



Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Real and Artificial Nest Predation and Parental Nest Attendance along the Lower Colorado River and Southern Nevada

Final Report



September 2011

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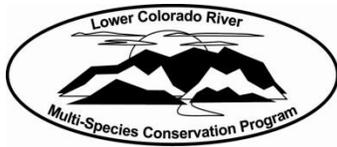
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Lower Colorado River Multi-Species Conservation Program

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Final Report

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ACRONYMS AND ABBREVIATIONS

AOV	analysis of variance
cm	centimeter(s)
CVCA	Cibola Valley Conservation Area
ha	hectare(s)
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
MANOVA	multivariate analysis of variance
NAU	Northern Arizona University
NWR	National Wildlife Refuge
Reclamation	Bureau of Reclamation
SD	standard deviation
SE	standard error
USFWS	U.S. Fish and Wildlife Service
UTM	Universal Transverse Mercator
WMA	Wildlife Management Area

Symbols (if any)

°C	degrees Celsius
%	percent

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EXECUTIVE SUMMARY

We monitored egg predation at artificial nests constructed to represent those of open-cup, tree-nesting passerine birds at 4 sites along the lower Colorado River in 2008 and at 11 sites in 2009. Sites were chosen to represent a spectrum of patch sizes, dominant vegetation types, and surrounding matrix. Clay eggs in artificial nests recorded both beak marks of birds and teeth marks of rodents, and automatic still cameras recorded photographs of animals visiting nests. Sites varied markedly in both time to predation of artificial nest loss and the identity of nest visitors, with some sites suffering rapid and complete loss while others experienced relatively light nest predation. Rodents were the dominant artificial nest visitor at some sites while birds dominated others. Nests placed in mesquite trees had proportionally higher rates of nest visitation by rodents than those placed in tamarisk, cottonwood, or willow, but there was no significant association between time to artificial nest predation or type of visitor with any of the other habitat parameters we investigated. Brown-headed cowbirds and yellow-breasted chats were the two most common species recorded at artificial nests, followed by Bewick's wrens (*Thryomanes bewickii*) and Bullock's orioles. We also recorded one common roadrunner and one pair of western screech owls at nests. Rodent artificial nest visitors included both *Peromyscus* spp. and *Neotoma* spp. Time to artificial nest loss did not differ between early (mid-May) and late (mid-June) season periods at the four sites studied in 2008. Time to nest loss was significantly faster in 2009 compared to 2008 at Mesquite, Nevada, but there was no difference between years at Pahrnagat National Wildlife Refuge (NWR). This increased artificial nest predation at Mesquite in 2009 was concordant with lack of water at the site, which resulted in premature leaf abscission and significantly lower canopy cover.

To determine how artificial nests compared to real nests, we followed the fate of 67 real nests in 2008, including those of Bell's vireos, yellow warblers, yellow-breasted chats, song sparrows, and southwestern willow flycatchers. In 2009–11, we placed microvideo cameras on 58 real nests at the Mesquite, Pahrnagat NWR, and Key Pittman Wildlife Management Area (WMA) study sites, including nests of southwestern willow flycatchers, yellow warblers, and yellow-breasted chats. We recorded 14 nest predation events at these real nests, including egg predation by a yellow-breasted chat, Bewick's Wren, gray catbird (*Dumetella carolinensis*), and American crows (*Corvus brachyrhynchos*); nestling predation by a red-shouldered hawk (*Buteo lineatus*), an American crow, a western king snake, a short-tailed weasel (*Mustela frenata*); and two instances of female brown-headed cowbirds killing nestlings at willow flycatcher (*Empidonax traillii*) nests at Mesquite, Nevada. The real nest predators we documented have all been documented as nest predators in previous studies. The overlap between nest predators we recorded at real nests and species we recorded visiting artificial nests suggests that (1) artificial nests may be an effective rapid assessment technique that could be used to assess potential avian egg predators at sites of management interest, (2) artificial nests would likely underestimate the potential for snake

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predation and overestimate the potential for rodent predation, and (3) real nest monitoring is the most accurate way to identify nest predators and is likely the only way to identify many nestling predators.

To investigate how ambient temperature could potentially affect parental behavior and thereby nest predation, we recorded nest attendance behavior using still cameras on two Bell's vireo nests and one yellow-breasted chat nest at Bill Williams River NWR in 2008 and at four yellow warbler, nine southwestern willow flycatcher, and one yellow-breasted chat nest using microvideo cameras in 2009. Of those nests, we focused our analyses on eight nests that contained eggs during our video surveillance—two yellow warbler and two willow flycatcher nests at Mesquite and four willow flycatcher nests at Pahrnagat NWR. The major results indicated (1) there was no relationship between ambient temperature and number or mean length of brooding bouts at either Pahrnagat NWR or Mesquite, (2) birds at Mesquite had more frequent and shorter brooding bouts and left nests unattended significantly longer than birds at Pahrnagat NWR, and (3) the amount of time away from nests decreased sharply at temperatures above 40 degrees Celsius ($^{\circ}\text{C}$), but behavioral shifts from brooding eggs to covering or shading them consistently occurred at much lower temperatures, approximately 29–31 $^{\circ}\text{C}$. We hypothesize that differences between Mesquite and Pahrnagat NWR in food availability and/or quality or perceived threat of nest predation and parasitism may be drivers of these behavioral differences in nest attendance.

Finally, we investigated the interaction between standing water, vegetative understory density, aerial insect abundance, parental nest attendance, and nest success at Pahrnagat NWR and Key Pittman WMA in 2010 and 2011. We found that (1) vegetative understory density increased through the season to levels significantly higher than that documented at active willow flycatcher nests; (2) aerial insect abundance, clutch size, and nestling feeding rates all decreased with increasing distance from water's edge; and (3) the number of territories, number of nests, and number of fledglings across years at Pahrnagat NWR indicated a relatively constant number of territories and output of fledglings regardless of whether the site was inundated or not. Our results suggest that maintaining or increasing standing water may positively impact flycatcher habitat by limiting undergrowth and potentially reducing nest predation while increasing the abundance of aquatic food resources, but that increasing the extent of standing water alone is unlikely to increase the number of territories without increases in available habitat. Therefore, increasing standing water to reduce nest predation and maintain insect prey while increasing overall patch size may be the management approach with the greatest potential for increasing the number of flycatchers at this and other occupied sites.

CHAPTER 1 – BACKGROUND

General Introduction and Rationale

For any species, a critical function of habitat is supporting reproductive rates that can maintain populations through time. For birds (including those species covered in the Lower Colorado River Multi-Species Conservation Program (LCR MSCP), reproductive success (productivity) depends on availability of suitable nest sites, adequate food resources, and fledgling survival, and it is influenced by nest predation and parasitism. These factors interact to determine whether a restored or managed area acts as a population source (reproductive success is high enough to produce excess offspring) or a population sink (reproductive success is too low to maintain the population). For many bird species that make open-cup nests (e.g., southwestern willow flycatcher, yellow-billed cuckoo, vermilion flycatcher, Arizona Bell's vireo, Sonoran yellow warbler, and summer tanager, covered in the LCR MSCP), nest predation has been identified as a major factor determining annual productivity (Ricklefs 1969; Martin 1988). The LCR MSCP conservation goals for these species call for (1) creating new habitat, (2) avoiding and minimizing impacts of implementing covered activities and the LCR MSCP conservation plan, and (3) implementing population enhancement conservation measures. Understanding how nest predation may vary under different restoration and management scenarios therefore becomes critical in developing plans that will meet the goal of maintaining and enhancing populations of these species. Moreover, plans developed and implemented for "Conservation Area Management" under the LCR MSCP should include "predator/competitor management" (MSCP Habitat Conservation Plan Section 5.5.3). Currently, no data are available regarding what predators are responsible for nest depredation of avian species within the LCR MSCP area.

Two factors that could affect the rate of nest predation and that are relevant to current habitat restoration along the lower Colorado River (LCR) are the relative size and shape of a riparian area (which affect both the amount of habitat available and the amount of habitat edge) and the broader landscape matrix in which that riparian area exists. For example, a small, narrow riparian area may support a different predator community than a large, wide one. Some studies have found a positive relationship between nest success and riparian-forest width or patch size (e.g., Vander Haegen and DeGraaf 1996; Peak et al. 2004) while others have not (e.g., Tewksbury et al. 1998; Knutson et al. 2000). Smaller, narrower riparian areas would also have more edge, and a host of studies have shown that the rate of nest predation is different along the edge of habitat than in the interior (e.g., Dijak and Thompson 2000; Chalfoun et al. 2002; Hoover et al. 2006). The rate of nest predation is also likely influenced by the larger matrix of habitat that surrounds the riparian area, with riparian areas surrounded by highly human-modified (e.g., agricultural, suburban) landscapes unlikely to support the same predator community as those surrounded by extensive stands of natural

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vegetation. For example, abundances of medium-sized predators like raccoons were positively associated with habitat fragments dispersed throughout developed and agricultural habitats (Pedlar et al. 1997; Dijak and Thompson 2000). Given that many of the existing riparian areas along the LCR (both natural and restored) are or will be placed within such a human-modified matrix, it is important to understand how this matrix affects predator communities. The configuration of restored or managed riparian areas may also interact with the broader habitat matrix to influence predator communities and rates of nest predation. Including these factors in LCR MSCP restoration plans may minimize the potential for creating ecological traps and potentially indicate whether bird populations could be enhanced through predator management.

Nest predation may also depend upon the interaction between the predator community and the ability of nesting birds to avoid detection by those predators. Nest predation may be reduced if females can limit the number of times they come and go to a nest by lengthening incubation bouts, or once off the nest, lengthening the time they leave eggs unattended. This behavior is likely influenced by the microclimate the incubating bird, eggs, and young experience at the nest site (Conway and Martin 2000). If nests are located where conditions remain within the optimal range for incubating adults and eggs/young, movements on and off the nest may be reduced, while nests experiencing considerable periods outside these optimal conditions may cause the female to move on and off more frequently. Increased movement on and off the nest by females could allow diurnal, visual predators to find the nest and thereby prey on eggs and young. Currently we know little about how ambient temperature around a nest affects parental attendance or the potential for temperature to influence nest predation.

The goals of this project were to (1) assess rates of nest predation and photograph potential nest predators at artificial nests placed at four study sites that varied in size, dominant vegetation type, and surrounding matrix, (2) follow the fate of real nests to determine whether real nest predation rates reflected that observed on artificial nests, and (3) simultaneously monitor parental behavior and ambient temperature near real nests to determine how nest attendance behavior interacted with ambient air temperature and distance to water.

CHAPTER 2 – ARTIFICIAL NEST PREDATION

Introduction

The use of artificial nests to assess nest predation potential has several advantages over using real nests. First, artificial nests can be placed at a site simultaneously and monitored for a pre-determined period, thereby controlling for seasonal changes in predation pressure. Second, artificial nests can be placed in areas where real nests are rare or non-existent, thereby allowing assessment of predation potential at sites currently unoccupied by focal species. Finally, artificial nests can reduce the time necessary to assess predation potential at a site by removing the need for nest searching and reducing nest monitoring time.

The validity of artificial nests as surrogates for real nests has been challenged both because artificial nests were often not very realistic and because they often did not attract the same predators that were attracted to real nests (e.g., Martin 1987; Faaborg 2004). Studies have shown that when better nest mimics are used, artificial nests are more likely to attract the same species of predators in similar proportions as natural nests (Davidson and Bollinger 2000; Pärt and Wertenberg 2002). Likewise, many artificial nest studies have used a surrogate species' egg that is easy to obtain (e.g., Japanese quail [*Coturnix* spp.]), but these eggs are often larger and more difficult to open than those of species of interest, thereby biasing the suite of predators that could successfully attack artificial nests baited with these eggs. By using eggs of smaller-bodied surrogate species, like zebra finches, or by including artificial plasticine (clay) eggs, artificial nests can better reflect potential predators of artificial nests (Thompson and Burhans 2004). We used a combination of quail, zebra finch, and plasticine eggs placed in artificial nests that were constructed from local, natural material to assess potential predators and predation rates of open-cup nesters at 13 study sites.

Study Sites

From May to July 2008, we carried out artificial nest experiments and monitored real nests at four study sites in Nevada and Arizona that differed in patch size and surrounding matrix (figure 2-1). The stand of tall (15–18 meters [m]), large-diameter Goodding's willow at the inflow of Upper Pahranaagat NWR Lake in Pahranaagat National Wildlife Refuge (NWR), Nevada, represented a small patch (4.5 hectares [ha]) dominated by native vegetation within a relatively natural matrix of pasture and Great Basin desert upland. A shorter stand (5m) of mixed willow and tamarisk along the Virgin River on the southern edge of the city of Mesquite, Nevada, represented a relatively small patch (18.2 ha) of non-native/native habitat in a human-dominated matrix, being bordered by a golf course and housing development on the side away from the river. The mature, dense stands of tamarisk at Topock Marsh within Havasu National Wildlife

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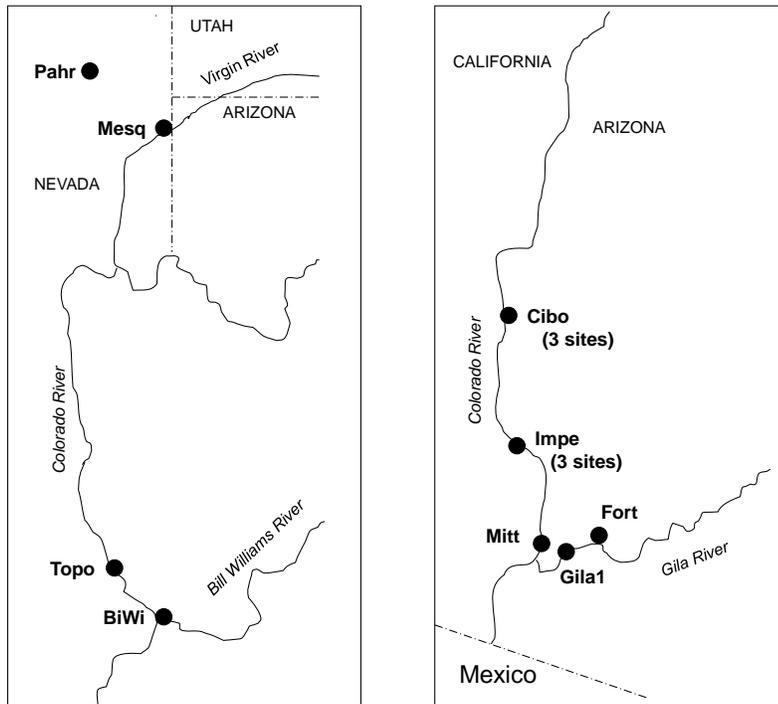


Figure 2-1.—Location of 13 study sites at which we monitored nest predation on artificial nests during May–July 2008 and 2009.

(Pahr = Pahrnagat NWR, Nevada; Mesq = Mesquite, Nevada; Topo = Topock Marsh, Arizona; BiWi = Bill Williams River NWR, Arizona; Cibo = three sites near Cibola NWR near Blythe, California, which included Cibola Valley Conservation Area Nursery, Cibola Nature Trail, and Cibola Sites 1 and 2 (Cib1); IMPE = three sites near Imperial NWR, which included Imperial Nursery (ImpN), Great Blue Heron (GBH), and Martinez Lake (Mart); and three sites near Yuma, Arizona, which included Mitt = Mittry Lake West, Gila1 = Gila Confluence North, and Fort = Fortuna.)

Refuge, Arizona, represented a relatively large (2000 ha), non-native dominated stand within a relatively natural matrix. The cottonwood and willow stand along the Bill Williams River in Bill Williams River NWR south of Lake Havasu City, Arizona, represented a relatively large stand (2,500 ha) of native-dominated habitat within a relatively natural matrix. In 2009 we repeated artificial nest experiments at Pahrnagat NWR and Mesquite and at nine additional sites, some of which we considered to be small patches within a human-modified, primarily agricultural matrix, Cibola Valley Conservation Area (CVCA) Nursery, Cibola Nature Trail, Imperial Nursery, Gila Confluence North, and Fortuna) or small sites within a relatively natural matrix (Cibola Sites 1 and 2, Great Blue Heron, Martinez Lake, and Mittry Lake West). We classified these sites based on the relative amount of native and non-native vegetation. Cibola Nature Trail, Imperial Nursery, and CVCA we classified as native (cottonwood, willow, and mesquite); Gila Confluence North, Mittry West, and Martinez Lake were classified as mixed-native (the native component was greater than the exotic); Cibola Sites 1 and 2 and Great Blue Heron were classified as mixed-exotic; and Fortuna was classified as exotic dominated.

Methods

In 2008, 20 artificial nests baited with 2 clay eggs and 1 quail/zebra finch egg were deployed at each of 4 study sites (Pahrnagat NWR, Mesquite, Topock, and Bill Williams River NWR) in 2 sets—1 set of 10 during early breeding season (mid-May to early June) and another 10 during late breeding season (mid-June to early July). We tested whether time to nest loss differed between these two sessions based on the log rank statistic generated by Kaplan-Meier tests run in SPSS version 12. Because we found no significant difference in nest predation rates between early and late season nests at 3 out of 4 sites in 2008, in 2009 we placed a total of 10 artificial nests at each of 13 study sites, thereby allowing us to increase the number of sites surveyed. We limited the total number of nests per site to 10, as many of the sites we studied were very small and would be unlikely to have a larger number of active real nests present simultaneously.

Artificial nests were constructed in the field from vegetation gathered near the area where the nest was to be placed to reduce the potential for foreign odors to attract predators. Natural material was either woven into a nest shape or woven through a supporting structure of 22-gauge galvanized wire. Artificial nests were placed in forks in tree branches and wired in place 1–3 m above the ground at randomly generated Universal Transverse Mercator (UTM) coordinates within each site. The total area from which random locations were drawn was kept the same at each site (200 m x 200 m) to keep artificial nest density similar across all sites. In some cases, real nests from previous years were found within a few meters of the randomly generated UTM, and the abandoned real nest was used instead of the artificial nest.

We used white modeling clay to create appropriately sized egg shapes. In addition to clay eggs, one *Coturnix* quail egg was placed in the early-season nests in 2008 so that any cues given by a real egg would be present in the nest. In the late-season experiment and in 2009 we used smaller, zebra finch eggs instead of quail eggs, as we felt the quail eggs were too large to mimic most passerine species' eggs. Latex gloves were worn throughout nest manufacture and nest and egg handling to reduce associating human odors with nests and eggs.

A motion-triggered still camera (either Moultrie Stealthcam or Wingscapes' Birdcam) was placed within 2–3 m of each artificial nest to monitor nest visitation. Both camera types were triggered by infrared motion detector systems. The Moultrie Stealthcam could monitor nests 24 hours per day and was fitted with infrared light source to capture nocturnal events. The Wingscapes' Birdcam was capable of capturing events from sunrise to sunset, but was not triggered at low light levels or at night. Due to poor performance in 2008, Moultrie Stealthcams were returned to the manufacturer and replaced with Wingscapes' Birdcams in 2009.

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After we placed eggs in nests, each nest and camera was monitored every other day. We recorded any movement or damage to eggs and collected any clay eggs showing potential predator marks. We refrigerated clay eggs retrieved from the field and later examined them under a dissecting microscope to identify the marks left on them. We removed nests that showed obvious egg predation if the camera recorded images of predators at the nest. If the camera failed to record an image at a predated nest, we replaced eggs and left the nest in place in the hope that the predator might return. All artificial nests were removed after 14 days, a period similar to the egg stage of most passerines in the study area.

At each artificial nest location we measured nest height and height of ground cover below the nest using a 2-m measuring stick marked in 1-centimeter [cm] increments. We visually estimated canopy cover above nest as the percentage of the area blocked by vegetation when the sky above the nest was viewed through a 2.5-cm-diameter viewing tube. We estimated percentage of ground cover below the nest as the area of a 2 x 2 m square centered under the nest covered by vegetation. Finally, we noted whether standing water was present below the structure upon which the nest was placed. We used Cox regression in SPSS version 12 to assess whether the habitat variables visually estimated at the nest and three site factors were associated with time to predation separately for data collected in 2008 and 2009. We entered all variables into the model in a single step (the "Enter" option) and coded nest height, canopy height directly above nest, canopy cover directly above nest, height, and percentage of ground cover below nest as continuous variables, and presence of water and patch size (small <50 ha versus large >1,000 ha), dominant vegetation type (native versus exotic), and surrounding matrix (human-modified versus natural) as categorical variables. We had data from two sites (Mesquite and Pahrnagat NWR) in both 2008 and 2009. For these sites, we used Kaplan-Meier tests to determine whether rate of nest loss differed between years.

Cox regression tests for associations with time to nest predation, but environmental parameters could also vary between nests that experience predation versus those that do not, independent of the time it took nests to be preyed upon. Therefore, we also tested whether nest height, canopy height, canopy cover, and ground cover height differed between nests that experienced predation and those that did not using multivariate analysis of variance (AOV), with site as a covariate. We examined these factors independently for 2008 and 2009 data. In 2009 we compared nests visited by rodents to unvisited nests separately from analyses of nests visited by birds because these two categories of nest predators likely search for nests in different ways. We did not do so in 2008 because no nests were visited by rodents in that year. To determine whether nest parameters changed across years, we compared nest height, canopy height, canopy cover, and ground cover across years using t-tests at the two sites where we monitored artificial nest predation in both 2008 and 2009. Before running t-tests and AOV, we tested data for deviation from normality using Shapiro-Wilk's W test and transformed data when they did not meet assumptions of normality. All analyses were run using SPSS version 12.

Results

2008 Field Season

Of the 80 artificial nests deployed in 2008, 42 (53 percent [%]) suffered loss of at least some artificial or real eggs. At 3 of the sites, time to nest predation on artificial nests was not significantly different between the early and late sets of 10 eggs (Pahr: log rank = 0.38, $p = 0.54$; Mesq: log rank = 0.05, $p = 0.82$; BiWi: log rank = 0.67, $p = 0.41$), but at Topock, predation rates were significantly higher in the second session compared to the first (log rank = 4.76, $p = 0.03$) (figure 2-2).

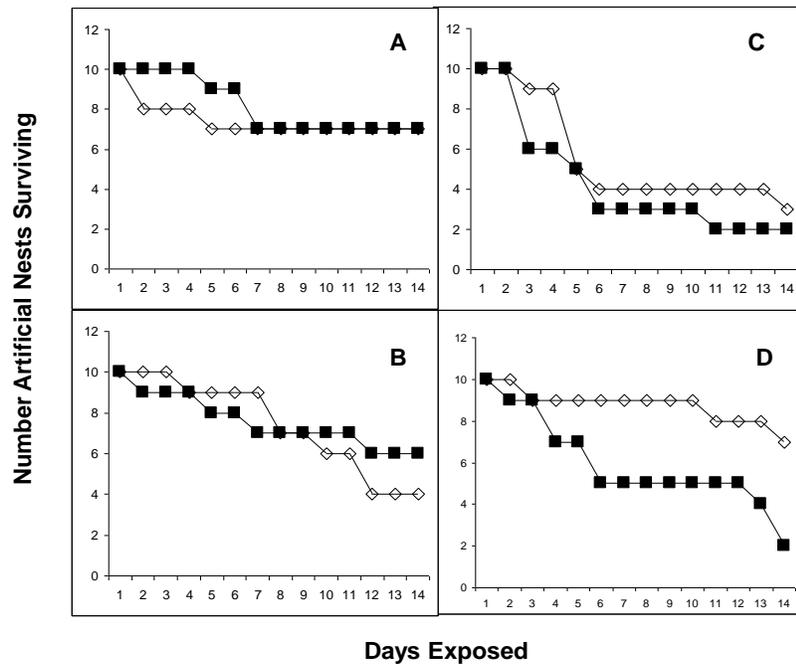


Figure 2-2.—Fate of 10 artificial nests exposed to predators for 14 days at four study sites in 2008 mid-May to early June (open diamonds) or mid-June to early July (solid squares).

(A = Mesquite, B= Pahrnagat NWR, C = Bill Williams River NWR, and D = Topock.)

Based on Cox regression analysis, we found no significant ($p < 0.05$) relationship with nest height, canopy height, canopy cover, water below nest, dominant habitat type (native versus exotic), or surrounding matrix (human versus natural) and time to artificial nest loss (table 2-1). We did find a significant association with patch size, with the two larger patches (Topock and Bill Williams River NWR) having a higher proportion of artificial nests experiencing predation. Artificial nests in larger patches also experienced predation more quickly than those placed in smaller patches (table 2-1). We found no significant difference in nest height, canopy height above the nest, canopy cover above the nest, or height of ground cover between artificial nests that were preyed upon and those that were not (table 2-2).

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Table 2-1.—Results of Cox regression analyses undertaken to determine whether time to predation on artificial nests was associated with nest height, canopy height at the nest, canopy cover at the nest, water below the nest, dominant habitat type (native willow and cottonwood dominated versus exotic tamarisk dominated), surrounding matrix (human-dominated versus natural) or patch size in 2008 (Note: Only patch size [bold face text] was significantly associated with time to nest predation.)

Variables	B ¹	SE ²	Wald ³	df ⁴	Significance
Nest height	-0.278	0.581	0.230	1	0.63
Canopy height	0.014	0.051	0.079	1	0.78
Canopy cover	-0.014	0.011	1.505	1	0.22
Water	-1.040	0.995	1.092	1	0.34
Habitat	0.656	0.700	0.878	1	0.35
Matrix	-0.471	0.823	0.327	1	0.57
Patch size	-1.730	0.771	5.042	1	0.03

¹ B = Regression coefficient.
² SE = Standard error of B.
³ Wald = Wald test statistic.
⁴ df = Degrees of freedom.

Table 2-2.—Mean (standard deviation, SD) of nest height (meters), canopy height (meters), percentage canopy cover, and percentage ground cover at 80 artificial nests that had eggs attacked versus those that did not at 4 study sites in 2008 (Note: F-values and p-values based on multivariate AOV are also shown. None of the interaction terms (not shown) were significant at p < 0.05.)

Variable	Mean (SD) of nests with no eggs attacked	Mean (SD) nests with eggs attacked	F	p
Nest height (m)	1.7 (0.3)	1.7 (0.3)	0.1	0.93
Canopy height (m)	7.8 (4.1)	9.3 (4.7)	2.3	0.13
Canopy cover (%)	71 (18)	73 (18)	0.2	0.30
Ground cover (%)	40 (31)	48 (32)	1.1	0.63

In 2008, of 42 nests that suffered at least some artificial or real egg predation, we obtained photos of potential avian nest predators at 10 (24%). Of these 10, in 8 cases (80%), the potential egg predators were yellow-breasted chats (*Icteria virens*), and in some of those photographs, chats were clearly interacting directly with eggs (figure 2-3a). Cameras at the remaining two nests captured photos of brown-headed cowbirds (*Molothrus ater*) (figure 2-3b), and again, in one of these the cowbird was photographed removing an egg.

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Figure 2-3.—(a) Yellow-breasted chat at an artificial nest with a clay egg in its beak. An unspotted *Coturnix* quail egg can be seen in the nest. (b) Brown-headed cowbird removing a zebra finch egg from an artificial nest.

All clay eggs collected from depredated artificial nests showed beak marks consistent in width and length to yellow-breasted chat and brown-headed cowbird beaks based on measurements made from one yellow-breasted chat and two brown-headed cowbird study skins obtained from the Museum of Northern Arizona and the Northern Arizona University (NAU) Vertebrate Museum. Although chats have a more decurved beak tip compared to cowbirds, in only one case was this characteristic clear enough for us to confidently assign an egg to chat predation based on examination of clay eggs under a dissecting microscope. In all other cases, beak marks could not be assigned to either of the two species with confidence (figure 2-4).



Figure 2-4.—Beak marks typical of those left on clay eggs retrieved from artificial nests depredated at the four field sites.

2009 Field Season

Of the 110 artificial nests deployed at 11 sites in 2009, 72 (65%) recorded predation. Sites varied in rate of artificial nest loss (figure 2-5).

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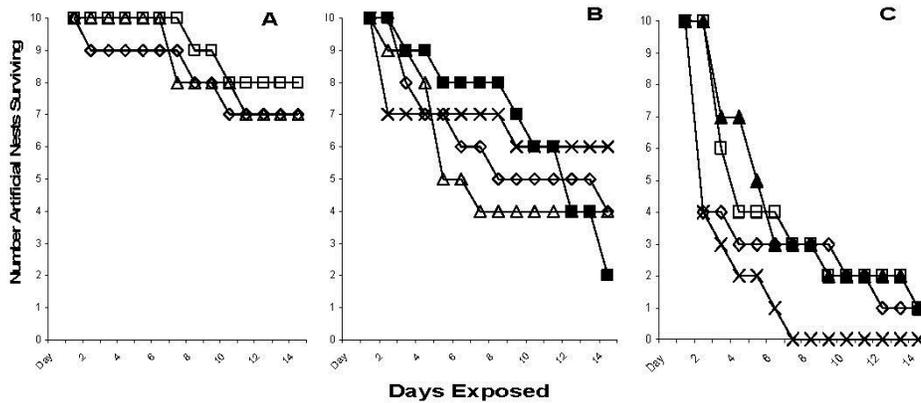


Figure 2-5.—Rate of artificial nest loss to predation varied across sites.
 (A) Sites with low rates of nest loss included Cibola Sites 1 and 2 (diamonds), CVCA (squares), and Great Blue Heron (triangles). (B) Sites with intermediate rates of nest loss included Imperial Nursery (diamonds), Gila Confluence (squares), Fortuna (triangles), and Pahrnagat NWR (crosses). (C) Sites with rapid rates of nest loss included Cibola Nature Trail (diamonds), Martinez Lake (squares), Mittry Lake (triangles), and Mesquite (crosses).

Beak and tooth marks on clay eggs indicated that potential egg predators differed across sites, with rodents being the major artificial egg predators at some sites (e.g., Fortuna, Cibola Nature Trail, Martinez Lake) and birds the major artificial egg predators at others (e.g., Mesquite) (figure 2-6).

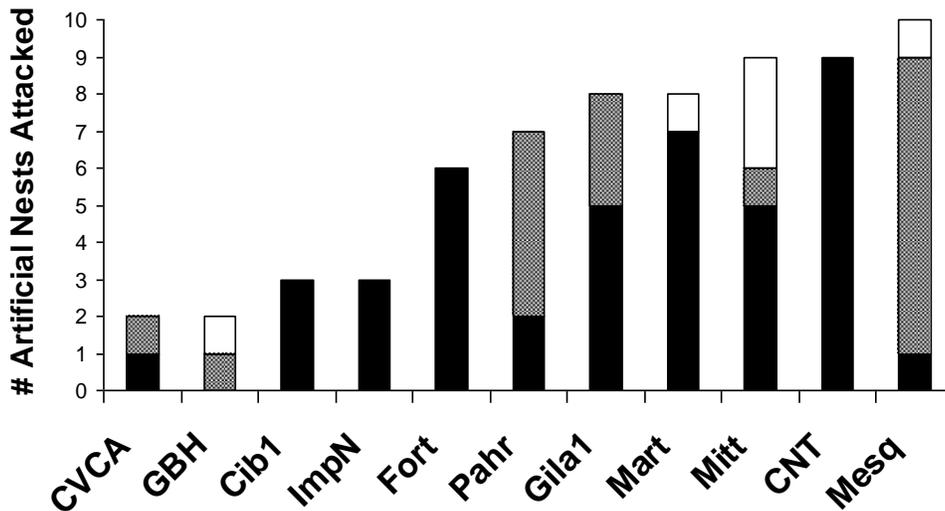


Figure 2-6.—Number of artificial nests at which marks on clay eggs indicated potential bird predators (gray), rodent predators (black), or where clay eggs were missing and the predator was therefore unknown (white).
 (Note: Site abbreviations correspond to those on figure 2-1.)

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Cameras on artificial nests recorded visits by female brown-headed cowbirds, Bewick's wrens (*Thryomanes bewickii*), female Bullock's orioles (*Icterus bullockii*), yellow-breasted chats, western screech owls (*Otus kennicottii*), greater roadrunner (*Geococcyx californianus*), deer mice (*Peromyscus* spp.), and woodrats (*Neotoma* spp.) (figure 2-7). Although in many cases cameras failed to capture visitors directly interacting with eggs, in others, birds and rodents were clearly handling real or artificial eggs (figure 2-6). In all cases where animals were not interacting with eggs in photos, beak and/or tooth marks on artificial eggs were consistent with the animals captured on film at that nest.



Figure 2-7.—Potential nest predators photographed at artificial nests in 2009.

(A) Yellow-breasted chat, (B) Bewick's Wren, (C) Bullock's oriole, (D) brown-headed cowbird, (E) western screech owl, and (F) woodrat.

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None of the parameters in our Cox regression model of rate of artificial nests lost to birds were significant (table 2-3). Likewise, nests attacked by birds did not differ from those not attacked in nest height, canopy height, canopy cover, or ground cover (table 2-4). When only nests attacked by rodents were considered, type of nest tree was significantly associated with rate of nest loss (table 2-5). Artificial nests placed in mesquite trees suffered 80% loss versus 30–50% for the other three tree types (figure 2-8). We found no significant differences among nests preyed upon by rodents and those that were not in canopy height, canopy cover, or ground cover, although nests attacked by rodents were marginally significantly lower in height (table 2-6).

Table 2-3.—Results of Cox regression analysis undertaken to determine whether rate of bird predation on artificial nests was associated with nest tree (cottonwood, willow, mesquite, tamarisk), nest height, canopy height at the nest, canopy cover at the nest, ground cover, dominant habitat type (native, mixed native, mixed exotic, exotic), surrounding matrix (human-dominated versus natural), or habitat size in 2009

Variable	B ¹	SE ²	Wald ³	df ⁴	Significance
Tree			1.089	3	0.780
Cottonwood	-1.213	1.320	0.844	1	0.358
Willow	-0.238	0.708	0.113	1	0.737
Mesquite	0.262	1.342	0.038	1	0.846
Nest height	-0.497	0.883	0.317	1	0.574
Canopy height	0.009	0.065	0.019	1	0.889
Canopy cover (%)	-0.004	0.012	0.097	1	0.755
Ground cover (%)	-0.621	0.387	2.572	1	0.109
Patch size	0.501	0.833	0.362	1	0.548
Matrix type			5.624	3	0.131
Dominant habitat	8.487	86.988	0.010	1	0.922
Native	10.42	86.986	0.014	1	0.905
Mixed	9.074	87.000	0.011	1	0.917
Exotic	9.067	0.053	1.574	1	0.210

¹ B = Regression coefficient.

² SE = Standard error of B.

³ Wald = Wald test statistic.

⁴ df = Degrees of freedom.

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Table 2-4.—Mean (standard deviation, SD) of nest height (meters), canopy height (meters), percentage canopy cover, and percentage ground cover at artificial nests that had eggs attacked by birds versus those that were not at 11 study sites in 2009 (Note: F-values and p-values based on multivariate AOV are also shown. None of the interaction terms (not shown) were significant at $p < 0.05$.)

Variable	Mean (SD) of nests with no eggs attacked	Mean (SD) nests with eggs attacked	F	p
Nest height (m)	2.1 (0.8)	1.9 (0.5)	0.1	0.37
Canopy height (m)	10.8 (4.9)	9.2 (4.7)	0.5	0.47
Canopy cover (%)	61 (16)	56 (27)	0.3	0.59
Ground cover (%)	42 (31)	45 (32)	0.2	0.69

Table 2-5.—Results of Cox regression analysis undertaken to determine whether rate of rodent predation on artificial nests was associated with nest tree (cottonwood, willow, mesquite, tamarisk), nest height, canopy height at the nest, canopy cover at the nest, ground cover, dominant habitat type (native, mixed, exotic), surrounding matrix (human-dominated versus natural), or habitat size in 2009

(Mesquite trees were associated with shorter times to nest predation [bold face.])

Variable	B ¹	SE ²	Wald ³	df ⁴	Significance
Tree			5.506	3	0.138
Cottonwood	0.503	0.680	0.547	1	0.459
Willow	0.286	0.530	0.292	1	0.589
Mesquite	1.340	0.613	4.782	1	0.029
Nest height	-0.272	0.429	0.403	1	0.526
Canopy height	-0.017	0.036	0.209	1	0.648
Canopy cover (%)	0.011	0.009	1.356	1	0.244
Ground cover (%)c	0.080	0.260	0.095	1	0.758
Patch size	-0.016	0.028	0.308	1	0.579
Matrix type	-0.231	0.489	0.224	1	0.636
Dominant habitat			2.899	3	0.408
Native	-0.435	0.690	0.398	1	0.528
Mixed	-0.080	0.627	0.016	1	0.899
Exotic	-1.417	1.020	1.929	1	0.165

¹ B = Regression coefficient.

² SE = Standard error of B.

³ Wald = Wald test statistic.

⁴ df = Degrees of freedom.

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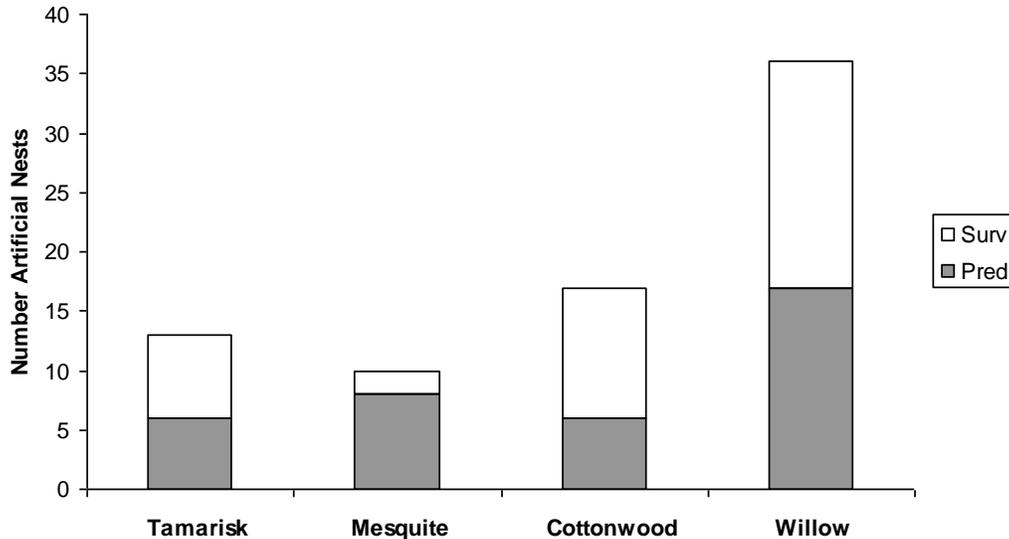


Figure 2-8.—Number of artificial nests surviving (open) versus preyed upon (gray) when placed in tamarisk, mesquite, cottonwood, and willow trees.

Table 2-6.—Mean (standard deviation, SD) of nest height (meters), canopy height (meters), percentage canopy cover, and percentage ground cover at artificial nests that had eggs attacked by rodents versus those that were not at 11 study sites in 2009 (Note: F-values and p-values based on multivariate AOV are also shown. None of the interaction terms (not shown) were significant at $p < 0.05$).

Variable	Mean (SD) of nests with no eggs attacked	Mean (SD) nests with eggs attacked	F	p
Nest height (m)	2.7 (0.8)	1.9 (0.3)	3.6	0.07
Canopy height (m)	10.8 (4.9)	9.8 (5.2)	1.2	0.25
Canopy cover (%)	61 (16)	65 (22)	0.3	0.69
Ground cover (%)	43 (28)	45 (31)	2.2	0.10

We monitored artificial nest predation at two sites, Mesquite and Pahrnagat NWR, in both 2008 and 2009. Comparison of the fate of 10 artificial nests placed at similar times (mid-May) at these sites across years showed significantly more rapid nest loss at Mesquite in 2009 compared to 2008 (Kaplan-Meier log rank = 18.2, $p < 0.001$). Seventy percent of artificial nests survived the full 14 days in 2008, whereas all nests had been preyed upon by day 7 in 2009. In contrast, the rate of artificial nest loss at Pahrnagat NWR did not differ significantly between years (Kaplan-Meier log rank = 1.75, $p = 0.19$), with 40% of nests surviving in 2008 and 30% surviving in 2009 (figure 2-9).

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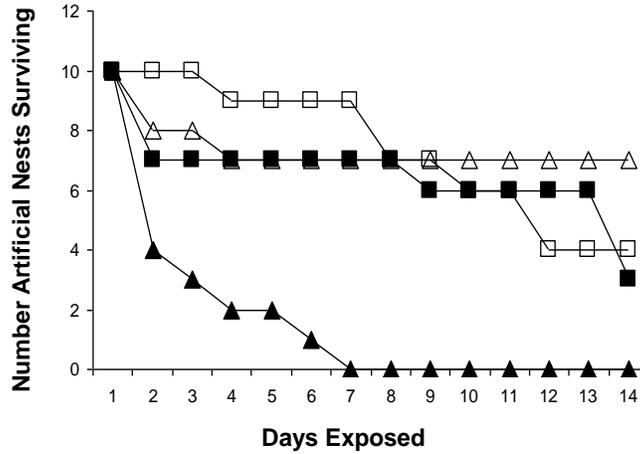


Figure 2-9.—Rate of predation on 10 artificial nests placed at Mesquite, Nevada (Mesq, triangles) and Pahrnagat NWR, Nevada (Pahr, squares) in mid-May in 2008 (open symbols) and 2009 (closed symbols).

When we compared nest parameters across years at Mesquite, we found significantly lower canopy cover at nests in 2008 ($T = 2.5, p = 0.002$), but no differences in nest height ($T = 1.6, p = 0.12$), canopy height ($T = 1.9, p = 0.08$), or ground cover ($T = 0.3, p = 0.79$). None of these parameters differed across years at Pahrnagat NWR (canopy cover, $T = 1.2, p = 0.23$; nest height $T = 1.2, p = 0.22$; canopy height $T = 0.1, p = 0.89$; ground cover $T = 0.3, p = 0.79$). The decrease in canopy cover at Mesquite in 2009 was likely due to the fact that the Mesquite site was partially flooded in 2008, but was dry in 2009, leading to premature leaf loss by many of the willows in 2009 (figure 2-10).

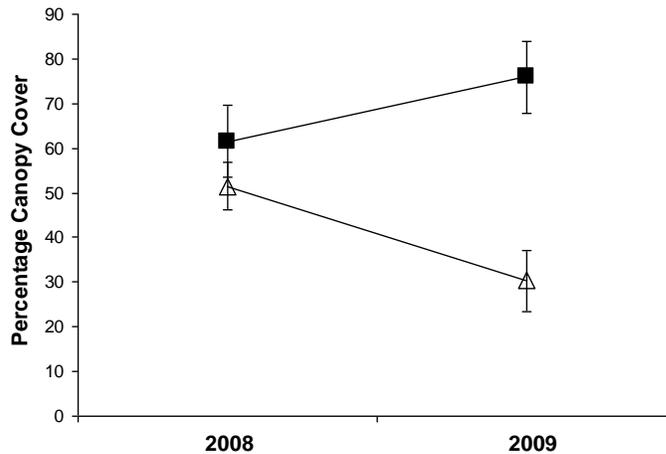


Figure 2-10.—Mean percentage canopy cover (\pm SE) at Mesquite (Mesq, triangles) and Pahrnagat NWR (Pahr, squares) study sites in 2008 and 2009.

Discussion

The potential avian nest predators we documented visiting artificial nests were relatively diverse, and most have been implicated as nest predators in the past. Relatively high rates of nest parasitism have been recorded for willow flycatchers (*Empidonax traillii*) nesting at several sites where we photographed brown-headed cowbirds (e.g., Mesquite and Topock) (McLeod et al. 2008). Although cowbirds typically remove one or more eggs from host nests before laying their own (Wood and Bollinger 1997), if cowbirds discover host nests too late in the nesting cycle, they may destroy the entire clutch, presumably to stimulate the host to re-nest so that the cowbird can obtain a second opportunity to parasitize the nest (Arcese et al. 1992; Smith and Arcese 1994). Thus, photographs of cowbirds at artificial nests, photos that documented them interacting with eggs and the beak marks left behind on clay eggs, all point to an important role of cowbirds as potential nest predators at some sites (e.g., Mesquite) as does video monitoring of real nests (chapter 3). Interestingly, we recorded no instances of cowbirds laying eggs in artificial nests. This may have been due to the presence of clay eggs, which may not have given the necessary cues to stimulate cowbirds to lay. For example, clay eggs may have been cold, lacking the warmth that would signal an actively incubated egg. Likewise, the soft texture of clay eggs may have been too different from that of the hard shell of real eggs, thereby causing cowbirds to abandon attempts to lay. In addition, all artificial eggs in our study were placed simultaneously, so if cowbirds were monitoring host egg laying by observing increases in egg number over time, this cue also would have been missing. Even in studies that used artificial eggs with more realistic shell characteristics and laying patterns, however, incidence of egg laying was low relative to the number of times eggs were removed or damaged (Lowther 1979).

Three relatively common riparian passerines were also photographed at artificial nests. We repeatedly photographed yellow-breasted chats visiting nests and interacting directly with eggs. Video monitoring of nests at Roosevelt Reservoir, Arizona, documented yellow-breasted chats preying on eggs in nests of one willow flycatcher and one yellow-breasted chat (Ellis et al. 2008). We also documented egg predation by a chat on a willow flycatcher nest at our Pahrnagat NWR site in 2009 (chapter 3). In contrast, although chats were the most common potential avian nest predator in their study area, Peterson et al. (2004) never documented chats at video monitored nests, although only 12 predation events were recorded in that study. Chats prefer nesting in dense habitat, and managers could potentially reduce chat predation on nests by reducing or eliminating complex habitat at ground and lower canopy levels.

In addition to chats, we documented visits by both wrens and female Bullock's orioles and photographed an oriole with an egg in her beak. Bullock's orioles were relatively common visitors to artificial nests in studies in oak woodland in California (Purcell and Verner 1999) and farm/forest edges in Pennsylvania

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(Zegers et al. 2000) and were documented preying on eggs in real nests (Sealy 1994). Marsh and house wrens have likewise been implicated as egg predators in previous studies of real nests and artificial nests (Belles-Isles and Picman 1986; Martin 1993, Picman and Schriml 1994; Hannon and Cotterill 1998). Given that these birds have habitat requirements similar to those of other riparian, passerine species of concern along the Colorado River, habitat restored or managed to support species of concern will also support an abundance of these potential nest predators.

Western screech owls were photographed multiple times at one artificial nest at Great Blue Heron. Birds were photographed holding artificial eggs in their talons. Screech owls were documented as egg predators at a southwestern willow flycatcher nest at Roosevelt Lake (Ellis et al. 2008). Interestingly, our photographs of this event were taken in the early evening (1700) when light levels were still quite high.

None of the habitat parameters we estimated were associated with rate of artificial nest loss for nests attacked by birds. In some cases, this was not surprising given bird predators' ability to access nests regardless of height, ground cover, or tree type. However, canopy cover was significantly lower at artificial nests preyed upon by birds, suggesting that higher canopy cover could be correlated with higher nest concealment from bird nest predators. The potential importance of canopy cover is highlighted by differences in canopy cover and nest predation rates at Mesquite in 2008 and 2009. In 2008 the area received input of water that maintained relatively high canopy cover values throughout the site, and the rate and number of artificial nests attacked by predators was relatively low. However, in 2009, water input to the site was significantly reduced, resulting in dry soils that caused premature leaf abscission by many of the trees. Artificial nest predation was strikingly higher in 2009, with all nests attacked by day 8. These data underscore the importance of maintaining water input to areas in order to maintain sufficient canopy cover for birds to avoid nest predation.

Rodents (*Peromyscus* and *Neotoma*) were the most common artificial nest visitors at several sites along the LCR. New world mice and rats have been implicated as nest predators many times in artificial nest studies (Bradley and Marzluff 2003), and correlation between variation in rodent numbers and nest predation has been argued to demonstrate a strong link between rodent and bird demography (McShea 2000). Still, nest visitation by rodents to artificial nests does not necessarily imply rodents will act as nest predators on real nests, as rodents may be attracted to artificial nests by unique odors or other stimuli. The rate of artificial nest loss to rodents was associated with tree type, with 80% of artificial nests in mesquite trees suffering rodent predation, roughly 25% higher than the proportion of nests in other tree types. Although mesquite trees had proportionally higher nest losses to rodents, nests placed in other tree types were also visited by rodents, indicating that tree type alone does not determine whether rodents will visit nests. Rodents may be more likely to find nests in mesquites

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because they afford both good cover and abundant seeds. Many studies have suggested that rodent nest predation should be higher in areas with greater ground cover, but neither Cox regression nor univariate tests found a significant effect of ground cover in our study. Unfortunately, the lack of standing water at all but one site (Imperial Nursery) did not allow us to test for the importance of water as a deterrent to rodent predation. Interestingly, the nests attacked by rodents at Imperial Nursery were in mesquite trees that bordered the flooded portion of the nursery but were themselves growing on dry land. We suspect standing water would prevent access to nests by rodents in most cases, except where interlocking canopies allowed rodents to move along branches from dry areas out to nests positioned over water.

Artificial nests obviously bias the potential suite of nest predators toward those preying primarily on eggs. For example, notably missing from our list of potential nest predators are snakes, accipiters, and buteos. Previous work in similar habitat at Roosevelt Lake recorded these and others nest predators like spiny lizards and spotted skunks (Ellis et al. 2008), but these predators took nestlings rather than eggs. Thus, the suite of potential nest predators recorded at artificial nests in this study appears to reflect those predators likely to impact only the eggs of open-cup nesting birds along the LCR. In addition, the lack of parent birds at artificial nests may either reduce visitation by egg predators that depend primarily on parental behavioral or olfactory cues to find nests or overestimate potential predation by predators that could be driven off by parents. For example, how often nocturnal rodents would drive brooding parents from the nest, or how effective parent birds would be at driving off many of these potential egg predators, remains largely unknown.

This artificial nest study revealed that (1) sites varied markedly in the level of artificial nest loss but this variation was not strongly associated with any of the nest- or site-level parameters we measured except that large patches had higher rates of nest predation in 2008 and lower canopy cover was associated with higher rates of avian artificial nest predation in 2009; (2) brown-headed cowbirds and yellow-breasted chats were the most common birds photographed at artificial nests; (3) artificial nests placed in mesquite trees were more likely to be attacked by rodents than nests placed in other tree types; and (4) a significantly higher rate of artificial nest loss at Mesquite, Nevada, in 2009 compared to 2008 was associated with significantly lower canopy cover at that site in that year presumably due to lack of surface water that caused premature leaf abscission.

CHAPTER 3 – REAL NEST PREDATION AND COMPARISON WITH ARTIFICIAL NEST RESULTS

Introduction

Nest predation and brood parasitism are the major causes of nest failures for cup-nesting passerines (Budnik et al. 2002; Chase 2002) and may cause population declines as a result of low reproductive success (Heske et al. 2001). The composition of nest predator communities in any one area may vary depending upon habitat type and surrounding matrix (Heske et al. 2001; Small 2005; Cain et al. 2006). A variety of animals can act as nest predators, and it is difficult to predict which predator may be the most important in any one habitat without actually monitoring nests. Snakes are particularly active predators of songbirds during the breeding season (Thompson and Burhans 2003) and can respond to adult activity near nest sites when searching for prey (Mullin et al. 1998). Medium-sized mammals like raccoons, a variety of rodents, as well as raptors and other passerine birds may also be important nest predators (Reitsma et al. 1990; Thompson et al. 1999; Peterson et al. 2004). Currently, the potential nest predator community along the LCR is not well studied, as are how those predator communities may differ with the size and location of riparian areas. Although artificial nests like those described in chapter 2 have often been used to assess potential egg predator communities, recent research has stressed that artificial nests should be used in conjunction with monitoring of real nests to test the validity of the assumption that predators on artificial nests reflect those on natural nests (Villard and Part 2004).

Methods

In 2008 we searched for natural nests of yellow warblers (*Dendroica petechia*), song sparrows (*Melospiza melodia*), yellow-breasted chats, and Bell's vireos (*Vireo bellii*) at four study sites in Nevada (Pahrnagat NWR, Mesquite) and Arizona (Topock, Bill Williams River NWR) by systematically walking through the habitat and noting behavior of adults. Once a nest was found, we noted the number and stage (eggs versus nestlings) of nest contents. For nests containing eggs, we returned every other day until eggs hatched or the nest was predated. In addition, we were able to use data on southwestern willow flycatcher (*Empidonax traillii extimus*) nest fate from SWCA Environmental Consultant's ongoing monitoring of southwestern willow flycatcher nests in both 2008 and 2009.

Because our photographs indicated that eggs in artificial nests could be attacked by both parasitic brown-headed cowbirds and other passerine birds, for all comparisons between artificial and real nests we combined the total number of

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real nests parasitized and depredated. Likewise, although real nests can suffer either partial or total clutch predation, the same was difficult to accurately assess with artificial nests because predators likely reacted differently to the combination of one real egg and two clay eggs. As a result, we combined partial and total clutch loss for real nests in all our comparisons. We then graphed relative rates of predation and parasitism combined of real and artificial nests at each site to determine whether predation and parasitism rates were similar between artificial and real nests. We tested for differences in artificial nest and real nest placement by comparing nest height, canopy height, canopy cover, and distance to edge for artificial and real nests using t-tests. We also graphed the locations of artificial and real nests to determine whether spatial patterns of predation and parasitism were similar between the two at each location.

In 2009, 2010, and 2011 we placed microvideo cameras (Fuhrman Diversified Inc., Seabrook, Texas, and Advanced Security Products, Belleville, Illinois) on real nests to identify nest predators. In 2009 we concentrated efforts at Mesquite and Pahrnagat NWR, while in 2010 and 2011 we monitored nests at Pahrnagat NWR and Key Pittman Wildlife Management Area (WMA). Key Pittman WMA, Nevada, is a high elevation site (3821 feet) located approximately 100 miles north of Las Vegas. Key Pittman WMA is characterized by small patches of coyote willow (*Salix exigua*) adjacent to Nesbit Lake. Video cameras were mounted on an articulating arm placed between 1 and 6 m from the nest and camouflaged with natural vegetation. We placed the recording device and battery 25 m away from the nest to avoid additional disturbance when changing batteries and memory cards. Batteries and digital video cards were changed every 2 days in order to collect continuous footage of the nest. To minimize risk that cameras might cause nest abandonment, we limited our time near nests to 7 minutes when initially placing cameras and then monitored the nest from a distance until the female returned and began either incubating eggs or feeding nestlings. If the female did not return within 30 minutes after placement of the camera, we removed the camera. To monitor the temperature near the nest site, a HOBO temperature data logger (Model U10-001), recording the temperature at 15-minute intervals, was placed within 1–3 m of the nest when the camera was deployed.

Results

In 2008 we found a total of 67 real nests across the 4 artificial nest study areas for which we were able to determine nest fate (table 3-1). Of these 67 nests, 35 were either depredated or parasitized. Combined across all species, relative rates of predation and parasitism varied across sites, with the lowest rates at Pahrnagat NWR (6/23 = 26%), followed by Bill Williams River NWR (4/13 = 31%), Mesquite (22/28 = 79%), and Topock (3/3 = 100%).

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Table 3-1.—Location, species, and fate of real nests discovered within the artificial nest study area at the four study sites May–July 2008 (Site abbreviations are as given on figure 2-1. Species: BEVI = Bell’s vireo, YWAR = yellow warbler, WIFL = southwestern willow flycatcher, YBCH = yellow-breasted chat, and SOSP = song sparrow.)

Site	Species	Total	Hatched	Depredated	Parasitized
Pahr	BEVI	2	2		
Pahr	SOSP	6	4	1	1
Pahr	YWAR	7	6		1
Pahr	WIFL	8	5	3	
Mesq	YBCH	1	1		
Mesq	YWAR	22	3	13	6
Mesq	WIFL	5	2	2	1
Topo	WIFL	3		3	
BiWi	WIFL	2	2		
BiWi	BEVI	2			2
BiWi	SOSP	5	4	1	
BiWi	YBCH	4	3	1	
Total		67	32	24	11

In 2009, 2010, and 2011 video cameras were placed at 64 nests of 3 bird species at various stages in the nesting cycle at Pahrnagat NWR, Mesquite, and Key Pittman WMA, Nevada (table 3-2). Seventeen of those nests experienced predation, and we were able to identify predators at 14 of those. We captured video footage of predators at six of the seven nests that were predated.

Table 3-2.—Number of nests monitored with video cameras at Pahrnagat NWR (PAHR), Mesquite (MESQ), and Key Pittman WMA (KEPI), Nevada, in 2009, 2010, and 2011 and the nest predators identified.

(YWAR = yellow warbler, WIFL = southwestern willow flycatcher, YBCH = yellow-breasted chat, BEWR = Bewick’s wren, RSHA = red-shouldered hawk, AMCR = American crow, BHCO = brown-headed cowbird, GRCA = gray catbird, and SSHA = sharp-shinned hawk.)

Year	Site	Species	Number of nests monitored	Nest predators
2009	PAHR	WIFL	6	YBCH, BEWR, RSHA
	PAHR	YWAR	1	
	PAHR	YBCH	1	AMCR
MESQ	WIFL	3	BHCO	
	YWAR	3		
2010	PAHR	WIFL	11	AMCR (2 nests), GRCA
	MESQ	WIFL	5	BHCO (3 nests)
	KEPI	WIFL	13	Common king snake, 2 unknown
2011	PAHR	WIFL	5	
	KEPI	WIFL	16	SSHA, short-tailed weasel, 1 unknown

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In 2009 video cameras captured predation events by yellow-breasted chats, Bewick's wrens (*Thryomanes bewickii*), American crows (*Corvus brachyrhynchos*), and red-shouldered hawks (*Buteo lineatus*) at Pahrnagat NWR, Nevada. On July 11, a brooding female southwestern willow flycatcher left her nest (12B) at 18:33. One and a half minutes later a yellow-breasted chat appeared at the nest and took one egg (figure 3-1). The visit took only 11 seconds. Ten days later, on July 21 at 18:17, the same nest containing two southwestern willow flycatcher nestlings was visited by a red-shouldered hawk. The hawk perched on the edge of the nest and consumed both nestlings, tearing the nest apart in the process (figure 3-2). The visit lasted 3 minutes. At 13:49 on July 1, a Bewick's wren visited another willow flycatcher nest (1B) for 1 minute while the brooding adult was off the nest (figure 3-3). Bewick's wrens were documented visiting this nest again on July 2 and 3. No eggs were seen to be taken by wrens, but eggs were found destroyed in the nest. Visits lasted approximately 1 minute. Finally, at 16:29:44 an American crow was videotaped at a yellow-breasted chat nest as it pulled nestlings from nest (figure 3-4). The event was over by 16:29:58, taking only 14 seconds.



Figure 3-1.—Yellow-breasted chat taking an egg from the nest (12B) of a southwestern willow flycatcher at Pahrnagat NWR, July 11, 2009.

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Figure 3-2.—Red-shouldered hawk visiting a southwestern willow flycatcher nest at Pahrnagat NWR on July 21, 2009.

(A) View of the head and body of the hawk as it consumed nestlings, (B) view of the tail as the hawk flew from nest, (C) tail of hawk at southwestern willow flycatcher nest compared to the tail of an accipiter (D) that has much broader gray bands compared to those of a red-shouldered hawk (E).



Figure 3-3.—Bewick's wren visiting a southwestern willow flycatcher nest at Pahrnagat NWR on July 1, 2009.

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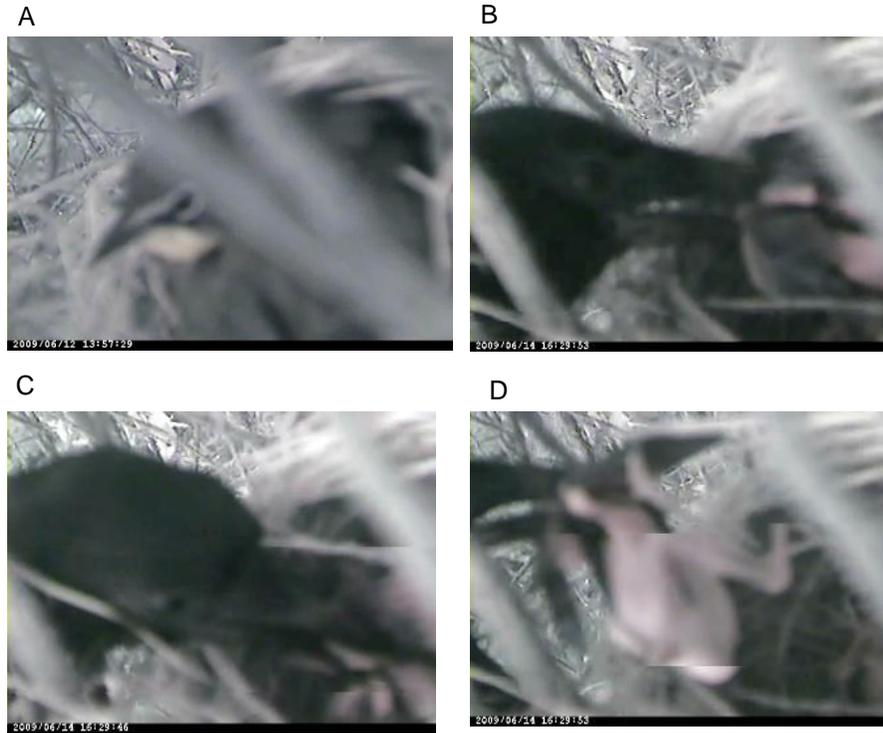


Figure 3-4.—Yellow-breasted chat brooding nestlings at Pahrnagat NWR (A) where an American crow later removed all three nestlings (B–D).

We documented two nest predation events at Mesquite, Nevada, in 2009; both were willow flycatcher nests and both were predated by brown-headed cowbirds. At 14:40:23 on June 21, a parent willow flycatcher brooding two eggs and one cowbird nestling (nest 7A) left the nest, and 3 seconds later, a female cowbird appeared at the nest with the willow flycatcher parent attacking it (figure 3-5). At 14:40:29 the parent pulled the cowbird off the nest, turning the cowbird upside down. The cowbird then flew out of the frame and returned 5 seconds later to snatch a nestling from the nest and then flew off. The parent returned and settled on the nest at 14:40:50 and then left the nest at 14:40:59. When the nest was next checked, it was empty. At 18:41:33 on June 21, a female cowbird visited willow flycatcher nest 42A after the parent vacated, perhaps in response to the cowbird's approach (figure 3-6). The cowbird stood on the nest rim, pecked and shook one nestling, and flung it to the side of the nest. The cowbird then grasped another nestling and flew off with it in its beak at 18:41:55. The willow flycatcher returned at 18:42:00 and settled on the nest at 18:44:00. The nestling on the edge of the nest moved, the parent pecked at it, and it fell off at 18:44:22. This nest eventually fledged the remaining willow flycatcher nestling.

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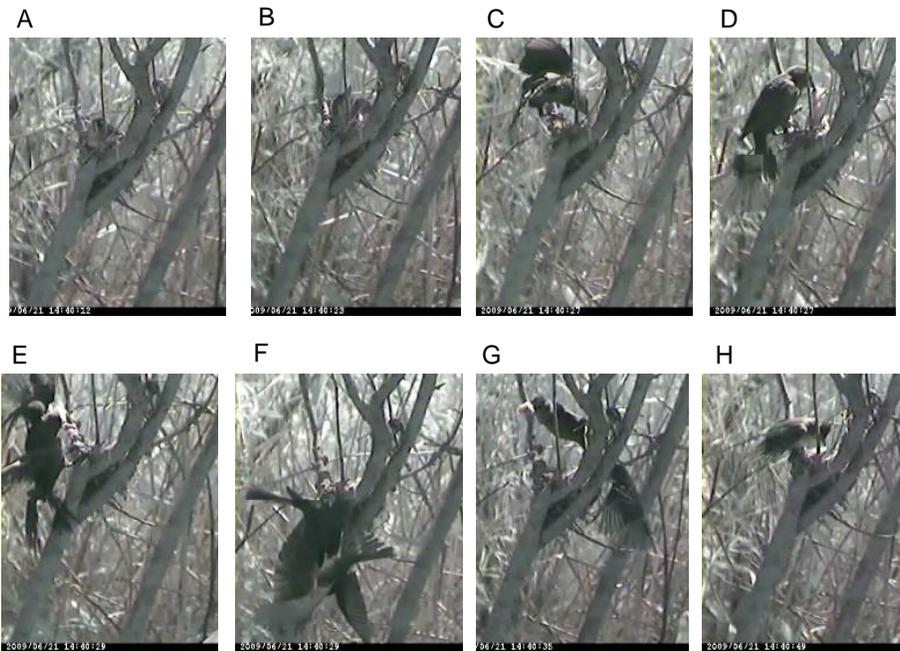


Figure 3-5.—Southwestern willow flycatcher brooding two flycatcher nestlings and a cowbird nestling at Mesquite, Nevada, on June 21, 2009. (A) The flycatcher looked up (B) then vacated the nest, and a female cowbird appeared (C) with a flycatcher attacking it (D and E), even pulling the cowbird off the nest (F). The cowbird returned to snatch a nestling (G) and then flew off as an irate flycatcher returned to the nest (H).



Figure 3-6.—A female cowbird attacking nestlings at a willow flycatcher nest at Mesquite, Nevada, on June 21, 2009.

The cowbird pecked and then flung one nestling to the side of the nest and then picked up another (A) and flew off. The parent returned (B), and the nestling on the side of the nest soon fell to its death while the parent brooded the remaining young.

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We obtained video of all 3 nest predation events documented on the 11 willow flycatcher nests we monitored at Pahranaagat NWR in 2010. Nest predators included a gray catbird (*Dumetella carolinensis*) that took one southwestern willow flycatcher egg from a clutch (figure 3-7) and two separate events in which American crows took one egg from a clutch from two different nests. In addition, we monitored 13 southwestern willow flycatcher nests and 4 yellow warbler nests at Key Pittman WMA during the 2010 season. Four of the 13 southwestern willow flycatcher nests we monitored experienced nest predation, but due to camera failure or timing of the predation event, we captured only 1 predation event on film. At that nest, we observed a California king snake preying upon four willow flycatcher nestlings (figure 3-8). The predation event lasted 50 minutes, with parental nest defense initially high but ineffective and tailing off approximately 10 minutes after the initial strike. The snake consumed all four nestlings during the attack.



Figure 3-7.—Gray catbird removing an egg from an active southwestern willow flycatcher nest at Pahranaagat NWR, June 2010.

We obtained video of only one of two predation events documented in 2011. A sharp-shinned hawk (*Accipiter striatus*) consumed all nestlings in a flycatcher nest on July 6 at 19:40 at Key Pittman WMA. The other nest predation event in 2011 was also at Key Pittman WMA, but was not video recorded. However, the predation event was witnessed by a field technician when a short-tailed weasel (*Mustela frenata*) preyed on nestlings.

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Figure 3-8.—Video of a California king snake attacking 10-day-old willow flycatcher nestlings at Key Pittman WMA, Nevada, June 2010.

Comparison of Real and Artificial Nests

Three nest predators (Bewick's wrens, yellow-breasted chats, and brown-headed cowbirds) that were documented as predators at real nests were also photographed visiting artificial nests, and two of those, yellow-breasted chats and Brown-headed cowbirds, were the most commonly photographed artificial nest visitor. The other species recorded visiting artificial nests (greater roadrunner, [*Geococcyx californianus*]; western screech owl [*Otus kennicottii*]; Bullock's oriole [*Icterus bullockii*]; deer mice [*Peromyscus* spp.]; and woodrats [*Neotoma* spp.]) and most of those recorded only at real nests in this study (American crow and red-shouldered hawk) have been documented as predators of real nests in previous studies.

The percentage of real nests escaping predation and parasitism at each site was negatively correlated with the percentage of artificial nests not predated or parasitized at those sites in 2008 (correlation coefficient = -0.44; figure 3-9). However, when the percentage of artificial nests that were not predated was compared to nest success of willow flycatchers across both 2008 and 2009, there was a strong positive correlation (correlation coefficient = 0.68; figure 3-10).

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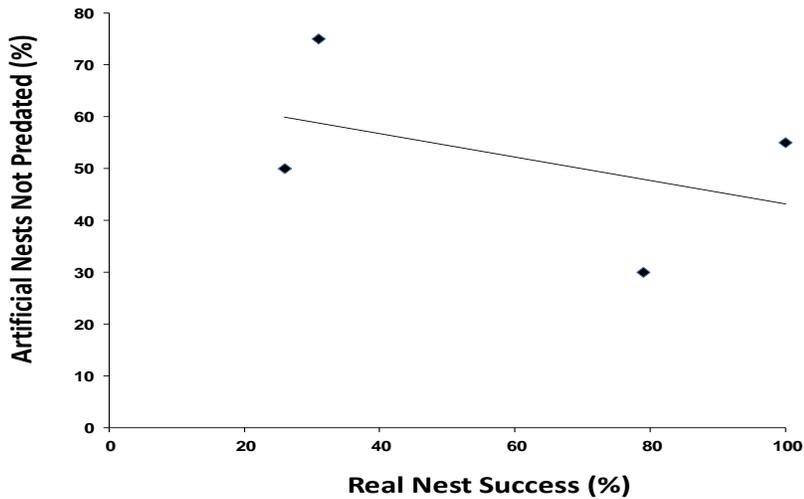


Figure 3-9.—Percentage of all real nests escaping predation and parasitism versus percentage of artificial nests not predated at Bill Williams River NWR, Topoc, Mesquite, and Pahrnagat NWR in 2008.

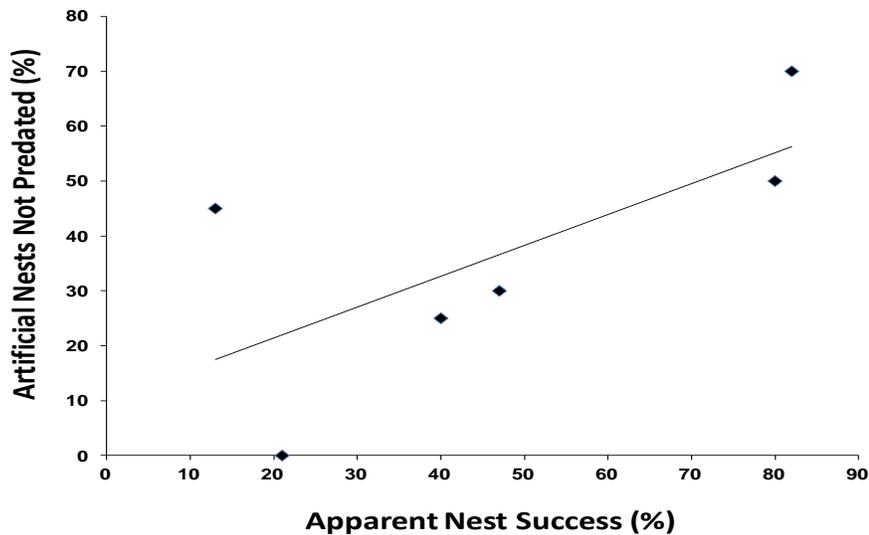


Figure 3-10.—Apparent nest success for willow flycatchers as determined by SWCA Environmental Consultants at each site in 2008 and 2009 versus percentage of artificial nests not predated at Bill Williams River NWR, Topoc, Mesquite, and Pahrnagat NWR in 2008 and Pahrnagat NWR and Mesquite in 2009.

Discussion

Most of the nest predators we documented attacking real nests at Pahranaagat NWR, Key Pittman WMA, and Mesquite have been implicated as nest predators in other studies. Female brown-headed cowbirds have been documented attacking nestlings of other host species (Dubois 1956; Tate 1967; Beane and Alford 1990; Sheppard 1996; Elliott 1999; Granfors et al. 2001; Stake and Cavanaugh 2001), but to our knowledge these are the first cases recorded for southwestern willow flycatchers. Yellow-breasted chats were documented taking both eggs and nestlings at nests monitored at Roosevelt Lake, Arizona (Ellis et al. 2008). House wrens (*Troglodytes aedon*) (Belles-Isles and Picman 1986) have been implicated as egg predators elsewhere, as have American crows (Sullivan and Dinsmore 1990). Hawks have been documented taking nestlings in several other studies (broad-winged Hawks (*Buteo platypterus*; Picman and Schriml 1994; Thompson et al. 1999). Northern harriers (*Circus cyaneus*) (Pietz and Granfors 2000), accipiters (Ellis et al. 2008; McCallum and Hannon 2001), and red-shouldered hawks were documented taking spotted towhee (*Pipilo maculatus*) nestlings in California (Small 2005). Nest predation at Pahranaagat NWR by a red-shouldered hawk was unexpected, as this species is not commonly seen at this study site and may have represented a wayward migrating or dispersing individual. Even more unexpected was the egg predation by a gray catbird we recorded at Pahranaagat NWR. Although catbirds have been implicated as egg predators in other studies (Picman and Shriml 1994), the presence of gray catbirds at Pahranaagat NWR is very unusual. These last two examples underscore that nest predators may include species that are uncommon or rare at sites, and this likely to be overlooked without video monitoring of nests.

Although snakes have been implicated as nest predators in studies of willow flycatchers in Arizona (Ellis et al. 2008), we documented only one predation event by a western king snake on nestling willow flycatchers at Key Pittman WMA. We did not record snakes as predators of eggs in artificial nests. Given the reliance of snakes on visual, olfactory, and temperature cues for finding prey, the lack of parents at artificial nests and the fact that artificial eggs did not give off the same thermal and olfactory cues as real eggs could make artificial nests poor gauges of the prevalence of snake predation. Thus, artificial nest studies could potentially overlook this important guild of nest predators.

In contrast, artificial nests generally attracted a similar suite of avian nest visitors compared to real nests, with brown-headed cowbirds and yellow-breasted chats the two most often recorded at artificial nests and both recorded preying on real nests. Likewise, Bewick's wrens were photographed at artificial nests at Pahranaagat NWR, the same site where we documented wrens attacking eggs in a willow flycatcher nest. We documented several potential avian nest predators at artificial nests that we did not detect at real nests in this study, including western screech owls, greater roadrunner, and Bullock's oriole. All of these, or at least congeners of these, have been documented to be nest predators in previous studies

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(e.g., Baltimore orioles [*Icterus galbula*], Sealy 1994; Zeger et al. 2000), western screech owls [Ellis et al. 2008], and common roadrunner [Stake et al. 2004]). We may have failed to detect these as predators at real nests in part because we did not monitor real nests at the same locations where these species were documented visiting artificial nests and in part due to the relatively small number of predation events we recorded at real nests overall.

We documented artificial nest visits by rodents in the genera *Peromyscus* and *Neotoma* at several sites. Although *Peromyscus* has been documented as a predator at real nests (Guillory 1987), we did not observe them visiting real nests. Observations of rodent visits to artificial nests must be viewed with caution because animals can visit artificial nests without the intent or potential to actually attack real eggs or nestlings. Rodents may be attracted to artificial nests due to unique odors emitted by artificial eggs or the novel stimulus of the artificial nest itself. Overall, our results suggest that artificial nests may fairly accurately reflect the potential avian nest predators at sites, but may underestimate the potential for snake predation and overestimate the threat from rodents. Although a general lack of correlation between artificial and real nest loss within a site might be expected given previous criticism of artificial nest studies (Faaborg 2004), other studies found that although predators at artificial and real nests differed, overall rates of nest loss did not (Thompson and Burhans 2004), suggesting that artificial nests could potentially give a relative measure of nest predation pressure across sites. This was not true in 2008 when we compared artificial nest loss to real nest loss based on real open-cup nests we found within the study area. This comparison was confounded by two factors: (1) it included real nests from a variety of bird species, and species may vary significantly in their susceptibility to parasitism and predation, and (2) the real nests for this comparison were found serendipitously and may have biased our sample to those nests most easily found by visual predators. In contrast, the positive correlation between artificial nests that were not parasitized or predated and success of willow flycatcher nests at selected sites in 2008 and 2009 suggested that artificial nests could reflect overall impact of nest predation at least for some species. Because willow flycatchers were being intensively studied at these sites independent of nest predation, nests were located in part through intensive observation of banded birds. Therefore, more nests were likely found, and a less biased assessment of nest predation/parasitism was the likely result. In summary, results of real nest predation at Pahrnagat NWR and Mesquite in 2009 indicated that (1) the major source of nest predation on real nests was a suite of avian predators that are naturally associated with riparian areas and that, of these, cowbirds and crows could potentially be managed through active trapping or shooting to reduce their impact and (2) overlap between the species documented visiting artificial nests and preying on real nests suggests that artificial nests may reflect the suite of potential avian egg predators at proposed restoration sites or at sites of management interest, but artificial nests likely underestimate the potential for nestling predators like snakes and raptors and overestimate the potential for predation by rodents.

CHAPTER 4 – LINKING NEST SITE TEMPERATURE AND PARENTAL BEHAVIOR

Introduction

Parental nest attendance may have important implications for nest success (Skutch 1949) and has been hypothesized to be influenced by the ambient temperature near the nest (Conway and Martin 2000). Throughout egg incubation and the nestling phase, parent birds must buffer eggs and young from temperature extremes while meeting their own energetic demands and those of their young. Ambient temperatures below the thermoneutral zone of eggs and nestlings require brooding by the parent, while temperatures above the thermoneutral zone require shading or covering (Webb 1987). Several studies have documented that the number and length of parental brooding bouts on the nest varies with temperature (*see review in* Conway and Martin 2000), and temperature-induced changes in parental behavior could make nests more susceptible to predation (Martin et al. 2000; Weidinger 2002). Most studies linking temperature to nest attendance have been conducted in areas of moderate to cold temperatures. For example, only 3 of 62 studies reviewed in Conway and Martin (2000) recorded maximum temperatures greater than 30 °C (87 degrees Fahrenheit). Little is known about how nest attendance may vary under the often extremely high temperatures faced by birds in areas like those along the LCR.

The goal of this portion of the study was to obtain ambient temperatures 2–3 m from active nests while recording parental behavior at the nest using still or video cameras. The amount of time incubating, shading, or away from the nest will then be compared to ambient temperature to gain a better understanding of how ambient temperature affected parental behavior.

Methods

We found active nests serendipitously or through active nest searches. Video cameras or still cameras were attached to nearby branches or trees within 2–3 m of nests while parents were away. Video camera support arms were camouflaged with a cloth cover. Still cameras were not camouflaged in any way. Video cameras were programmed to record one frame per second from dawn until dusk, while still cameras were set to take one frame per minute. All cameras were left in place until nest failure or fledging. At the same time cameras were deployed, a HOBO H8 temperature/humidity data logger (Onset Computer Corporation, Pocasset, Massachusetts) was hung within 2–3 m of the nest to record temperature every 30 minutes. Cameras were checked every other day to download files, replace the memory card, and check nest contents.

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We estimated the relative time parents spent incubating eggs, shading eggs, or away from the nest based on times recorded with each image. We restricted our analysis to those birds and time periods when eggs were in the nest to avoid the confounding effects of feeding nestlings. To capture temporal variation in behavior, we focused on three 2-hour blocks—one in the morning (0700–0900), one mid-day (1200–1400), and one in the evening (1700–1900). For 2009 data, we used multivariate analysis of variance (MANOVA) in SPSS version 12 to test for differences using the mean number of bouts per each 2-hour block, mean brooding bout length during each 2-hour block, and total time away from the nest in each 2-hour block as dependent variables and site and time of day as fixed factors. These analyses were based on four birds at each site—two willow flycatchers and two yellow warblers at Mesquite and four willow flycatchers at Pahranaagat NWR, all brooding eggs. To examine whether mean bout length or time away from nest was associated with ambient temperature, we visually inspected graphs comparing these two parameters.

Results

In 2009, we recorded behavior using video cameras on the 14 active nests described in chapter 3 (table 3-2). Of those, we focused our analyses on the eight nests that contained eggs during our video surveillance—two yellow warbler nests and two willow flycatcher nests at Mesquite and four willow flycatcher nests at Pahranaagat NWR. In addition, in 2008 we recorded nest attendance behavior using still cameras on two Bell's vireo nests and one yellow-breasted chat nest at Bill Williams River NWR.

We found no relationship between ambient temperature and on-bout length or time away from nest for southwestern willow flycatchers brooding eggs at either Mesquite or Pahranaagat NWR in 2009 (figure 4-1). Ambient temperatures never reached above 35 °C at Pahranaagat NWR during the periods we monitored, but we had several observation periods at temperatures over 40 °C at Mesquite.

Across the four species we monitored in both years (yellow warbler, yellow-breasted chat, Bells' vireo, and willow flycatcher), a consistent behavioral shift from brooding to shading the eggs occurred between 29 °C and 31 °C. In each case, parental behavior shifted from sitting tightly on the nest to standing over eggs, often accompanied by partly fanning the wings and panting by the adult. At one nest at Mesquite, we observed both willow flycatcher parents tending the nest during the middle part of the day when ambient temperatures were 43–44 °C.

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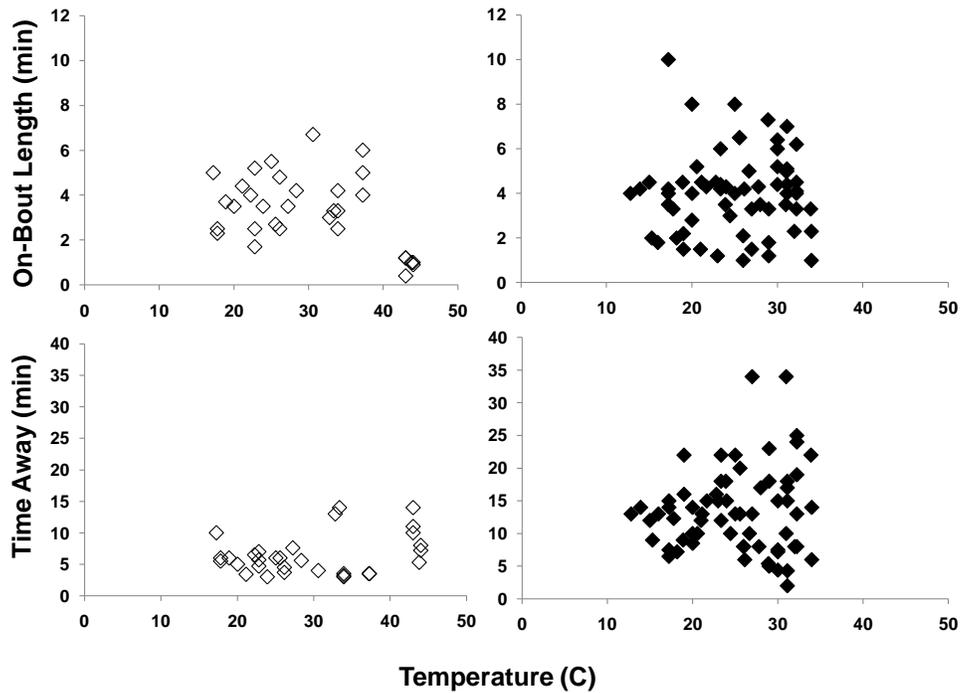


Figure 4-1.—Ambient temperature within 2–3 m of the nest versus mean brooding bout length (on-bout length) and total time away from nest during the 2-hour period (time away) for two yellow warblers and two southwestern willow flycatchers at Mesquite, Nevada (open diamonds) and four southwestern willow flycatchers Pahrnagat NWR, Nevada (closed diamonds) in 2009.

Brooding behavior differed between Mesquite and Pahrnagat NWR (MANOVA, $p < 0.001$ for Pillai's Trace, Wilk's Lambda, and Hotellings Trace), but there was no significant effect of time of day and no significant interaction ($p > 0.05$ for Pillai's Trace, Wilk's Lambda, and Hotellings Trace). Univariate tests showed that all three measures of brooding behavior differed significantly between sites, with mean number of brooding bouts significantly higher at Mesquite ($F = 52$, $p < 0.001$), mean bout length shorter at Mesquite, ($F = 16.9$, $p = 0.001$), and birds at Mesquite absent from nests for longer during 2-hour periods ($F = 8.8$, $p = 0.01$; figure 4-2).

Discussion

Conway and Martin (2000) proposed a model of nest attendance and ambient temperature that predicted that on- and off-bout duration would be positively correlated with ambient temperatures between 9 and 26 °C, uncorrelated with temperatures between 26 and 40 °C, and then would decrease as ambient temperatures approach or exceeded 40 °C. Although there was a hint of a positive

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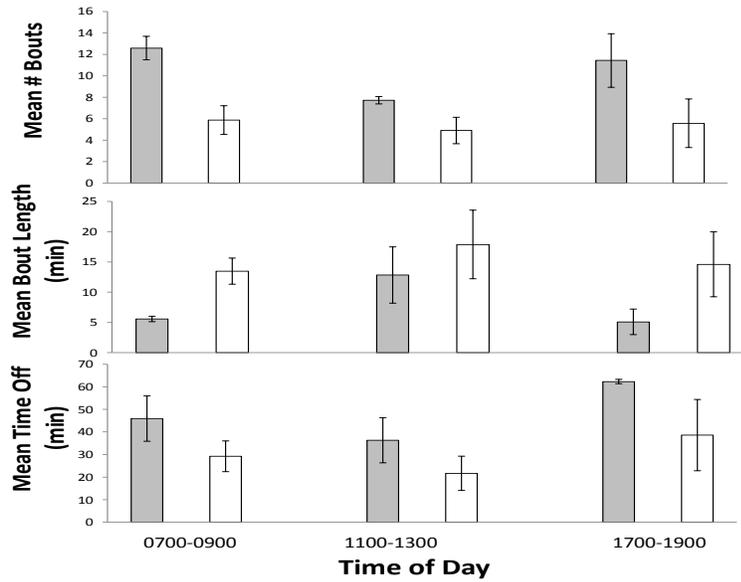


Figure 4-2.—Mean (\pm SD) number of brooding bouts, bout length, and time off nest during 2-hour blocks representing morning, mid-day, and evening for four birds at Mesquite, Nevada (two yellow warblers and two willow flycatchers, gray bars) versus four willow flycatchers at Pahranaagat NWR, Nevada (open bars).

relationship between on-bout duration and off-bout durations at temperatures lower than 24°C in our data from willow flycatchers at Pahranaagat NWR and Mesquite, respectively, the relationship was extremely weak at best. We did detect that off-bout durations were reduced at temperatures above 40 °C at Mesquite, consistent with the prediction that parents would have to remain at the nest to protect eggs from lethal temperatures when ambient temperatures were this high. Interestingly, across all four species of open-cup nesting passerines we studied, birds consistently shifted from brooding eggs to shading or covering eggs at ambient temperatures much lower than this, approximately between 29 and 31 °C. Although this shift in behavior could potentially result in significant changes in nest attendance behaviors, we detected no noticeable shift in off-bout or on-bout durations associated with this temperature range. This suggests that birds rarely may be free from the constraints of tending the nest even when ambient temperatures are high enough to significantly reduce the rate of egg cooling.

The most consistent pattern in nest attentiveness we documented, in addition to the shift from brooding to covering, was a significant difference between Pahranaagat NWR and Mesquite in the number of brooding bouts, on-bout length, and time away from the nest. Overall, birds at Mesquite moved back and forth from nests more often than birds at Pahranaagat NWR and had significantly shorter

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bout lengths and nests remained untended for longer periods of time. Birds at Pahranaagat NWR had significantly longer on-bouts, roughly 2–3 times longer than Mesquite birds. Although we had predicted that nest attentiveness might differ at Mesquite due to overall higher ambient temperatures, our lack of correlation between ambient temperature and nest behaviors was not consistent with this hypothesis. Likewise, on a day when ambient temperatures were very similar at the two sites, this difference in brooding behavior was still evident at the two nests we could compare.

Several other factors can influence patterns of nest attentiveness in addition to ambient temperature. For example, food supplementation increases nest attentiveness (Nilsson and Smith 1988; Moreno 1989), suggesting that differences in overall food abundance could drive differences in bout number and length. Likewise, perceived predation or parasitism threat could also alter parental behavior (Ghalambora and Martin 2002; Eggers et al. 2008). For example, yellow warblers that had cowbird eggs added to their nests increased nest attentiveness compared to birds that did not have eggs added, apparently in an attempt to avoid subsequent egg removal by cowbirds (Tewksbury et al. 2002). Parasitism rates were high at Mesquite and non-existent at Pahranaagat NWR, and Mesquite birds had higher rates of nest visitation as expected from this hypothesis. However, because birds at Mesquite also had shorter on-bout lengths, nests at Mesquite were left unattended for longer periods of time, presumably leaving these nests more vulnerable to parasitism.

Overall, our results indicate that patterns of parental nest attentiveness varied significantly between Mesquite and Pahranaagat NWR. We found no indications that nest attendance varied predictably with ambient temperature at either site. Thus, we suggest that differences in nest attendance between these two sites are not driven by differences in ambient temperature. Two other factors that potentially influence parental nests attentiveness could have varied between the sites and merit further investigation. First, differences in overall food abundance and quality could cause parents to alter nest attentiveness due to their own foraging constraints. Second, the perceived or actual threat of predation/parasitism likely differs between the sites, especially given the lower number of cowbirds recorded at Pahranaagat NWR in recent years. If the latter is an important driver, then we would predict nest attentiveness should change at Pahranaagat NWR if cowbird numbers increase in the absence of cowbird trapping. Given that parental nest attentiveness can have important implications for nest fate, a better understanding of the factors driving the difference between these sites is warranted. We stress that the results reported here should be viewed as suggestive rather than definitive due to the small number of nests examined and the fact that nests were pooled across two species at Mesquite.

CHAPTER 5 – LINKING NEST PREDATION AND NEST PRODUCTIVITY WITH WATER PARAMETERS AT PAHRANAGAT NWR AND KEY PITTMAN WMA

Introduction

Nest predation and brood parasitism are the major causes of nest failures for cup-nesting passerines (Budnik et al. 2002; Chase 2002) and may cause population declines as a result of low reproductive success (Heske et al. 2001). Several factors may affect nest predation, including composition of nest predator communities, surrounding matrix, canopy cover, understory density, and presence of water (Heske et al. 2001; Small 2005; Cain et al. 2006). Both presence of water and water depth have been implicated as important factors in reducing nest predation in a variety of marsh-dwelling passerines (Picman et al. 1993; Fletcher and Koford 2004) as well as riparian species (Hoover 2006). Likewise, studies of willow flycatchers and yellow warblers in California suggested that flooding portions of meadows could limit access to nests by important terrestrial nest predators associated with the forest edge (Cain et al. 2003). Water levels are often one habitat variable that can be controlled by managers, and thus the potential for water to alter nest predation or productivity is important to understand.

Water could also affect nest productivity by altering prey abundance and distribution. Energy transport from aquatic habitats via aquatic insect emergence is an important factor maintaining community diversity and production in riparian areas (Jackson and Fisher 1986; Power and Rainey 2000). Many riparian insectivorous passerines, including southwestern willow flycatchers, include significant amounts of aquatic insects in their diet (Busby and Sealy 1979; Wiesenborn and Heydon 2007; Durst et al. 2008), and radio-telemetered male southwestern willow flycatchers were documented leaving their territories to exploit the emergence of aquatic insects at Roosevelt Reservoir in central Arizona (Cardinal 2005). The abundance of this food source may be tightly linked to distance from water. Analyses of aquatic insect abundance along several rivers in Japan, for example, revealed that abundance of emergent aquatic insects decreased exponentially with distance from the stream edge, decreasing over 8-fold in the first 10 m (Iwata et al. 2003). As a result, Muscicapid flycatchers in that study concentrated their foraging in areas within 5 m of stream edges (Iwata et al. 2003). These studies suggest that the more distant nests are from water, the less available aquatically derived insect prey may be to riparian birds like southwestern willow flycatchers and that this could translate into differences in nestling feeding rates and ultimately nest productivity.

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Research in 2008 and 2009 at Pahrangat NWR documented that Bewick's wrens, yellow-breasted chats, and red-shouldered hawks were nest predators of southwestern willow flycatchers, while studies using artificial nests also implicated wrens and chats (Theimer et al. 2010). Chats, wrens, and rodents are likely positively associated with complex understory, created either from dead branches and litter fall, or from annual growth of understory plants. Before 2008, the majority of nesting habitat occupied by flycatchers at Pahrangat NWR was inundated with water, but since that time water levels have dropped, and many exposed areas now support thick stands of Indian hemp (*Apocynum cannabinum*) that can grow to 1.5–2 m during the breeding season. Here we report (1) patterns of understory vegetation change through the breeding season and comparisons with understory at flycatcher nests in 2010, (2) biomass of aerial insects at differing distances from standing water at Pahrangat NWR and Key Pittman WMA in 2011, (3) patterns of nestling feeding rates and distance to water, and (4) comparisons of nest success, productivity, and distribution during years when nesting habitat was inundated (2004–07) to those parameters during the 3-year period from 2008–10 when it was not.

Study Site

Pahrangat NWR (1026 m elevation) lies in the Pahrangat NWR Valley approximately 150 kilometers north of Las Vegas, Nevada. Our study concentrated on the northernmost patch of mature, riparian vegetation within the refuge boundaries. The patch southern boundary lies along the edge of one of the many lakes encompassed by the refuge, while to the northwest is a cattle pasture and to the northeast native upland vegetation. Trees at the site are large-diameter Goodding willow (*Salix gooddingii*), with Fremont cottonwood (*Populus fremontii*) lining a nearby irrigation canal. Canopy height within the patch is 15–18 m, and canopy closure is >90% (McCleod et al. 2008). From 2003 to 2007, as much as 100% of the site contained standing water in mid-May, and as much as 95% of the site contained standing water and saturated soil until mid-July (McCleod et al. 2008).

Key Pittman WMA, Nevada, is a higher elevation site (3821 feet) located approximately 100 miles north of Las Vegas. Key Pittman WMA is characterized by small patches of coyote willow (*Salix exigua*) adjacent to Nesbit Lake. We used Key Pittman WMA as a comparison to Pahrangat NWR due to a high density of breeding willow flycatchers coupled with a similar elevation and lakeside habitat.

Methods

Nest Monitoring

Throughout the breeding season from mid-May through July 2010 and 2011, we opportunistically placed miniature video cameras (1 cm in diameter by 3 cm long, Fuhrman Diversified Inc., Seabrook, Texas) on 17 southwestern willow flycatcher nests at Pahrangat NWR and 29 nests at Key Pittman WMA. Cameras were mounted on an articulating arm with a camouflage sleeve and were placed 1.5–3 m from active nests while the attending female was away. If the female did not return and begin brooding within 45 minutes of initial camera placement, the camera was removed. Cameras were connected to the power source and video recorder by a long cable, enabling us to put the batteries and recorder at least 25 m from the nest. As a result, birds were not disturbed from the nest by subsequent visits to change batteries or replace video cards. Batteries powering the cameras and recorders were replaced every other day, as were the video cards on which images were recorded. Cameras were left in place until the nest was preyed upon, abandoned, or the young fledged. To monitor the temperature near the nest site, a HOBO data logger recording the temperature at 15-minute intervals was placed within 1–3 m of the nest when the camera was deployed.

Understory Vegetation and Water Mapping

To document the amount and temporal change in understory vegetation, we established 35 permanent survey points marked with rebar stakes. Survey points were established at intersections of a grid within suitable habitat grid lines running N-S and E-W and spaced 50 m apart. At each point we estimated understory density in mid-May, mid-June, and mid-July. To estimate vegetation density, we placed a 2 m x 15 cm board marked off at 20-cm increments, upright on the ground, and visually classified the amount of vegetation that obscured each 15 x 20 cm segment when viewed at a distance of 2 m. Vegetation density was scored as 1 if 0–25% of the 15 x 20 cm section was covered by vegetation, 2 if 25–50% was covered, 3 if 50–75% was covered, and 4 if more than 75% of the board was covered. In this way we could characterize understory vegetation density from the ground to 2 m above the ground in 20-cm segments. The same procedure was used to opportunistically characterize understory at willow flycatcher nests once that nest had either fledged young or failed. We compared changes in vegetation density across the three census periods by comparing the mean density estimates of the five 2-cm segments in the lowest 1m at each permanent sampling location using repeated measures of AOV followed by Tukey's test to determine at which time periods differences occurred. We compared mean vegetation density in the 1 m above the ground measured at our permanent sampling plots in mid-June to that under willow flycatcher nests using a two-sample t-test assuming unequal variances.

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The position of open water that flooded the site from the south was mapped two times during the breeding season (late May and late June) in 2010 and 2011 by walking the water's edge and entering way-points into a handheld Garmin Oregon GPS unit at 10-m intervals.

Aerial Insect Surveys

We used malaise traps to determine the density of flying insects at three distances (0 m, 15 m, and 30 m) from standing water. Because the habitat was composed of dense vegetation, we chose trap line positions based on those locations that satisfied both our distance from water treatment and had a clearing large enough to fit a trap. Traps were open for 24 hours at both Pahrnagat NWR and Key Pittman WMA over a 2-month period from June to August 2011. We collected samples for 3 consecutive days per sampling period, changing the site of the traps each day for a total of 9 triplets per 3-day sampling period, resulting in 27 trap nights per month. Insect samples were preserved by air drying by placing them in plastic vials sealed with cotton and then placed in a freezer for long-term storage. Dried insect samples were weighed to the nearest 0.001 gram to obtain dry biomass.

We tested for relationships between aerial insect biomass and distance to water at each site using ANOVA after testing for normality using the Shapiro-Wilk's W test and log-transforming data when it failed to meet this assumption. All analyses were run using SPSS version 9.0.

Initial Clutch Size, Incubation Behavior, and Nestling Feeding Rate and Distance to Water

We estimated the distance of each nest to standing water based on the maps derived from walking the water's edge. The distance was determined for each nest based on the mapped location of water at the time incubation and feeding rates were assessed. To determine whether distance to standing water was related to initial clutch size, we regressed the initial number of eggs recorded in a nest against the distance of the nest from the nearest standing water. We quantified the number of feeding visits parents made to nests based on three 1-hour periods (07:30 to 08:30, 11:30. to 12:30, and 17:00 to 18:00) at three different nestling periods: 4–5 days after hatching, 7–8 days, and 9–10 days. Feeding events were scored when an adult returned to the nest and placed a food item into a nestling's mouth. We tested for effects of standing water by regressing the mean number of feeding bouts averaged across the entire day against the distance to water for each time block separately.

Analyzing Current and Past Patterns of Nest Predation and Productivity

To investigate patterns of productivity through time, with special emphasis on comparison between the period from 2004–07 when the site was inundated compared to the period from 2008–10 when it was not, we obtained nest fate data from SWCA Environmental Consultants for the years 2004–09. We then graphed the number of territories, total number of nests, and total number of nestlings fledged for each year to develop a visual representation of change in these parameters through time.

Results

Understory Vegetation and Water

Understory vegetation at permanent plots was higher and more dense in the second census in mid-June and then did not change significantly from mid-June to mid-July (repeated measures AOV, $F = 57.5$, $p < 0.001$; figure 5-1). This change was in the first 1 meter from the ground and was driven by growth of Indian hemp. Understory density at southwestern willow flycatcher nests was typified by relatively open understory in the first 1 meter and then moderate vegetation from 1.2–2 m (figure 5-2). Understory density in the lower 1 m at nests was significantly lower than that at permanent sampling points in mid-June ($T = 9.3$, $P < 0.001$). Patterns of understory density and standing water within the site changed through time, and generally flycatcher nest sites were located near the two large areas of standing water (figure 5-3).

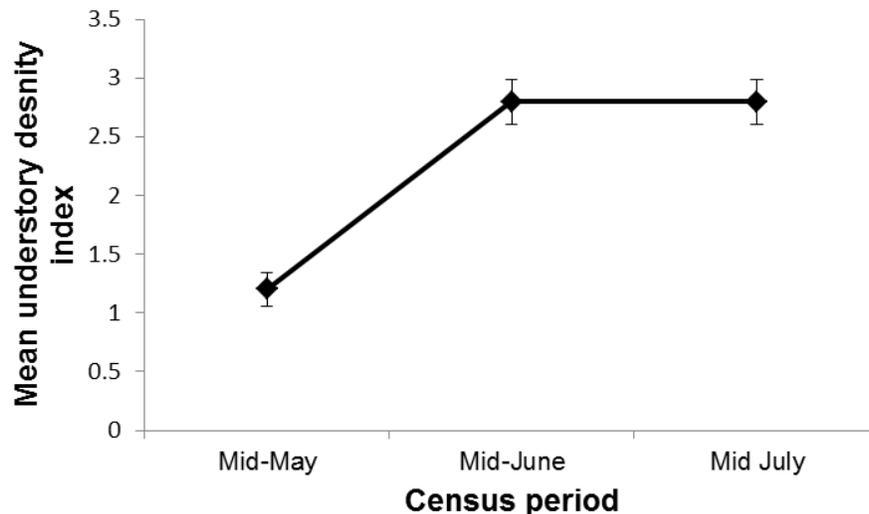


Figure 5-1.—Mean understory density index in the 1 m above ground at 35 permanent sampling locations at Pahrnagat NWR measured in mid-May, mid-June, and mid-July 2010.

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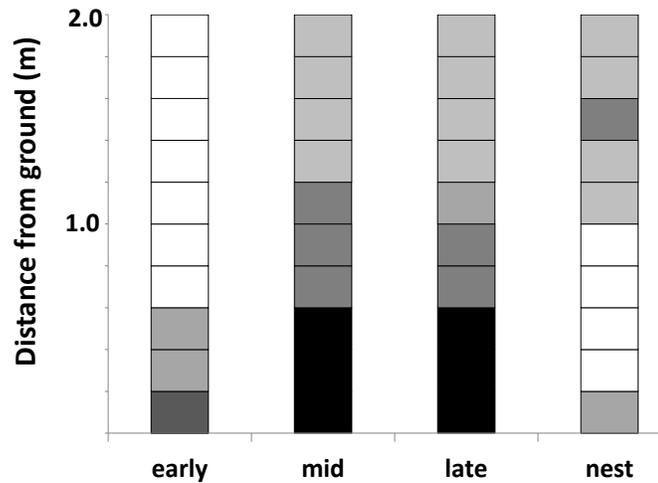


Figure 5-2.—Bars representing the 2-m cover board and each 20 x 15 cm section in which vegetative density was estimated taken at 35 permanent subplots in the early season (mid-May), mid-season (mid-June), late season (mid-July), and at 11 southwestern willow flycatcher nests at Pahranaagat NWR in 2010. Shading corresponds to how much of the 20 x 15 cm section was visually obscured by vegetation, with white = 0–25%, light gray = 25–50%, dark gray = 50–75%, and black = 75–100%.

Distance to Water and Aerial Insect Biomass

Aerial insect biomass decreased with increasing distance from water’s edge at both Pahranaagat NWR and Key Pittman WMA (figure 5-4). Sites differed significantly in overall insect abundance ($F = 8.4, P = 0.005$), and distance had a significant effect at both sites ($F = 18.9, P < 0.0001$). We found no significant interaction between site and distance ($F = 1.4, P = 0.262$).

Initial Clutch Size, Incubation Behavior, and Nestling Feeding Rate

We found that as distance to water increased, clutch size decreased (figure 5-5; $F = 9.9, \text{Adj } R^2 = 0.44, P = 0.01$). We found no significant relationship between distance to water and the length of time birds incubated eggs (incubation on-bout length) during either morning or mid-day incubation periods (0700-0900: $F=2.3, p = 0.17$; 1200–1400: $F = 0.91, p = 0.37$) nor with the length of time birds were away from the nest (incubation off-bout length) during either time period (periods 0700–0900: $F=0.17, p = 0.69$; 1200–1400: $F = 0.13, p = 0.73$).

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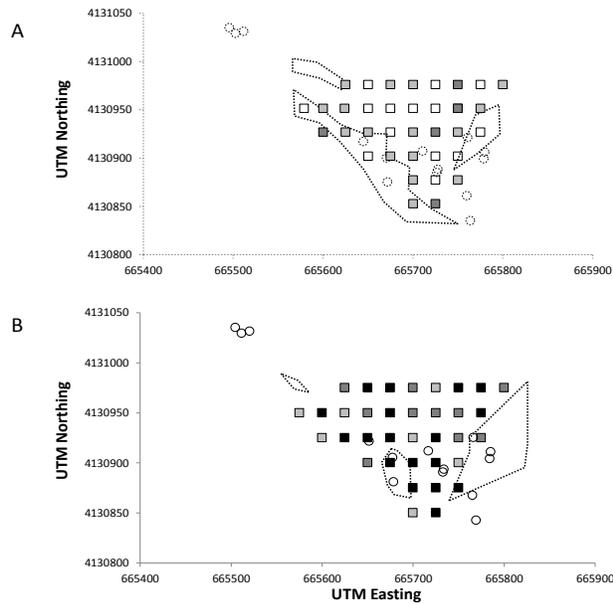


Figure 5-3.—Location of southwestern willow flycatcher nests (open circles), perimeter of standing water (dotted lines), and density of understory 1 m above ground at 35 permanent sampling locations (boxes) at Pahrnagat NWR in mid-May (A) and in mid-June 2010 (B).

Open boxes = mean index of vegetation density of 0–25%, light gray boxes = 25–50%, dark gray = 50–75%, and black = more than 75%.

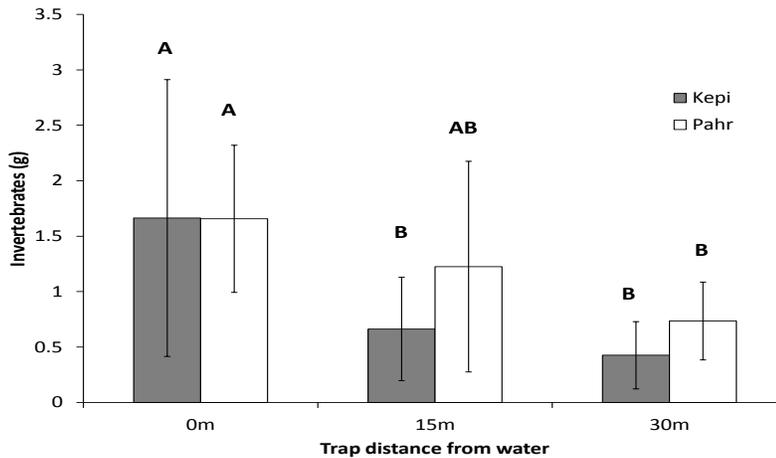


Figure 5-4.—Mean (\pm SD) biomass of aerial insects captured in malaise traps set at the water's edge and at 15 m and 30 m from the water's edge at Key Pittman WMA (gray bars) and Pahrnagat NWR (open bars), Nevada, averaged across three sampling periods in summer 2011.

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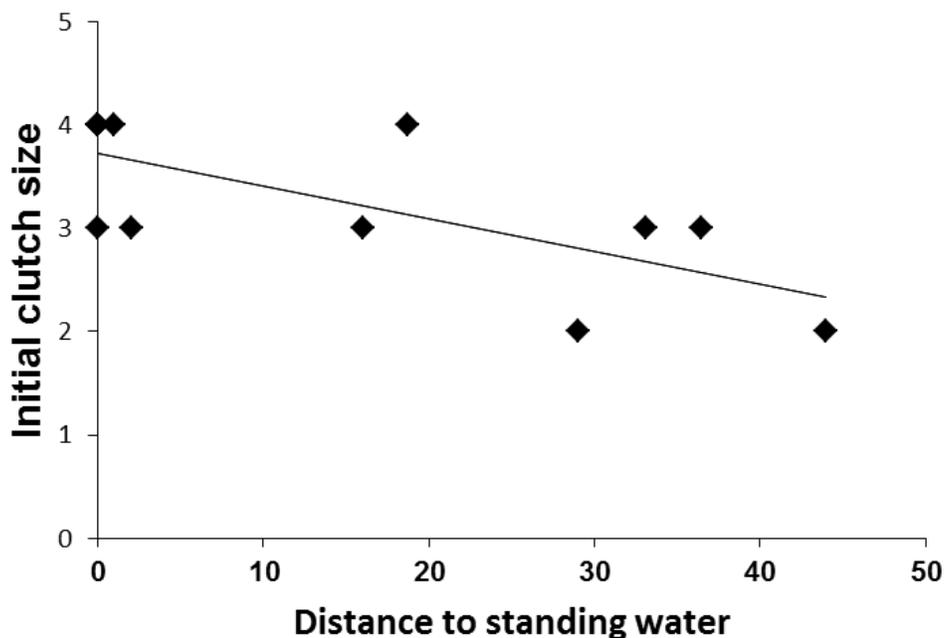


Figure 5-5.—Initial clutch size of 11 southwestern willow flycatchers nesting at Pahrangat NWR in 2010 decreased with distance from standing water ($F = 9.9$, $\text{Adj } R^2 = 0.44$, $P = 0.01$).

We found a significant interaction between nestling age and distance to water at Pahrangat NWR, with nestling feeding rates decreasing with increasing distance from water only for nestlings older than 10 days (figures 5-6C and D) and not for nestlings 5–9 days old (figures 5-6A and B, repeated measures AOV, Water x Age: $p < 0.01$; Water: $p = 0.34$; Age: $p = 0.54$). At Key Pittman WMA, where nests were overall much closer to water, nestling feeding rates were lower farther from water at all nestling ages (figures 5-6A–D, repeated measures AOV, Water x Age: $p < 0.37$; Water: $p = 0.05$; Age: $p = 0.44$).

Comparisons of Current and Past Patterns of Nest Predation and Productivity

The number of nests that were predated or that failed for any reason at Pahrangat showed a sharp spike in 2005 and an increase from 2008 through 2010 (figure 5-7). Other than a drop from 2004 to 2005, the number of fledges remained relative constant across this period (figure 5-8). The number of nests increased in 2009 and 2010 primarily as a result of re-nesting after the increased number of nest failures.

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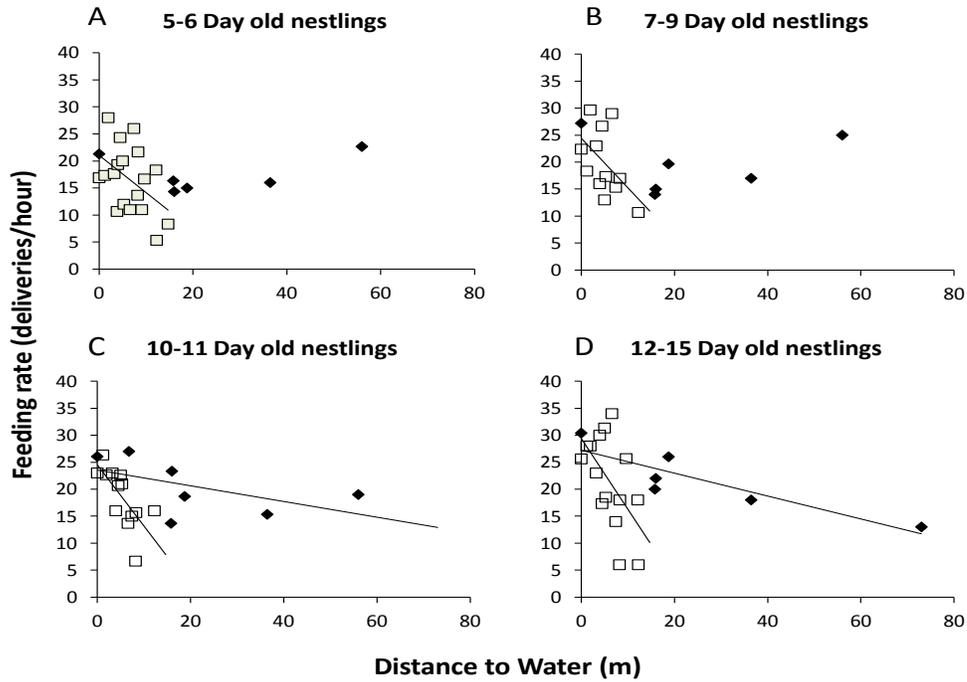


Figure 5-6.—Nestling feeding rate (prey deliveries per hour) at four different nestling ages (A = nestlings 5–6 days old, B = nestlings 7–9 days old, C = nestlings 10–11 days old and D = nestlings 12–15 days old) for nests at differing distances from water at Pahrnagat NWR (solid diamonds) and Key Pittman WMA (open squares) in 2010 and 2011. Points at 0 m distances represent the mean of all nests at or above standing water.

Based on 103 flycatcher nests monitored at Pahrnagat NWR from 2004–11, the percentage of nests that suffered predation or abandonment/desertion was higher for nests less than 10 m from standing water compared to nests greater than 30 m from standing water (figure 5-9A). A similar pattern held for the 57 flycatcher nests monitored at Key Pittman WMA in 2010 and 2011, with a greater percentage of nests less than 10 m from standing water suffering predation and abandonment/desertion than those >10 m from water (figure 5-9B). Contingency table Chi-Square tests indicated these differences were not significant at either Pahrnagat NWR (Chi-square = 1.3, $p = 0.80$) or at Key Pittman WMA (Chi-square = 3.3, $p = 0.30$).

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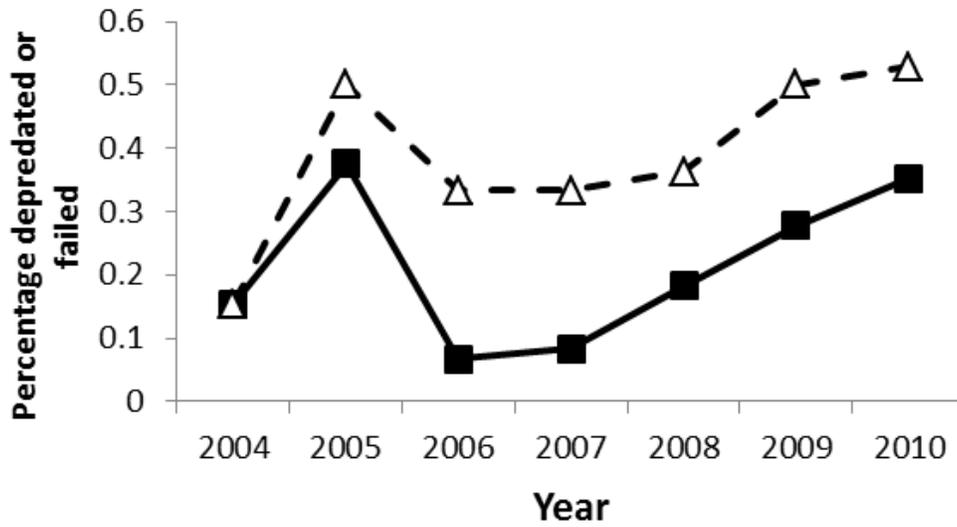


Figure 5-7.—The percentage of southwestern willow flycatcher nests predated (solid line) or that failed for any reason (predated + abandoned/deserted) (dashed line) at Pahrnagat NWR from 2004 through 2008.

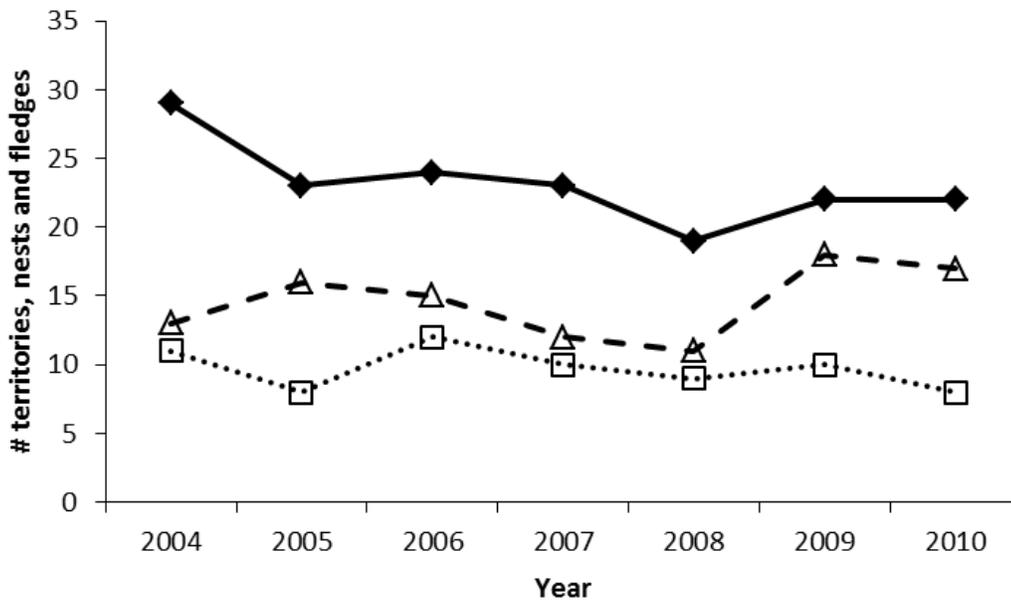


Figure 5-8.—The number of southwestern willow flycatcher territories (dotted line), nests (dashed line), and fledges (solid line) at Pahrnagat NWR from 2004 through 2010.

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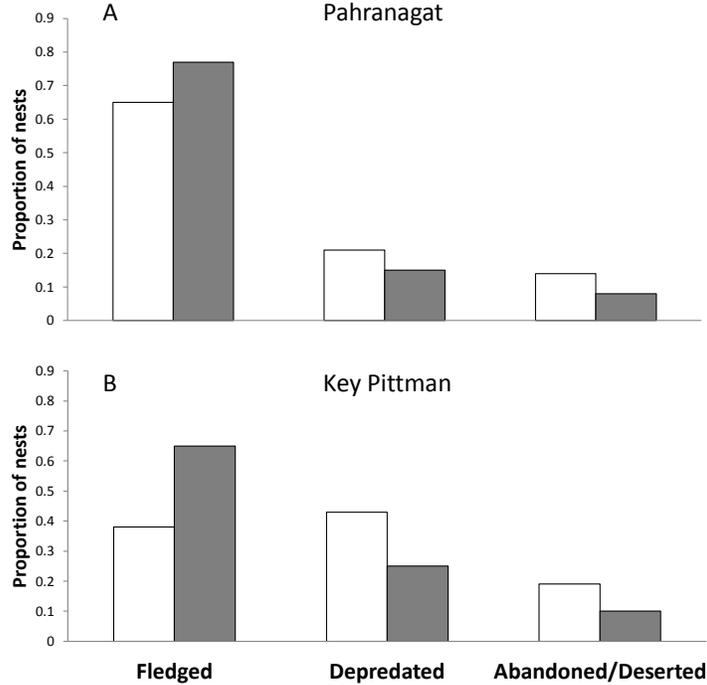


Figure 5-9.—(A) Proportion of 103 nests that fledged, were preyed upon, or were abandoned/deserted < 10 m from standing water or > 30 m from standing water at Pahrnagat NWR between 2004 and 2011. (B) Proportion of 57 nests that fledged, were preyed upon, or were abandoned/deserted <10 m from standing water or > 10 m from standing water at Key Pittman WMA in 2010 and 2011.

Discussion

We hypothesized that standing water could impact nesting willow flycatchers by (1) decreasing nest predation by reducing access to nests by ground predators and (2) increasing fledging success by acting as a source of emergent aquatic insect food that would allow birds to increase clutch size, maximize efficiency of incubation behavior, and maximize nestling feeding rates. We found limited support for both hypotheses.

The increase in nest predation since 2008 is consistent with the hypothesis that standing water may reduce nest predation, although the high rate of nest failure in 2005, when the site was inundated, is not consistent with this view. We did find that understory vegetation increased through the season, especially in the 1–1.5 m above ground, and this growth would be unlikely if the site were inundated. Rodents are the most likely nest predator to respond to increased vegetative growth in the absence of standing water (Carey and Johnson 1995; Bowman

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et al. 2000; Bradley and Marzluff 2003), and although we documented rodents as nest predators at our artificial nests (chapter 2), we have yet to document rodents attacking real nests (chapter 3).

Instead, real nest predators at Pahranaagat NWR have been primarily birds, including American crows, Bewick's wrens, and yellow-breasted chats, as well as unexpected vagrants like the gray catbird and red-shouldered hawk (chapter 3). Standing water would obviously not prevent this suite of avian nest predators from accessing nests, but standing water could reduce understory development and thereby influence the foraging and nest searching patterns of some of them (Thompson and Nolan 1973; Ricketts and Ritchison 2000). Perhaps most important, however, is that in spite of changes in nest predation over time, the total number of fledglings produced has not changed in concert with changes in predation, suggesting that birds at the site may be able to compensate for losses to predation through re-nesting, as has been argued for nest parasitism in other studies (May and Robinson 1985). Re-nesting typically results in nestlings fledging later, and later fledging dates are correlated with lower return rates the following year (Sedgwick and Iko 1999; Paxton et al. 2007). Willow flycatchers nesting at study sites along the LCR, including Pahranaagat NWR, show the same pattern, with fledgling survival to the following year decreasing from 57% for nestlings fledging in mid-June to 18% for those fledging in mid-July (McLeod et al. 2008).

Understory vegetation density in the first meter above the ground during June and July was significantly lower at southwestern willow flycatcher nests than at our regularly spaced monitoring sites. This suggests that nest sites may have lower density of vegetation at or near ground level where it would be most likely to offer cover for ground predators like rodents. Whether birds are selecting nest sites in part based on this characteristic, or whether lower vegetation density at ground level is correlated with some other factor that flycatchers may select for remains unknown. Standing water could limit understory development at or near ground level, increasing the amount of habitat that falls within the level of understory development we recorded at flycatcher nests. However, if increasing standing water alone was limiting habitat, we would have expected a reduction in the number of territories at the site since 2007 when the site was no longer regularly inundated. Instead, the total number of territories has remained relatively constant.

Our finding that aerial insect biomass decreased significantly with increasing distance to water, even over the relatively short distances of 10s of meters, is consistent with studies of riparian areas in other parts of the world (Iwata et al. 2003). Muscivorous flycatchers foraged preferentially 5 m from the river's edge as a result of higher insect abundances closer to water (Iwata et al. 2003). This difference in insect abundance suggests that insectivorous birds like flycatchers that nested farther from water would have less potential prey near their nest sites.

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The negative relationship we documented between distance to water and clutch size suggests that standing water may either impact female fecundity directly or that more fecund females are able to obtain territories nearer water.

Although willow flycatchers could easily fly the relatively short distance to water to exploit richer insect abundance, and have been documented moving well beyond their home range to exploit hatches of aquatic insects (Cardinal 2005), farther trips, repeated again and again throughout the nesting cycle, could result in cumulative energetic costs that could reduce reproductive potential, especially if trips toward water also incurred attacks from birds with territories nearer the water. This, combined with the lower prey delivery rate to nestlings at nests farther from water that we documented in this study, would suggest overall lower nest success farther from water and potentially higher rates of nest abandonment and desertion. However, we found the exact opposite, with higher proportions of nests abandoned and deserted when near water than when farther away. One consequence of higher prey delivery rates to nestlings at nests near water could be higher predation rates due to increased parental activity that alerts predators to the location of the nest. Though not significantly different, the proportion of nests that were depredated was higher for nests nearer water than for those farther from water, consistent with the hypothesis of higher predation rates at nests near water.

The differences between Pahrangat and Key Pittman WMA in both the relative amount of aerial insects at differing distances from water and the effect on nestling feeding rate suggest that site differences in habitat may interact with nestling provisioning rates. Nesting habitat at Key Pittman WMA is overall a narrower band of vegetation that runs along an artificial water source with a relatively steep embankment into the water. The position of the water's edge remains relatively constant through the breeding season. This relative sharp and temporally constant water's edge, combined with a relatively narrow band of available habitat, may cause a more rapid decrease in aerial insect abundance over shorter distances at Key Pittman WMA. In contrast, breeding habitat at Pahrangat NWR is broader and extends away from the water's edge in a gradual slope, with low-lying and temporarily inundated areas interspersed throughout the habitat. As a result, the location of the water's edge is more variable through time, and the edge itself is more diffuse, with highly saturated soils extending some distance from the water's edge. This may explain why the effect of distance on aerial insect abundance was more gradual over distance at Pahrangat NWR, and why the effect on nestling feeding rate was only evident at later stages of nestling development.

Overall, the comparison of the number of territories, number of nests, and number of fledglings between 200–10 at Pahrangat NWR indicated a relatively constant number of territories and output of fledglings regardless of whether the site was inundated or not. Likewise, although we documented both significantly lower aerial insect abundances and lower nestling feeding rates farther from water, we did not find that nests farther from water suffered higher proportional predation or

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abandonment. Any difference in productivity in nests near versus far from water would likely be due to differences in clutch size, though the driver for why clutch sizes were higher near water remains unknown. Although our results suggest that increasing standing water may positively impact flycatcher habitat quality by limiting understory growth and potentially increasing the abundance of aquatic food resources, longer term comparisons suggest that increasing the extent of standing water alone is unlikely to increase the number of territories. Increasing the total amount of habitat available to flycatchers by expanding the current patch through additional plantings of willow would create habitat for returning juveniles to colonize. Thus, increasing standing water to maintain insect prey while increasing overall patch size may be the management approach with the greatest potential for increasing the number of flycatchers at this and other occupied sites.

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LITERATURE CITED

- Arcese, P., J.N.M. Smith, W.M. Hochachka, C.M. Rogers, and D. Ludwig. 1992. Stability, regulation, and the determination of abundance in an insular song sparrow population. *Ecology* 73:805–822.
- Beane, J.C. and S.L. Alford. 1990. Destruction of a Pine Warbler brood by an adult cowbird. *Chat* 54:85–87.
- Belles-Isles, J.C. and J. Picman. 1986. House Wren nest-destroying behavior. *The Condor* 88:190–193.
- Bowman, J.C., D. Sleep, G.J. Forbes, and M. Edwards. 2000. The association of small mammals with coarse woody debris at log and stand scales. *Forest Ecology and Management* 129:119–124.
- Bradley, J.E. and J.M. Marzluff. 2003. Rodents as Nest Predators: Influences on Predatory Behavior and Consequences to Nesting Birds. *Auk* 120:1180–1187.
- Budnik, J.M., F.R. Thompson, and M.R. Ryan. 2002. Effect of habitat characteristics on the probability of parasitism and predation of Bell's vireo nests. *Journal of Wildlife Management* 66:232–239.
- Busby, D.G. and S.G. Sealy. 1979. Feeding ecology of a population of nesting yellow warblers. *Canadian Journal of Zoology* 57:1670–1681.
- Cain III, J.W., M.L. Morrison, and H.L. Bombay. 2003. Predator activity and nest success of willow flycatchers and yellow warblers. *The Journal of Wildlife Management*, 600–610.
- Cain III, J.W., K S. Smallwood, M.L. Morrison, and H.L. Loffland. 2006. Influence of mammal activity on nesting success of passerines. *Journal of Wildlife Management* 70:522–531.
- Cardinal, S.N. 2005. Conservation of southwestern willow flycatchers: home range and habitat use by an endangered passerine. MS Thesis. Northern Arizona University, 73p.
- Carey, A.B. and M.L. Johnson. 1995. Small Mammals in Managed, Naturally Young, and Old-Growth Forests. *Ecological Applications* 5:336–352.
- Chalfoun A.D., F.R. Thompson, III, and M.J. Ratnaswamy. 2002. Nest predators and fragmentation: A review and meta-analysis. *Conservation Biology* 16:1–13.

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- Chase, M.K. 2002. Nest site selection and nest success in a song sparrow population: the significance of spatial variation. *The Condor* 104:103–116.
- Conway, C.J. and T.E. Martin. 2000. Effects of ambient temperature on avian incubation behavior. *Behavioral Ecology* 11:178–188.
- Davidson, W.B. and E. Bollinger. 2000. Predation rates on real and artificial nests of grassland birds. *Auk* 117:147–153.
- Dijak W.D. and F.R. Thompson, III. 2000. Landscape and edge effects on the distribution of mammalian predators in Missouri. *Journal of Wildlife Management* 64:209–215.
- Dubois, A.D. 1956. A cowbird incident. *Auk* 73:286.
- Durst, S.L., T.C. Theimer, E.H. Paxton, and M.K. Sogge. 2008. Age, habitat, and yearly variation in the diet of a generalist insectivore, the southwestern willow flycatcher. *The Condor* 110:514–525.
- Eggers, S., M. Griesser, and J. Ekman. 2008. Predator-induced reductions in nest visitation rates are modified by forest cover and food availability. *Behavioral Ecology* 19:1056–1062.
- Elliott, P.F. 1999. Killing of host nestlings by the brown-headed cowbird. *Journal of Field Ornithology* 70:55–57.
- Ellis, L.A., D.M. Weddle, S.D. Stump, H.C. English, and A.E. Graber. 2008. Southwestern willow flycatcher final survey and monitoring report. Arizona Game and Fish Department, Research Technical Guidance Bulletin #10, Phoenix, Arizona, USA.
- Ellison, K. and S.G. Sealy. 2007. Small hosts infrequently disrupt laying by brown-headed cowbirds and bronzed cowbirds. *Journal of Field Ornithology* 78:379–389.
- Faaborg, J. 2004. Truly artificial nest studies. *Conservation Biology* 18:369–370.
- Fletcher, R.J. and R.R. Koford. 2004. Consequences of rainfall variation for breeding wetland blackbirds. *Canadian Journal of Zoology* 82:1316–1325.
- Ghalambora, C.K. and T.E. Martin. 2002. Comparative manipulation of predation risk in incubating birds reveals variability in the plasticity of responses. *Behavioral Ecology* 13:101–108.

**Real and Artificial Nest Predation and Parental Nest Attendance
Along the Lower Colorado River and Southern Nevada**

- Granfors, D.A., P.J. Pietz, and L.A. Joyal. 2001. Frequency of egg and nestling destruction by female brown-headed cowbirds at grassland nests. *Auk* 118:765–769.
- Guillory, H.D. 1987. Cavity competition and suspected predation on Prothonotary Warblers by *Peromyscus*. *Journal of Field Ornithology* 58:425–427.
- Hannon, S.J. and S.E. Cotterill. 1998. Nest predation in aspen woodlots in an agricultural area in Alberta: the enemy from within. *The Auk*, 16–25.
- Heske, E.J., S.K. Robinson, and J.D. Brawn. 2001. Nest predation and neotropical migrant songbirds: piecing together the fragments. *Wildlife Society Bulletin* 29(1):52–61.
- Hoover, J.P. 2006. Water depth influences nest predation for a wetland-dependent bird in fragmented bottomland forests. *Biological Conservation* 127:37–45.
- Hoover, J.P., T.H. Tear, and M.E. Baltz. 2006. Edge effects reduce the nesting success of Acadian flycatchers in a moderately fragmented forest. *Journal of Field Ornithology* 77:425–436.
- Iwata, T., S. Nakano, and M. Murakami. 2003. Stream meanders increase insectivorous bird abundance in riparian deciduous forests. *Ecography* 26:325–337.
- Jackson, J.K. and S.G. Fisher. 1986. Secondary production, emergence, and export of aquatic insects of a Sonoran desert stream. *Ecology* 67:629–638.
- Knutson, M.G, S.J. Gutreuter, and E.E. Klaas. 2000. Patterns of artificial nest depredation in a large floodplain forest. *Journal of Wildlife Management* 64:576–583.
- Lowther, P.E. 1979. Nest selection in Brown-headed Cowbirds. *Wilson Bulletin* 91:118–122
- Martin T.E. 1987. Artificial nest experiments: Effects of nest appearance and type of predator. *The Condor*. 89:925–928.
- _____. 1988. Habitat and area effects on forest bird assemblages: is nest predation an influence? *Ecology* 69:74–84.
- _____. 1993. Nest predation and nest sites. *BioScience*, 43(8), 523–532.

**Real and Artificial Nest Predation and Parental Nest Attendance
Along the Lower Colorado River and Southern Nevada**

- Martin T.E., J. Scott, and C. Menge. 2000. Nest predation increases with parental activity: separating nest site and parental activity effects. *Proc. R. Soc. Lond. B*:2287–2293.
- May, R.M. and S.K. Robinson. 1985. Population dynamics of avian brood parasitism. *Am. Nat.* 126:475–494.
- McCallum, C.A. and S.J. Hannon. 2001. Accipiter predation of American Redstart nestlings. *The Condor* 103:192–194.
- McLeod, M.A., T.J. Koronkiewicz, B.T. Brown, W.J. Langeberg, and S.W. Carothers. 2008. Southwestern willow flycatcher surveys, demography, and ecology along the lower Colorado River and tributaries, 2003–2007. Five-year summary report submitted to the Bureau of Reclamation, Boulder City, Nevada, by SWCA Environmental Consultants, Flagstaff, Arizona, 206 p.
- McShea, W.J. 2000. The influence of acorn crops on annual variation in rodent and bird populations. *Ecology*, 81(1), 228–238.
- Moreno, J. 1989. Energetic constraints on uniparental incubation in the wheatear *Oenanthe oenanthe* (L.). *Ardea* 77:107–115.
- Morton, M.L. and M.E. Pereyra. 1985. The regulation of egg temperatures and attentiveness patterns in the Dusky Flycatcher (*Empidonax oberholseri*). *Auk* 102:25–37.
- Mullin, S.J., R.J. Cooper, and W.H.N. Gutzke. 1998. The foraging ecology of the gray rat snake (*Elaphe obsoleta spiloides*). Searching for different prey types in structurally varied habitats. *Canadian Journal of Zoology* 76:548–555.
- Nilsson, J.A. and H.G. Smith. 1988. Incubation feeding as a male tactic for early hatching. *Animal Behavior* 36:641–647.
- Pärt, T. and J. Wretenberg. 2002. Do artificial nests reveal relative nest predation risk for real nests? *Journal of Avian Biology* 33:39–46.
- Paxton, E.H., M.K. Sogge, S.L. Durst, T.C. Theimer, and J.R. Hatten. 2007. The ecology of the southwestern willow flycatcher in central Arizona – a 10-year synthesis report. U.S. Geological Survey Open-File report 2007–1381, 143 p.
- Peak R.G., F.R. Thompson, III, and T.L. Shaffer. 2004. Factors affecting songbird nest survival in riparian forests in a midwestern agricultural landscape. *Auk*. 121:727–737.

**Real and Artificial Nest Predation and Parental Nest Attendance
Along the Lower Colorado River and Southern Nevada**

- Pedlar J.H., L. Fahrig, and H.G. Merriam. 1997. Raccoon habitat use at 2 spatial scales. *Journal of Wildlife Management* 61:102–112.
- Peterson, B.L., B.E. Kus, and D.H. Deutschman. 2004. Determining nest predators of the Least Bell's vireo through point counts, tracking stations, and video photography. *J. Field Ornithology* 75:85–95.
- Picman, J., M.L. Milks, and M. Leptich. 1993. Patterns of predation on passerine nests in marshes: effects of water depth and distance from edge. *Auk* 110:89–94.
- Picman, J. and L.M. Schriml. 1994. A camera study of temporal patterns of nest predation in different habitats. *Wilson Bulletin* 106:456–465.
- Pietz, P.J. and D. Granfors. 2000. Identifying predators and fates of grassland passerine nests using miniature video cameras. *Journal of Wildlife Management* 64:71–87.
- Power, M.E. and W.E. Rainey. 2000. Food webs and resources sheds: towards spatially delimiting trophic interactions. In: Hutchings, M.J., E.A. John, and A.J.A. Stewart (eds.), *Ecological consequences of environmental heterogeneity*. Blackwell, pp. 291–314.
- Purcell, K.L. and J. Verner. 1999. Nest predators of open and cavity nesting birds in oak woodlands. *The Wilson Bulletin*, 251–256.
- Reitsma, L.R., R.T. Holmes, and T.W. Sherry. 1990. Effects of removal of red squirrels, *Tamiasciurus hudsonicus*, and eastern chipmunks, *Tamias striatus*, on nest predation in a northern hardwood forest: An artificial nest experiment. *Oikos* 57:375–380.
- Ricketts, M. and G. Ritchison. 2000. Nesting Success of Yellow-Breasted Chats: Effects of Nest Site and Territory Vegetation. *The Wilson Bulletin* 112:510–516.
- Ricklefs, R.E. 1969. An analysis of nesting mortality in birds. *Smithsonian Contributions to Zoology* 9:1–48.
- Sealy, S.G. 1994. Observed acts of egg destruction, egg removal, and predation on nests of passerine birds at Delta marsh, Manitoba. *Canadian Field-Naturalist* 108:41–51.
- Sedgwick, J.A. and W.M. Iko. 1999. Costs of brown-headed cowbird parasitism to willow flycatchers. *Studies in Avian Biology* 18:167–181.

**Real and Artificial Nest Predation and Parental Nest Attendance
Along the Lower Colorado River and Southern Nevada**

- Sharp, B.L. and B.E. Kus. 2004. Sunrise nest attendance and aggression by Least Bell's vireos fail to deter cowbird parasitism. *Wilson Bulletin* 116:17–22.
- Sheppard, J.M. 1996. Nestling Kentucky warblers and cowbird attacked by brown-headed cowbird. *Journal of Field Ornithology* 67:384–386.
- Skutch, A.F. 1949. Do tropical birds rear as many young as they can nourish? *Ibis* 108:1–16.
- Small, S.L. 2005. Mortality factors and predators of spotted towhee nests in the Sacramento Valley, California. *Journal of Field Ornithology* 76:252–258.
- Smith, J.N.M. and P. Arcese. 1994. Brown-headed cowbirds and an island population of song sparrows: A 16-year study. *The Condor* 96:916–934.
- Stake, M.M. and P.M. Cavanaugh. 2001. Removal of host nestlings and fecal sacs by brown-headed cowbirds. *Wilson Bulletin* 113:456–459.
- Stake, M.M., J. Faaborg, and F.R. Thompson, III. 2004. Video identification of predators at golden-cheeked warbler nests. *Journal of Field Ornithology* 75:337–344.
- Sullivan, B.D. and J.J. Dinsmore. 1990. Factors affecting egg predation by American crows. *The Journal of Wildlife Management* 54:433–437.
- Tate, J., Jr. 1967. Cowbird removes warbler nestling from nest. *Auk* 84:422.
- Tewksbury, J.J., S.J. Hejl, and T.E. Martin. 1998. Breeding productivity does not decline with increasing fragmentation in a western landscape. *Ecology* 79:2890–2903.
- Tewksbury J.J., T.E. Martin, S.J. Hejl, M.J. Kuehn, and J.W. Jenkins. 2002. Parental care of a cowbird host: caught between the costs of egg-removal and nest predation. *Proc. R. Soc. Lond. B* 269:423–429.
- Theimer, T.C., M.A. McLeod, and T.J. Koronkiewicz. 2010. Real and artificial nest predation along the lower Colorado River. Draft final report submitted to the Bureau of Reclamation, Boulder City, Nevada, by NAU Department of Biology and SWCA Environmental Consultants, Flagstaff, AZ. 35 p.
- Thompson, C.F. and V. Nolan, Jr. 1973. Population Biology of the Yellow-breasted Chat (*Icteria virens* L.) in Southern Indiana. *Ecological Monographs* 43:145–171.

**Real and Artificial Nest Predation and Parental Nest Attendance
Along the Lower Colorado River and Southern Nevada**

- Thompson, F.R. and D.E. Burhans. 2003. Predation of songbird nests differs by predator and between field and forest habitats. *Journal of Wildlife Management* 67:408–416.
- Thompson, F.R., III, W. Dijak, and D.E. Burhans. 1999. Video identification of predators at songbird nests in old fields. *Auk* 116(1):259–264.
- _____. 2004. Differences in predators of artificial and real songbird nests: evidence of bias in artificial nest studies. *Conservation Biology* 18:373–380.
- Vander Haegen, M.W. and R.M. DeGraaf. 1996. Predation on artificial nests in forested riparian buffer strips. *Journal of Wildlife Management* 60:542–550.
- Villard, M.A. and T. Part. 2004. Don't put all your eggs in real nests: a sequel to Faaborg. *Conservation Biology* 18:371–372.
- Webb, D.R. 1987. Thermal tolerance of avian embryos: a review. *The Condor* 89:874–898.
- Weidinger, K. 2002. Interactive effects of concealment, parental behavior and predators on the survival of open passerine nests. *Journal of Animal Ecology* 71:424–437.
- Wiesenborn, W.D. and S.L. Heydon. 2007. Diets of breeding southwestern willow flycatchers in different habitats. *Wilson Journal of Ornithology* 119:547–557.
- Wood, D.R. and E.K. Bollinger. 1997. Egg removal by brown-headed cowbirds: A field test of the host incubation efficiency hypothesis. *The Condor* 99:851–857.
- Zegers, D.A., S. May, and L.J. Goodrich. 2000. Identification of nest predators at farm/forest edge and forest interior sites. *Journal of Field Ornithology* 71:207–216.