unsealed bands.

Federal aluminum 0A and 0 bands are associated with low rates of injury (Sedgwick and Klus 1997; M. Whitfield, pers. com.) and contributed to no injuries observed in this study. Our measurements indicate they are a better fit to the Willow Flycatcher tarsus than are unmodified plastic bands, and therefore less likely to slide along and abrade the tarsus. An over-sized band moves easily around and along the tarsus, and would therefore be more likely to cause abrasion than bands of more appropriate fit. In addition to abrasion injuries, oversized bands can slide over the distal joint severely restricting use of the foot, and can circumscribe the distal joint to cause ischaemic injury (a deficiency of blood as a result of functional constriction). This would ultimately lead to tissue necrosis and loss of part or all of the extremity, possibly amplified by self-mutilation. Privation of foot use and foot loss are potentially serious enough to preclude survivorship through an entire annual cycle. Unmodified federal bands probably rarely slide over the distal joint, reducing their potential to cause injury.

Other band features that probably contribute to abrasion are sharp or rough edges, including unsealed edges, improper seal (e.g., resulting in offset edges), and band gauge. The gauge of thin-striped bands in our study was smaller (mean = 0.40 mm ± 0.03 SD, range = 0.35–0.45) than solid and broad-striped celluloid bands collectively (mean = 0.50 mm ± 0.03 SD, range = 0.45–0.55). Being relatively narrow, the lower rim of the thin-striped bands we used during the initial years of our field study (prior to discontinued use due to the aforementioned injuries) may have acted like a cutting edge, especially under the weight of a second band. Although it was not possible to test this, we have not detected band-caused injuries subsequent to eliminating this type of band and reducing the number of bands per leg from two to one.

Trapping of debris and mud under the band contributes to leg injuries in shorebirds (Amat 1999), and trapped plant debris has been implicated in impairment of foot function and occasional foot loss in Least Bell's Vireos (*Vireo bellii pusillus*; B. Kus, pers. comm.). Although we have found plant material imbedded in and wrapped around the tarsi of a small number of flycatchers during initial and subsequent capture (N = 1 banded, N = 3 unbanded), we have seen no injuries that appear related to these plant materials.

RECOMMENDATIONS

Band Size

Based on tarsus and distal joint measurements, we recommend use of size 0A federal aluminum bands on Southwestern Willow Flycatchers. We have no data to indicate harmful effects to flycatchers resulting from use of the slightly larger size 0 band, but size 0A bands would seem to preclude the possibility of slippage over the distal joint. Because tarsal diameter and width of the distal joint may vary between subspecies of the Willow Flycatcher, we recommend the determination of leg size prior to banding. If color marking Southwestern Willow Flycatchers, celluloid color bands should be resized to 2.0 mm ± 0.1 inside diameter.

Band Material

A few studies have reported that the federal aluminum bands have a low frequency of band injury (Sedgwick and Klus 1997; M. Sogge and M. Whitfield, pers. comm.; W. Haas, pers. obs.). We believe the low incidence of leg injury from federal bands is due to their gauge, weight, and their smooth surfaces that lack sharp edges. Metal bands can be colored to provide auxiliary marking schemes, and we recommend that any such metal color bands mimic the federal Size 0A bands in size (including inside diameter), weight, and edge characteristics. Bands should be inspected for appropriate thickness and smooth, rounded edges prior to entering the field; sharp, acute, and/or rough edges should be repaired using sandpaper, file, emery board, or other similar abrasive agent.

Plastic color bands are inexpensive, commercially available in a large number of colors and color combinations, and maintain color throughout the typical 3 to 5-year Southwestern Willow Flycatcher lifespan. Although they can cause leg injuries if used "as purchased," we found that celluloid bands can be safely used on Southwestern Willow Flycatchers if (a) re-sized, (b) smoothed to remove sharp edges (see below) and to provide a continuous seal at the butt-ends, and (c) closed with acetone or other appropriate sealing agent to reduce the amount of potentially abrasive surface and maintain a prescribed inside diameter. Although correctly modified plastic color bands are suitable for use, thin-walled celluloid bands (e.g., the thin-striped bands from our study), bands with rough or sharp edges, and incorrectly sized bands are not appropriate for use on Willow Flycatchers.

Band Modification

We used the following techniques to re-size and modify the XF celluloid color bands used in our study. We removed sufficient material to create a band of approximately 2.0 mm inside diameter by filing down the butt-end of each band. We filed rather than cut the edges to create a more porous and nearly parallel surface that enhances later bonding by increasing available surface area; cutting with scissors or nail clipper can compress the butt ends and reduce bonding surface area. Once altered, the bands were temporarily re-closed and measured to assure we had reached the proper inside diameter. We then inspected the upper and lower edges of the bands, and used an emery board, file, or application of acetone to smooth and round all rough edges. In the field, after applying the band to the bird's tarsus, we inspected the band's fit to ensure that it would not slide over the distal joint. After ascertaining the band was the correct size, we bonded the ends of the band with acetone or an alternate adhesive. Note that small celluloid bands do not maintain plastic "memory" and do not easily regain their original circular conformation without time-consuming heating and re-conforming (Haas and Fisher 1999). Sealing the bands after placement is thus mandatory. After bonding, we re-inspected the band to be sure it did not adhere to the tarsus or present other physical risk.

Treatment of Injuries

Because it is impossible to conduct banding activities with 100% certainty that no band-related injuries will occur (see Marion and Shamis 1977), it is important to design banding studies that include sufficient time and efforts to look for band-related injuries. When an injured bird is found, we recommend an attempt to re-capture the bird, replace or remove any worn, improperly sized, or otherwise flawed bands, and administer to the injury. In our study, we removed the offending bands (but generally maintained the federal numbered band) and treated the wounds with a full strength 10% povidone-iodine solution, then released the bird at the point of capture; if the band injury was sufficiently serious we removed all bands. Abrasive band injuries appeared to heal after band removal and treatment with this antibiotic solution (Table 1).

Commercial Manufacture of Bands

For the Willow Flycatcher and other small passerines (e.g., California Gnatcatcher, *Polioptila californica*; Least Bell's Vireo), commercially manufactured plastic bands may not be suitable for use without time-consuming modification. A preferred alternative would be to have appropriately-sized bands manufactured to the correct specifications. Also, we feel there is a need for improved quality control so that inside band diameter is less variable than we found in this study. We also suggest that commercial manufacturers specify the approximate weight and gauge of their bands, allowing banders a clear choice when deciding which bands to order for their specific needs.

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USING RADIOTELEMETRY TO DETERMINE HOME RANGE SIZE, HABITAT USE, AND MOVEMENT PATTERNS OF WILLOW FLYCATCHERS

EBEN H. PAXTON, SUZANNE N. CARDINAL, AND THOMAS J. KORONKIEWICZ

Abstract. In 2002, we tracked four Willow Flycatchers (*Empidonax traillii*) for eight days with radiotransmitters. Although conducted for only a brief period of time and on a small number of individuals, this is the first radiotelemetry study of Willow Flycatchers, and the information gleaned has potentially important implications for current and future Willow Flycatcher research and management. An average of 30 locations were collected on each individual, yielding insight into home range, habitat use, and movements. The average size of the home range of three of the four flycatchers was 1.2 ha (based on the minimum convex polygon method). The fourth individual was tracked over a much larger area than the other three, with movements of up to 2.5 km documented. Home range estimates for all four flycatchers were still rapidly increasing by the end of the study, indicating that the documented sizes are under-estimates. All flycatchers used a variety of habitat types, including the mature riparian vegetation that they nest in, surrounding sparsely vegetated young riparian habitat, and non-riparian upland habitat. This study found that telemetry is a viable research technique for the Willow Flycatcher, and can provide important information on home range, habitat use, and movement patterns. Further study is needed to evaluate how common or rare our findings are for the Willow Flycatcher across its range.

Key Words: *Empidonax traillii;* habitat use; home range; movements; radiotelemetry; Willow Flycatcher.

Understanding the habitat requirements of a species requires information on the size of area it occupies, types of habitat it uses, and how it moves throughout its environment. Willow Flycatchers (*Empidonax traillii*) are small neotropical migrants that breed only in riparian habitat in the arid West. They nest in dense riparian vegetation patches, which are typically surrounded by a patchwork of multiple habitat types. Willow Flycatcher habitat is sometimes considered as only that habitat in which nesting occurs; however, observations of breeding flycatchers outside of the riparian nesting area (E. Paxton, unpubl. data) suggest that flycatchers may use a much larger area and a broader range of habitats than is commonly assumed. Habitat that is not used for nesting, but is interspersed with it, may be an important component of breeding site selection and overall patch use. Flycatchers may move outside of their nesting area to acquire resources (e.g., food, water) or to obtain extra-pair copulations (EPCs). Documenting these possible uses is important for understanding habitat needs, local population estimates (under- or over-counting), and genetic diversity patterns.

Radiotelemetry has proven to be an important tool for answering questions about habitat requirements and other important aspects of a species' natural history (Kenward 2001). Furthermore, telemetry is the best method for finding and tracking flycatchers in the dense riparian habitat in which they breed, as flycatchers are difficult to detect unless near a nest or vocalizing. However, some studies have found harmful effects of transmitters on birds (Bowman and Aborn 2001, Hooge 1991), which argues for a pilot study to evaluate the technique, for each species, before application on a large group of individuals (Brigham 1989). This study was undertaken to evaluate the feasibility of applying radiotelemetry techniques to the Willow Flycatcher and to gather preliminary information on home range size, habitat use, and movement patterns.

STUDY AREA AND METHODS

This study was conducted at Fish Creek, Utah County, Utah (39°46′N, 110°15′W). Fish Creek is a high elevation (2560 m) meandering creek, with a narrow floodplain situated at the base of a steep mountain valley. Three general habitat types were identified at the study area. Mature riparian habitat was characterized by a single, dense vegetative layer of willow (*Salix* spp.) with a canopy height of 3 to 6 m. This habitat type was interspersed and surrounded by young riparian scrub, which consisted of a mix of short willow (< 2 m), herbaceous plants, grass, and open areas. Immediately adjacent to the riparian floodplain, on the steep mountain slopes, was non-riparian upland habitat. The upland habitat consisted primarily of sagebrush (*Artemisia* spp.), with fir (*Abies* spp.) and spruce (*Picea* spp.) present on the north-facing slopes.

We captured Willow Flycatchers via mist-nets and a targeted capture technique (Sogge et al. 2001), and each flycatcher was color-banded to facilitate individual identification. We determined sex based on the presence of a cloacal protuberance for males or brood patch for females. Breeding status was determined by

TABLE 1. HOME RANGE SIZE, MOVEMENT DISTANCES, AND HABITAT USED BY WILLOW FLYCATCHERS AT FISH CREEK, UTAH 2002

Bird	Sex	Territory	No. of locations	Home range size (ha)[a]	Distance among all locations (m)		Percent of locations in each habitat type (number of locations)		
					Maximum	Average	Mature	Young	Upland
WIFL1	M	A	41	[b]	2900	218	41% (17)	39% (16)	20% (8)
WIFL2	F	B	23	0.94	128	47	39% (9)	35% (8)	26% (6)
WIFL3	M	B	29	1.07	107	49	59% (17)	34% (10)	7% (2)
WIFL4	M	C	27	1.66	149	52	52% (14)	26% (7)	22% (6)

[a] Home range sizes were estimated using the minimum convex polygon method and all locations.
[b] WIFL1 was documented traveling over large distances, resulting in a minimum convex polygon area estimate of 106 ha; it is not apparent which subset of this area should be considered as home range.

observation of pair interaction and/or nest attendance, and nests were located by searching areas frequented by vocalizing females.

We used a glue-on method (Johnson et al. 1992) for attaching LB-2 transmitters (Holohil, Inc., 0.47 g) to the backs of flycatchers. Prior to capture, we glued a small piece of grid cloth to the bottom of the transmitters to facilitate a greater surface area for contact with the bird. We then trimmed the cloth to a size just larger than the transmitter's footprint. We held captured flycatchers in one hand and clipped the feathers from an area slightly larger than the circumference of the transmitter, approximately 20 mm above the uropygial gland. A moderate and even amount of Skin-Bond was applied with a soft brush to the transmitter and exposed skin, and allowed to dry for 5 mins. The transmitter was then pressed into place on the bird and held with light pressure for 2–5 min. After a gentle pull to ensure the transmitter was in place, the contour feathers were rearranged to cover the transmitter, and the bird was released.

We tracked flycatchers using an R-1000 Telemetry receiver (Communications Specialists, Inc.) and a standard hand-held 3-element yagi antenna. Locations of flycatchers were determined by moving in the direction of a radio signal until an individual was seen. When an individual was observed, we looked for any apparent effects of the transmitters and noted its behavior (e.g., perching, foraging, singing, interactions, flight). After the bird moved, we recorded the location's coordinates via a Garmin E-trek Legend GPS unit, accurate to 3.5 m ± 2.5 m. Our sampling regime consisted of tracking flycatchers from dawn to dusk, in a random order, with at least one hour between successive locations of a particular individual (to eliminate auto-correlation of data points). However, one flycatcher (WIFL1, see below) was tracked continuously while it conducted long-distance forays out of its territory.

We defined home range as the area encompassed within a polygon drawn from the outermost points of all locations (minimum convex polygon method; White and Garrott 1990). We could not define home range for the one flycatcher that traveled over large areas. Habitat was determined by field observations and overlaying the location coordinates onto a rectified aerial photograph of the study area using Arcview (v. 3.2) software. We also used Arcview with the Animal Movement extension (Hooge and Eichenlaub 1997) to calculate home range, average and maximum distance between all locations, and to produce Figures 1 and 2.

RESULTS

Four Willow Flycatchers were tracked with radio-transmitters for eight days from July 8 to July 15, 2002. WIFL1 was a paired male from territory A, with an approximate nest location identified based on the female's behavior. WIFL2 and WIFL3, female and male, respectively, were paired in territory B. Their nest contained eggs at the beginning of the study but was depredated mid-way through the study; the female re-nested by the end of the study. WIFL4 was a male paired in territory C, with its nest containing 2–3 day old young at the beginning of the study (Table 1).

Radiotelemetry was very successful in tracking the flycatchers over large distances and among the dense riparian habitat that they nested in. We were able to locate individuals over 1 km away, track them through dense vegetation, and track extra-territorial movements that were unlikely to have been detected without telemetry. Furthermore, we did not observe any behaviors indicating problems with the attached transmitters. However, we were not able to evaluate potentially subtle effects of the transmitters, such as reduced productivity, survivorship, and territory maintenance.

HOME RANGE

An average of 30 locations was collected on each flycatcher (Table 1, Figs. 1, 2). WIFL2, WIFL3, and WIFL4 had an average home range of 1.2 ± 0.4 ha. WIFL1 was documented traveling long distances from its defended territory, yielding a minimum convex polygon size of 106 ha. However, the flycatcher appeared to only pass through, rather than use, large areas within the minimum convex polygon (Fig. 2), so we believe its true home range is much smaller than this minimum convex polygon estimate. The average distance between locations of all flycatch-

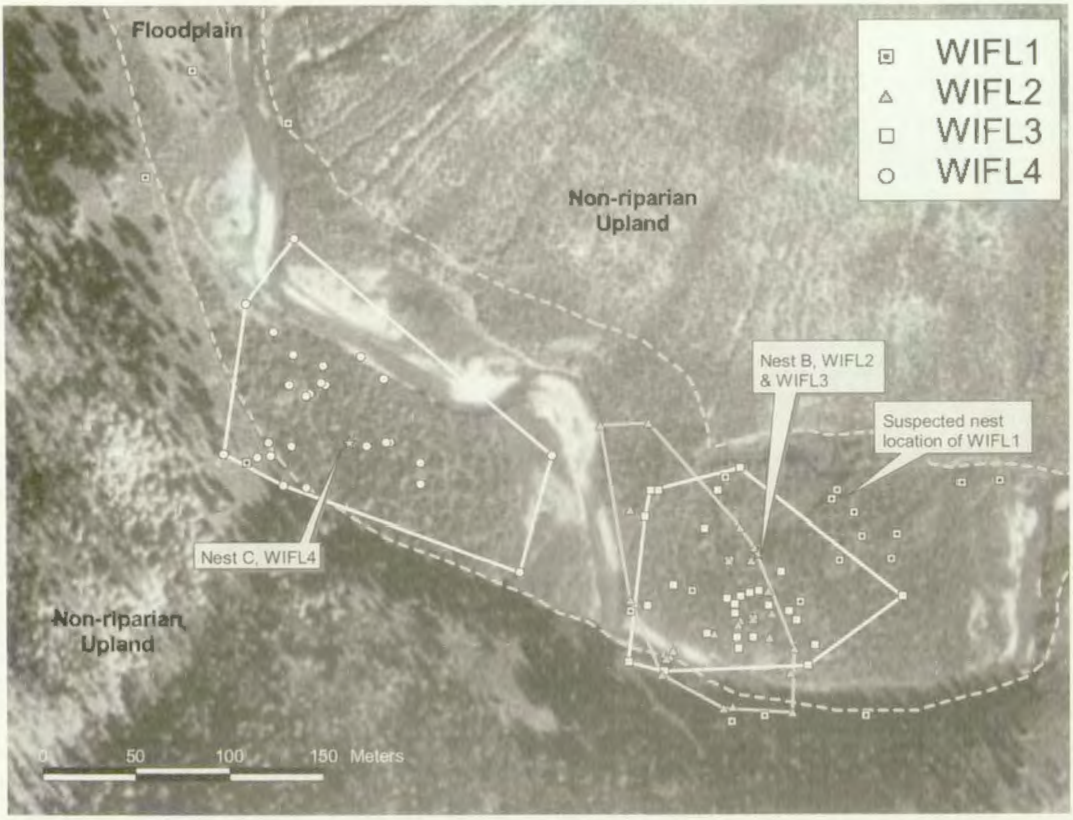

FIGURE 1. Locations of the Willow Flycatchers and nests at the 2002 Fish Creek, UT, core study area. Individual locations and minimum convex polygon home ranges are shown for WIFL2, WIFL3, and WIFL4. Only individual locations are shown for WIFL1. Dashed lines indicate the boundary between the non-riparian upland and the floodplain. Mature willow, young riparian scrub vegetation, and non-vegetated areas occur within the floodplain.

ers except WIFL1 was 49 ± 2.5 m, with an average maximum distance of 128 ± 21 m. WIFL1 averaged 218 m between locations, with a maximum distance of 2.9 km. For all flycatchers, home range estimates continued to increase rapidly by the end of the study, without appearing to reach an asymptote, indicating that these home range sizes are under-estimates.

Habitat Use

All four flycatchers were observed using the three general habitat types identified at the study area (mature riparian, young riparian scrub, non-riparian upland). Almost half (48%) of the four flycatchers' locations were recorded in the mature riparian habitat, and 34% and 18% were

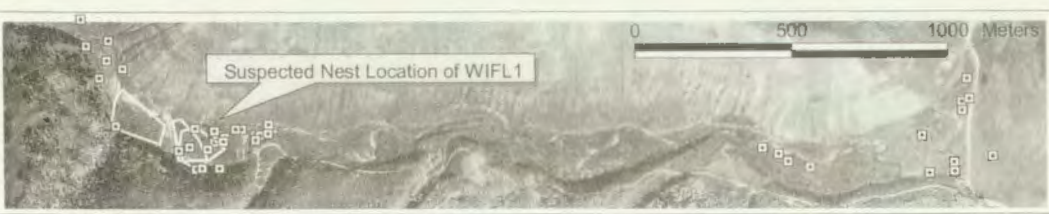

FIGURE 2. All detection locations for WIFL1 (white squares with black centers), and minimum convex polygons for WIFL2, WIFL3, and WIFL4 (white bordered polygons; refer to Fig. 1 for details), at the Fish Creek, UT, study area.

recorded in the young riparian scrub and non-riparian upland habitats, respectively (Table 1).

Activities in the various habitats were not always identifiable, but in general activities in the mature riparian included nest attendance, singing, foraging, resting, and territory intrusion. We observed flycatchers foraging and resting in the young riparian scrub, but only foraging activities were noted in the non-riparian upland habitat type.

MOVEMENTS

Observed movements varied among the four individuals. All but WIFL1 were consistently found in either their nesting patch, in immediately adjacent young riparian scrub, or in non-riparian habitat near their breeding patches.

During the tracking period, WIFL1 exhibited strikingly different movement activities from the other three flycatchers, with three notable long distance movements observed. The first was a two-hr foraging foray, where the bird progressed gradually upstream from one upland hillside to another. After moving 0.5 km upstream, it flew to the riparian zone and foraged in young riparian scrub habitat. At the end of the two-hr period, it returned to its suspected nesting area. The second notable movement occurred when the flycatcher was located in late morning 1 km downstream from its suspected nesting area. It continued to go downstream, and was tracked all afternoon and into the evening as it moved around the riparian habitat at the mouth of Fish Creek. The flycatcher spent the night at this downstream area, then returned to its defended area within one hr of dawn the next morning. The third long-distance movement occurred several days later, when the flycatcher was detected again in the same downstream area. These downstream movements occurred as far as 2.5 km from the flycatcher's defended territory and suspected nesting location.

Foraging appeared to be the primary activity that occurred when flycatchers moved beyond their defended territories; territory intrusion was a second. During WIFL1's 2.5-km downstream movement, we observed it entering, and being chased out of, another active Willow Flycatcher territory. It was also tracked into WIFL4's nest area, and a territorial interaction was heard just before it flew away. A third activity may have been mate guarding. WIFL3 was twice seen following his mate (WIFL2) across the creek to forage on the upland sagebrush hillsides. The female was rebuilding a depredated nest, and had not yet laid eggs; thus, this concurrent movement may have been extra-territorial mate guarding behavior rather than simply a joint foraging foray.

DISCUSSION

HOME RANGE

Territory size and home range are spatial measures with biological importance, and both are commonly used in defining habitat requirements (White and Garrott 1990). We used the most inclusive definition of home range for this study to evaluate the full extent of habitats used and maximum area utilized. However, home ranges are often presented as a subset of the total number of locations, such as excluding 5% of the outermost locations. Our home range estimates were still rapidly increasing in size by the end of the study, indicating that gathering more locations would have yielded larger area estimates. Although the number of locations and duration of study is minimally adequate for home range estimates (Kenward 2001), we believe it important to track more individuals over a longer period, to evaluate the total area utilized by individuals, to learn whether area used changes over the breeding season, and to determine what subset of locations should be used for home range estimate. Further, more study is needed to determine how frequently long distance forays (such as seen for WIFL1) occur, and whether some areas utilized in such forays should be included in home range estimates.

Most studies that have attempted to define the area occupied by Willow Flycatchers are not directly comparable to this study because they used mapping of flycatcher song perches to define a territory, which excludes detection of any extra-territorial movements (Hanski and Haila 1988). Given the difficulty of sighting flycatchers in the dense vegetation, many of the movements outside the core home range would not likely have been detected without telemetry-based research techniques. Flycatchers may require different amounts of area to support their breeding efforts at different sites, and in different years. Documenting these differences, and evaluating potential corollary factors, could provide important insight into general habitat needs of the flycatcher.

HABITAT USE

Although flycatchers spent most of their time in the mature riparian habitat, they frequently used the surrounding young riparian scrub and non-riparian upland habitat. All individuals were detected in the upland sagebrush, suggesting that this adjacent non-riparian habitat may be important, although further study is needed to evaluate its importance for breeding success. The narrow, linear structure of the Fish Creek study area may have facilitated flycatcher use of nearby non-riparian habitat types. Flycatchers breeding at sites in broad floodplains may not utilize more distant non-riparian habitats.

Across its range, the Willow Flycatcher breeds in a wide variety of habitats (Sedgwick 2000, Sogge and Marshall 2000). Documenting flycatcher habitat use, home range, and movement patterns across a range of habitat types would provide much needed insight into habitat requirements of the flycatcher in general, and the interaction of local landscapes and flycatcher movements. Also, because this study covered only a small portion of the breeding season, it will be important to determine how use changes over time. Our findings suggest that studies of flycatcher habitat characteristics and use may need to quantify vegetation beyond nest and song perch locations, and that a broader landscape-scale approach, taking into account adjacent habitats and land uses, may be important.

Movements

Flycatchers displayed a wide variety of movements. The frequent movement of all flycatchers out of the mature riparian habitat into surrounding areas, particularly the non-riparian upland habitat, throughout the day, was notable. Longer-term studies are needed to evaluate whether this frequency of movements occurs throughout the breeding season and at different sites.

The long-distance movements of WIFL1 were also unexpected. Whether the long distance movement of WIFL1 is unusual, or simply seldom observed, cannot be answered by this study. One explanation for this movement might be due to the different nesting stages of the flycatchers. Although we documented that the other three flycatchers were on active nests (eggs, young nestlings, and/or nest rebuilding), the nest of WIFL1 was not found. WIFL1 was paired at the beginning of the study, but it appeared that the pair bond degraded by the end of the study, and no fledglings were observed with either WIFL1 or its mate. Thus, WIFL1's long-distance movement may have been due to the collapse of its pair bond, and its search for other breeding opportunities.

CONCLUSION

We conclude that radiotelemetry is a viable technique for Willow Flycatcher research. We were able to successfully track individuals through dense vegetation and across relatively large distances, and we did not detect any negative effects of the transmitters on Willow Flycatchers. Results from this study suggest that flycatchers at Fish Creek use a much larger area than their defended territory, regularly utilize adjacent non-riparian habitat, and are capable of long-distance movements in a relatively short period of time. Future telemetry studies, especially at other sites, should provide information on how common, or rare, the findings of this study are. Objectives for further study include determining (1) the importance of the different habitat types used, (2) the importance of areas used during extra-territorial forays, and (3) whether the landscape composition at different sites influences flycatcher home range size and habitats use. Finding answers to these questions is particularly important for the management of the endangered Southwestern Willow Flycatcher (*E. t. extimus*).

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