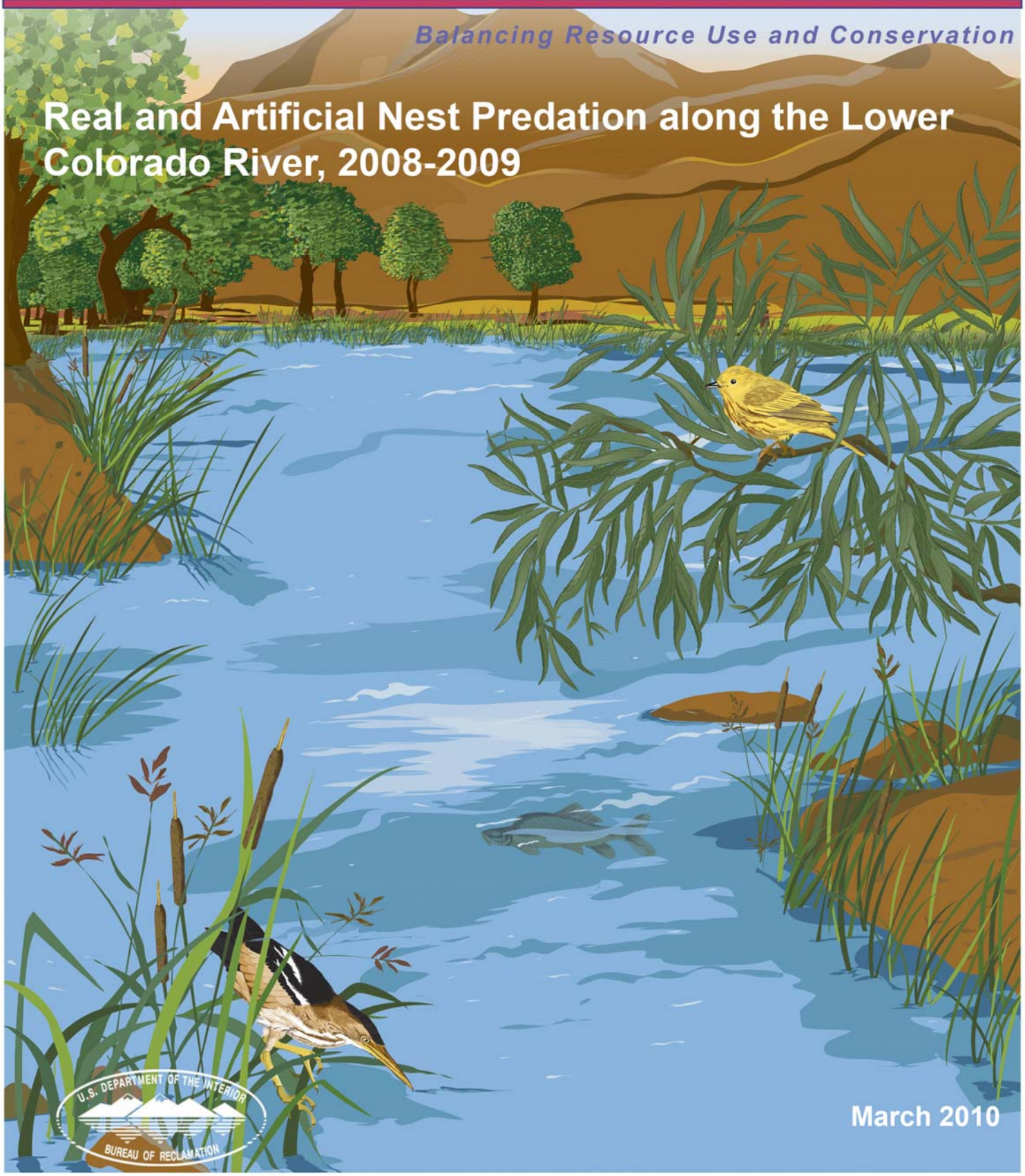
Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Real and Artificial Nest Predation along the Lower Colorado River, 2008-2009



March 2010

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Lower Colorado River Multi-Species Conservation Program

Real and Artificial Nest Predation along the Lower Colorado River, 2008-2009

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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 four 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. Likewise, rodents were the dominant artificial nest visitor at some sites while birds dominated others, but there was no significant association between time to artificial nest predation or type of visitor with any of the habitat parameters we investigated. The single pattern that did arise was that nests placed in mesquite trees had proportionally higher rates of nest visitation by rodents than those placed in tamarisk, cottonwood or willow. Brown-headed Cowbirds and Yellow-breasted Chats were the two most common species recorded at artificial nests, followed by Bewick's Wrens 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 Pahranagat. 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, and placed micro-video cameras on 14 real nests in 2009, including nests of Yellow Warblers, Southwestern Willow Flycatchers and Yellow-breasted Chats. In 2009, we recorded six nest predation events at real nests at Pahranagat, Nevada and Mesquite, Nevada . These events included egg predation by a Yellow-breasted Chat and a Bewick's Wren on Willow Flycatcher eggs, as well as Red-shouldered Hawk predation on Willow Flycatcher nestlings and American Crow predation on Yellow-breasted Chat nestlings, all at Pahranagat, Nevada. We also documented two instances of female Brown-headed Cowbirds killing nestlings at Willow Flycatcher 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 artificial nests may be an effective rapid-assessment technique that could be used to assess potential nest predators at sites of management interest when combined with real nest monitoring to verify predators. In addition, although artificial and real nest predation rates were not correlated in 2008, artificial nest success and nest success of Southwestern Willow Flycatchers was positively correlated, suggesting that artificial nests may also reflect relative nest predation pressure across sites.

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 in 2008 and at four Yellow Warbler, nine Southwestern Willow Flycatcher and one yellow-breasted Chat nests using micro-video cameras in 2009. Of those nests, we focused our analyses on 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 Pahranagat. The major results indicated 1) there was no relationship between ambient temperature and number or mean length of brooding bouts at either Pahranagat or Mesquite, 2) birds at Mesquite had more frequent and shorter brooding bouts and left nests unattended significantly longer than birds at Pahranagat and 3) amount of time away from nests decreased sharply at temperatures above 40°C, but behavioral shifts from brooding eggs to covering or shading them consistently occurred at much lower temperatures, approximately 29-31°C. We hypothesize that differences between Mesquite and Pahranagat in food availability and/or quality or perceived threat of nest predation and parasitism may be drivers of these behavioral differences in nest attendance.

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 LCR MSCP), reproductive success (productivity) depends on availability of suitable nest sites, adequate food resources, and fledgling survival and 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 in annual productivity (Ricklefs 1969, Martin 1988). The LCR MSCP conservation goals for these species call for 1) creating new habitat, 2) avoiding and minimizing the impacts of activities undertaken under the LCR MSCP, and 3) implementing population enhancement 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/predator assemblages 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 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 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, and understanding these factors will inform the development of restoration plans that create riparian habitat that maintains productive bird populations, minimizes the potential for creating ecological traps for birds of special concern, and potentially allows for enhancing bird populations 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 at 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 off and on 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 fate of real nests at the same sites 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.

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 1). The stand of tall (15–18m), large-diameter Goodding's Willow at the inflow of Upper **Pahranagat** Lake in Pahranagat National Wildlife Refuge, Nevada, represented a small patch (4.5 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 in **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 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 National Wildlife Refuge 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 Pahranagat and Mesquite and at 9 additional sites, some of which we considered to be small patches within a human-modified, primarily agricultural, matrix, (**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, mesquite), Gila Confluence North, Mittry West, Martinez Lake we

classified as mixed-native (the native component was greater than the exotic), Cibola 1 and 2 and Great Blue Heron as mixed-exotic and Fortuna as exotic dominated.

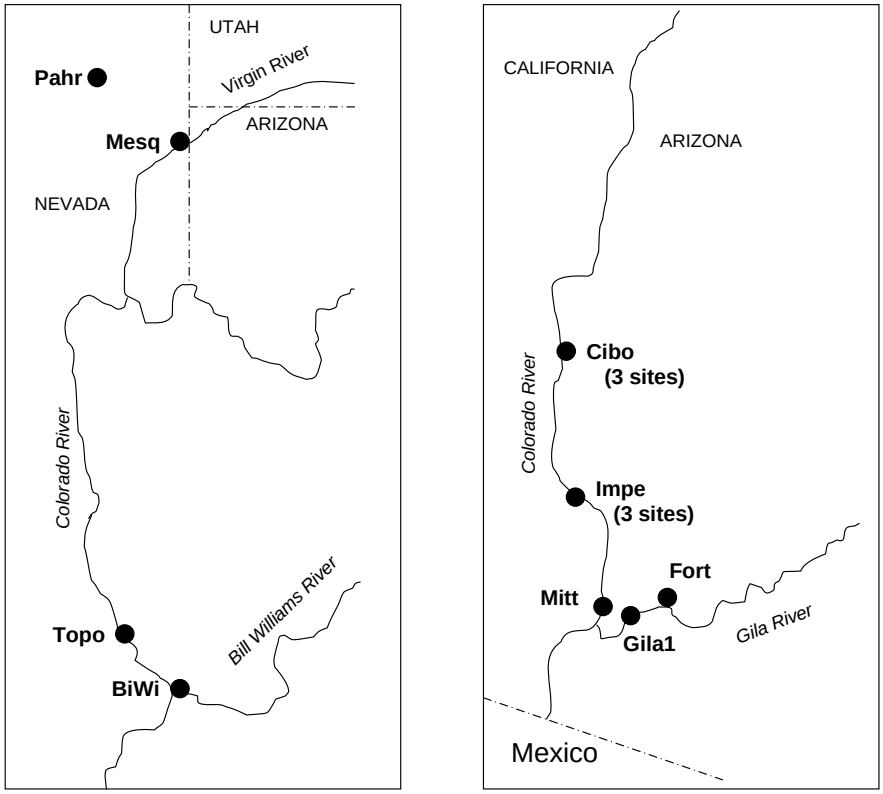

Figure 1.1. Location of 13 study sites at which we monitored nest predation on artificial nests during May – July 2008 and 2009. Pahr = Pahranagat National Wildlife Refuge, Nevada, Mesq = Mesquite, Nevada, Topo = Topock Marsh, Arizona, BiWi = Bill Williams River National Wildlife Refuge, Arizona, Cibo = 3 sites near Cibola National Wildlife refuge including CVCA Nursery, Cibola Nature Trail (CNT), and Cibola Sites 1 and 2 (Cib1), IMPE = 3 sites near Imperial National Wildlife Refuge including Imperial Nursery (ImpN), Great Blue Heron (GBH) and Martinez Lake (Mart), Mitt = Mittry Lake West, Gila1 = Gila Confluence North, Fort = Fortuna.

CHAPTER 2

ARTIFICIAL NEST PREDATION

Introduction

The use of artificial nests to assess nest predation potential has several advantages over using real nests to assess predation. 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 out of local, natural material to assess potential predators and predation rates of open cup nesters at 13 study sites.

Methods:

In 2008, twenty artificial nests baited with two clay eggs and one quail/zebra finch egg were deployed at each of four study sites (Pahranagat, Mesquite, Topock, and Bill Williams) in two sets, one set of 10 during early breeding season (mid-May- early June) and another 10 during late breeding season (mid-June – 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 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 Stealthcam could monitor nests 24 hrs/day and was fitted with infra-red 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 Birdcams in 2009.

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 eggs. 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 visually estimated nest height, canopy height directly above nest, canopy cover directly above nest, height and percentage of ground cover below the nest and presence of standing water below the structure upon which the nest was placed. We used Cox regression in SPSS version 12 to assess whether the habitat variables measured 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 the nest as continuous variables and presence of water and patch size (small <50 ha versus large >1000 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 Pahranagat) 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 don't 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 t-tests. 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 groups 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, 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%) suffered loss of at least some artificial or real eggs. At three of the sites, time to nest predation on artificial nests were 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 2.1).

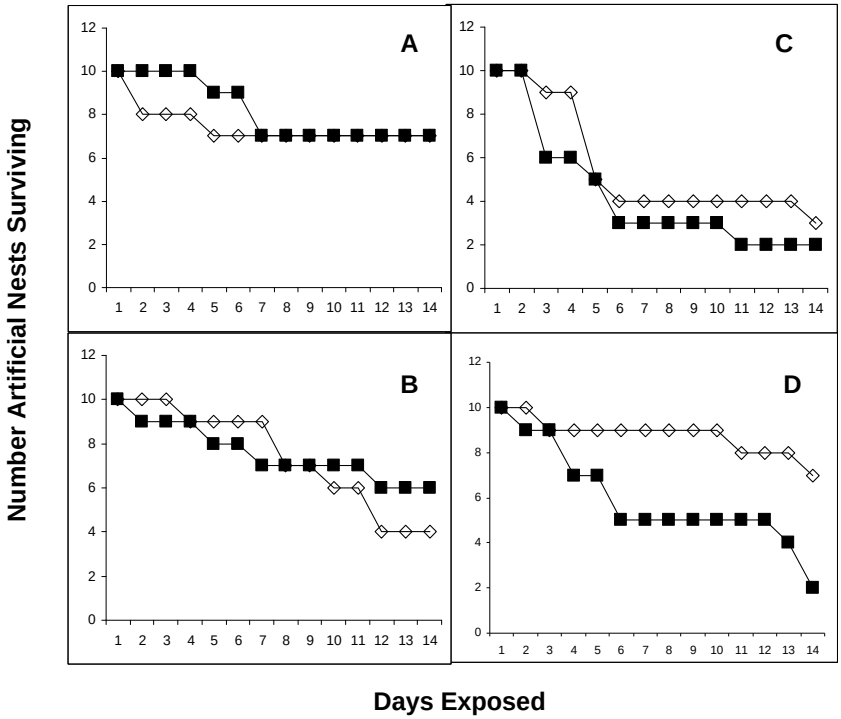

Figure 2.1. Fate of 10 artificial nests exposed to predators for 14 days at four study sites in 2008 mid-May to early June (open diamonds) or mid-June to early July (solid squares). A = Mesquite, B= Pahranagat, C = Bill Williams, D = Topoc.

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) having a higher proportion of artificial nests experiencing predation and doing so more quickly than nests 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).

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. Only patch size (bold face text) was significantly associated with time to nest predation.

Variables	B	SE	Wald	df	Significance	Exp (B)
Nest Height	-0.278	0.581	0.230	1	0.632	**0.757**
Canopy Height	0.014	0.051	0.079	1	0.778	**1.014**
Canopy Cover	-0.014	0.011	1.505	1	0.220	**0.987**
Water	-1.040	0.995	1.092	1	0.337	**0.629**
Habitat	0.656	0.700	0.878	1	0.349	**1.927**
Matrix	-0.471	0.823	0.327	1	0.567	**0.624**
Patch Size	**-1.730**	**0.771**	**5.042**	**1**	**0.025**	**0.177**

Table 2.2. Results of t-tests comparing nest height, canopy height, canopy cover, and ground cover estimates at artificial nests that were preyed upon versus those that were not in 2008.

	t	df	Significance
Nest Height	-0.301	77	0.764
Canopy Height	-1.438	78	0.154
Canopy Cover	-0.455	78	0.650
Ground Cover	-0.590	77	0.557

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 2.2A). Cameras at the remaining two nests captured photos of Brown-headed Cowbirds (*Molothrus ater*) (Figure 2.2B) and again in one of these the cowbird was photographed removing an egg.

A B

Figure 2.2. 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 YBCH and BHCO 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 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 2.3).

Figure 2.3. A. 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, with some sites experiencing rapid and heavy losses (Mesquite, Cibola Nature Trail and Martinez Lake), some slow and low rates of nest loss (CVCA, Great Blue Heron, Cibola 1 and 2), and others intermediate (Fig 2.4).

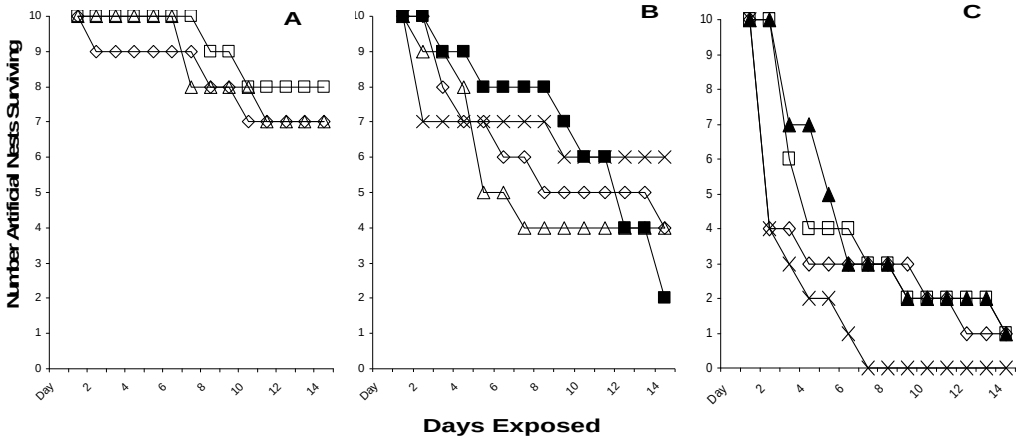

Figure 2.4. Rate of artificial nest loss to predation varied across sites. A. Sites with low rates of nest loss included Cibola 1 and 2 (diamonds), CVCA (squares), and Great Blue Heron (triangles). B. Sites with intermediate rates of nest loss included Imperial Nursery (diamonds), Gila Confluence (squares), Fortuna (triangles), and Pahranagat (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 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) (Fig. 2.5).

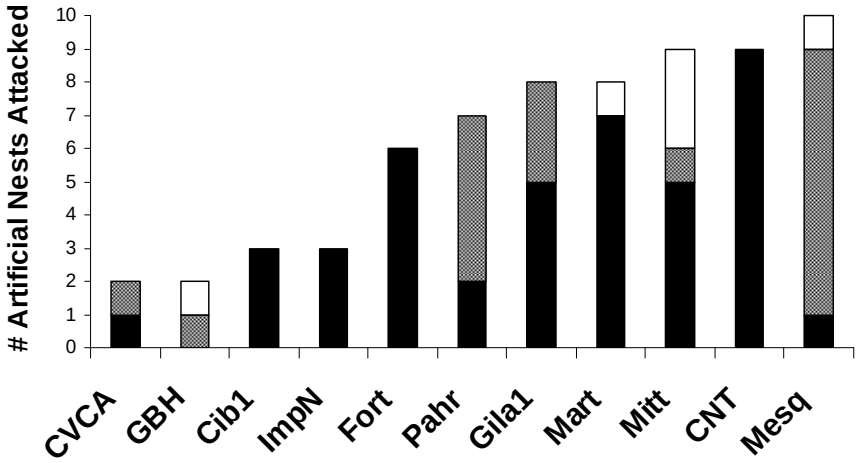

Fig 2.5. Number of artificial nests at which marks on clay eggs indicated potential bird predators (gray), rodent predators (black), or where clay eggs were missing and predator was therefore unknown (white). Site abbreviations correspond to those in Fig 1.1.

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.) (Fig. 2.6). 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 (Fig 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.

None of the parameters in our Cox regression model of rate of artificial nests lost to birds were significant (Table 2.3). However, univariate comparisons revealed that artificial nests preyed upon by birds had significantly less canopy cover than those that were not preyed upon (42.7%$\pm$ 6SE versus 63.6% $\pm$ SE, 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), but there were no significant differences among nests preyed upon and those that were not in nest height, canopy height, canopy cover, or ground cover (Table 2.6). Artificial nests placed in mesquite trees suffered 80% loss versus 30-50% for the other three tree types (Figure 2.7).

Figure 2.6. 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 (*Neotoma* sp.).

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.

	B	SE	Wald	df	Sig.	Exp(B)
Tree			1.089	3	.780	
Cottonwood	-1.213	1.320	.844	1	.358	.297
Willow	-.238	.708	.113	1	.737	.788
Mesquite	.262	1.342	.038	1	.846	1.299
Nest Height	-.497	.883	.317	1	.574	.608
Canopy Height	.009	.065	.019	1	.889	1.009
Canopy Cover (%)	-.004	.012	.097	1	.755	.996
Ground Cover (%)c	-.621	.387	2.572	1	.109	.537
Patch Size	.501	.833	.362	1	.548	1.650
Matrix Type			5.624	3	.131	
Dominant Habitat	8.487	86.988	.010	1	.922	4849.360
Native	10.429	86.986	.014	1	.905	33833.458
Mixed	9.074	87.000	.011	1	.917	8725.239
Exotic	.067	.053	1.574	1	.210	1.069

Table 2.4. Results of t-tests comparing nest height, canopy height, canopy cover, and ground cover estimates at artificial nests preyed upon by birds versus those that were not in 2009. Canopy cover was significantly lower at nests that were preyed upon (bold face type).

	T	**df**	**Significance**
Nest Height	-1.088	101	0.279
Canopy Height	-1.432	101	0.155
Canopy Cover	**-3.653**	**101**	**0.005**
Ground Cover	-1.533	101	0.128

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).

	B	SE	Wald	df	Sig.	Exp(B)
Tree			5.506	3	.138	
Cottonwood	.503	.680	.547	1	.459	1.653
Willow	.286	.530	.292	1	.589	1.332
Mesquite	**1.340**	**.613**	**4.782**	**1**	**.029**	**3.817**
Nest Height	-.272	.429	.403	1	.526	.762
Canopy Height	-.017	.036	.209	1	.648	.983
Canopy Cover (%)	.011	.009	1.356	1	.244	1.011
Ground Cover (%)c	.080	.260	.095	1	.758	1.083
Patch Size	-.016	.028	.308	1	.579	.984
Matrix Type	-.231	.489	.224	1	.636	.794
Dominant Habitat			2.899	3	.408	
Native	-.435	.690	.398	1	.528	.647
Mixed	-.080	.627	.016	1	.899	.924
Exotic	-1.417	1.020	1.929	1	.165	.242

Table 2.6. Results of t-tests comparing nest height, canopy height, canopy cover, and ground cover estimates at artificial nests preyed upon by rodents versus those that were not in 2009.

	T	df	Significance
Nest Ht	-1.419	104	0.159
Canopy Ht	-.418	104	0.677
Canopy Cover	1.189	104	0.237
Ground Cover	-.676	104	0.501

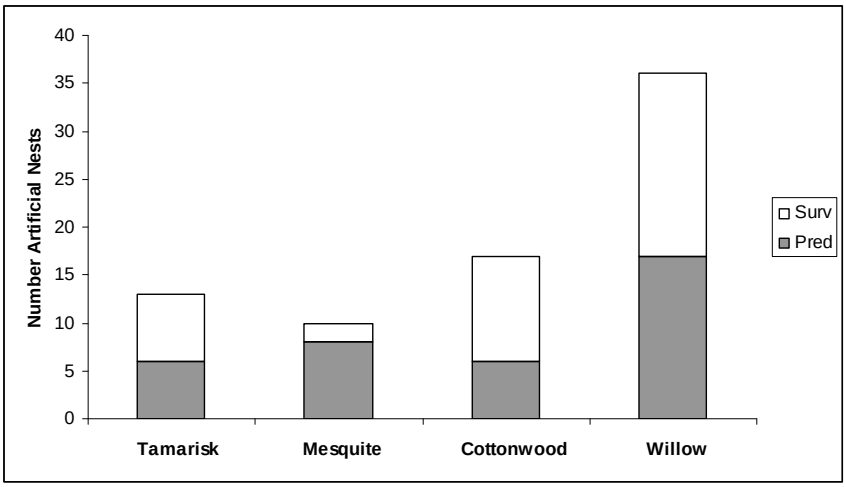

Figure 2.7. Number of artificial nests surviving (open) versus preyed upon (gray) when placed in tamarisk, mesquite, cottonwood, and willow trees.

We monitored artificial nest predation at two sites, Mesquite and Pahranagat, 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 2009 (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, rate of artificial nest loss at Pahranagat 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 (Fig 2.8).

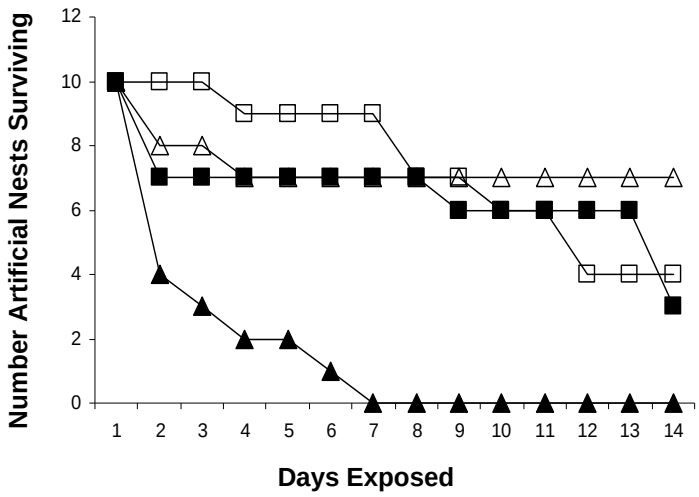

Figure 2.8. Rate of predation on 10 artificial nests placed at Mesquite, Nevada (Mesq, triangles) and Pahranagat, Nevada (Pahr, squares) in mid-May in 2008 (open symbols) and 2009 (closed symbols).

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 Pahranagat (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 (Fig. 2.9).

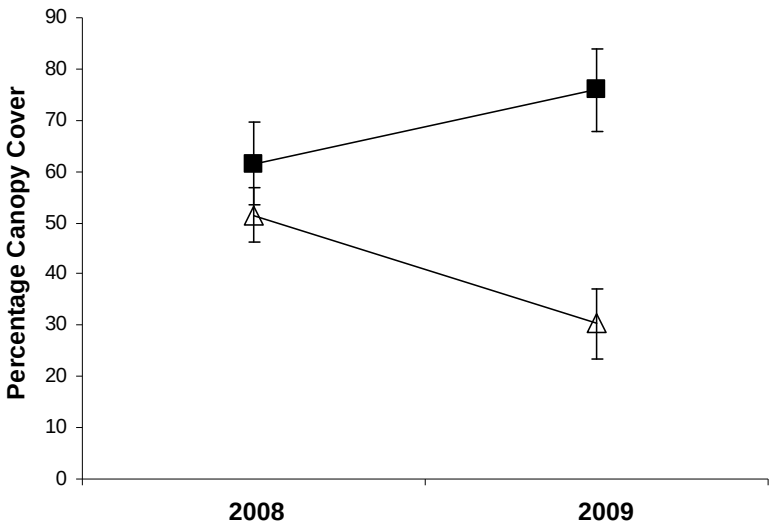

Figure 2.9. Mean percentage canopy cover (± SE) at Mesquite (Mesq, triangles) and Pahranagat (Pahr, squares) study sites in 2008 and 2009.

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 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 renest 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 have given inappropriate cues for acceptable nests when pierced by cowbirds. 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 Pahranagat 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 (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 (1700hrs) 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 and 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 lower Colorado River. New World mice and rats have been implicated as nest predators many times in artificial nest studies (e.g. 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 (e.g. 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. 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 because mesquites 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 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 Lower Colorado River. 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 over-estimate 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.

Conclusions

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). 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 (e.g., Reitsma et al. 1990, Thompson et al. 1999, Peterson et al.2004). Currently the potential nest predator community along the LCR is unknown, 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 *(Icteria virens*), and Bell's Vireos (*Vireo bellii)* at four study sites in Nevada (Pahranagat, Mesquite) and Arizona (Topock, Bill Williams) 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'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 (*Molothrus ater*) and other passerine birds, for all comparisons between artificial and real nests we combined the total number of 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 we concentrated efforts at two study sites, Mesquite and Pahranagat, and focused on placing video cameras on real nests to identify real nest predators at these sites. Video cameras fitted with infrared emitting diodes (Fuhrman Diversified Inc., Seabrook, Texas) allowed continuous 24-hour surveillance. 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 from the nest. If the female did not return and begin brooding within 45 minutes of camera placement, the camera was removed. 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 temperature near the nest site, a HOBO data logger recording 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 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. Species were not evenly represented across sites, with Yellow Warblers dominating real nests found at Mesquite while no nests of this species were found at Topock or Bill Williams. Likewise, only nests of Willow Flycatchers were found within the Topock artificial nest area. Combined across all species, relative rates of predation and parasitism combined varied across sites, with the lowest rates at Pahranagat (6/23 = 26%), followed by Bill Williams (4/13 = 31%), Mesquite (22/28 = 79%) and Topock (3/3 = 100%).

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 in Fig. 1.1. Species: BEVI = Bell's Vireo, YWAR = Yellow Warbler, WIFL = Southwestern Willow Flycatcher, YBCH = Yellow-breasted Chat, 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	
Mwsq	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, video cameras were placed at nests of three bird species at various stages in the nesting cycle at Pahranagat and Mesquite, Nevada (Table 3.2). Variation in the stage of nesting at which each nest was found and the ultimate fate of the nest resulted in nests being monitored over a range of durations, from 8–28 days. We captured video footage of predators at six of the seven nests that were predated.

Table 3.2. Bird species monitored with video cameras at Pahranagat and Mesquite, Nevada and the nest stage monitored, the number of days a nest was monitored with cameras and nest fate. YWAR = Yellow Warbler, WIFL = Southwestern Willow Flycatcher, YBCH = Yellow-breasted Chat. We obtained video of nest predators at six of the seven nests that experienced nest predation (bold faced text).

Species	Site	Stage Monitored	Days	Fate
WIFL	Pahr	Eggs	8	**Predation**
WIFL	Pahr	Eggs	14	**Predation**
WIFL	Pahr	Eggs→Fledge	27	Fledge
WIFL	Pahr	Eggs→Nestlings	12	**Predation**
WIFL	Pahr	Eggs→Fledge	28	Fledge
WIFL	Pahr	Nestlings→Fledge	13	Fledge
YWAR	Pahr	Eggs→Nestlings	22	Predation
YBCH	Pahr	Eggs→Nestlings	14	**Predation**
YWAR	Mesq	Eggs→Fledge	28	Fledge
YWAR	Mesq	Eggs→Fledge	18	Fledge
YWAR	Mesq	Eggs→Fledge	20	Fledge
WIFL	Mesq	Eggs→Nestlings	12	**Predation**
WIFL	Mesq	Eggs→Fledge	16	**Pred/Fledge**
WIFL	Mesq	Eggs→Fledge	22	Fledge

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 Pahranagat, Nevada. On 11 July, a brooding female WIFL left her nest (12B) at 18:33. One and a half minutes later a YBCH appeared at the nest and took one egg (Fig 3.1). The visit took only 11 seconds. Ten days later, on 21 July, at 18:17 the same nest containing two WIFL 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 (Fig. 3.2). The visit lasted 3 minutes. At 13:49 on 1 July a Bewick's Wren visited another Willow Flycatcher nest (1B) for 1 minute while the brooding adult was off the nest (Fig. 3.3). Bewick's Wrens were

documented visiting this nest again on 2 and 3 July. 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 (Fig 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 of WIFL 12B at Pahranagat, 11 July 2009.

Figure 3.2. Red-shouldered Hawk visiting a Southwestern Willow Flycatcher nest at Pahranagat on 21 July 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 WIFL nest compared to the tail of an accipiter (D) that has much broader gray bands compared to those of a Red-Shouldered Hawk (E).

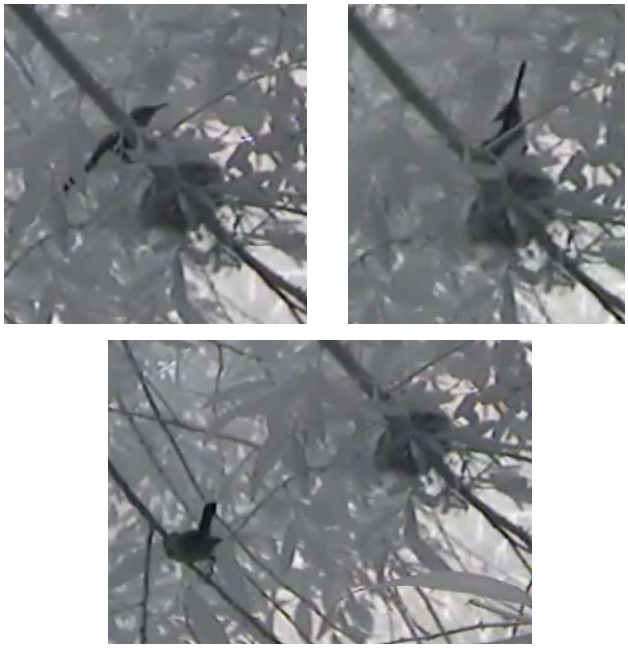

Figure 3.3. Bewick's Wren visiting a Southwestern Willow Flycatcher nest at Pahranagat on 1 July 2009.

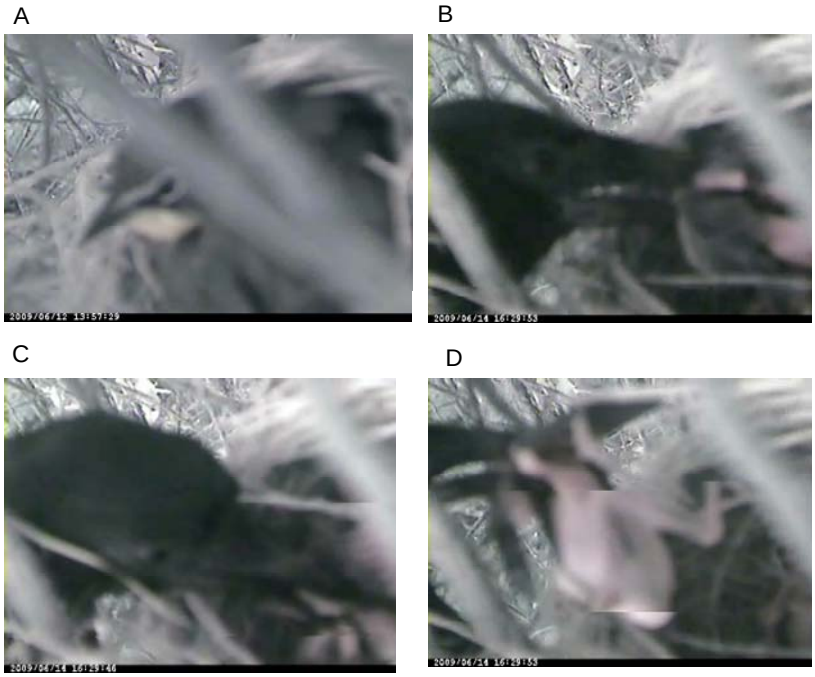

Figure 3.4. Yellow-breasted Chat brooding nestlings at Pahranagat (A) where an American Crow later removed all three nestlings (B-D).

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 21 June a

parent Willow Flycatcher brooding two eggs and one cowbird nestling (nest 7A) left the nest and three seconds later a female cowbird appeared at the nest with the Willow Flycatcher parent attacking it (Fig. 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 five seconds later to snatch a nestling from the nest and then flew off. The parent returned and settled on nest at 14:40:50, then left nest at 14:40:59. When the nest was next checked it was empty. At 18:41:33 on 21 June a female cowbird visited Willow Flycatcher nest 42A after the parent vacated, perhaps in response to the cowbird's approach (Fig 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.

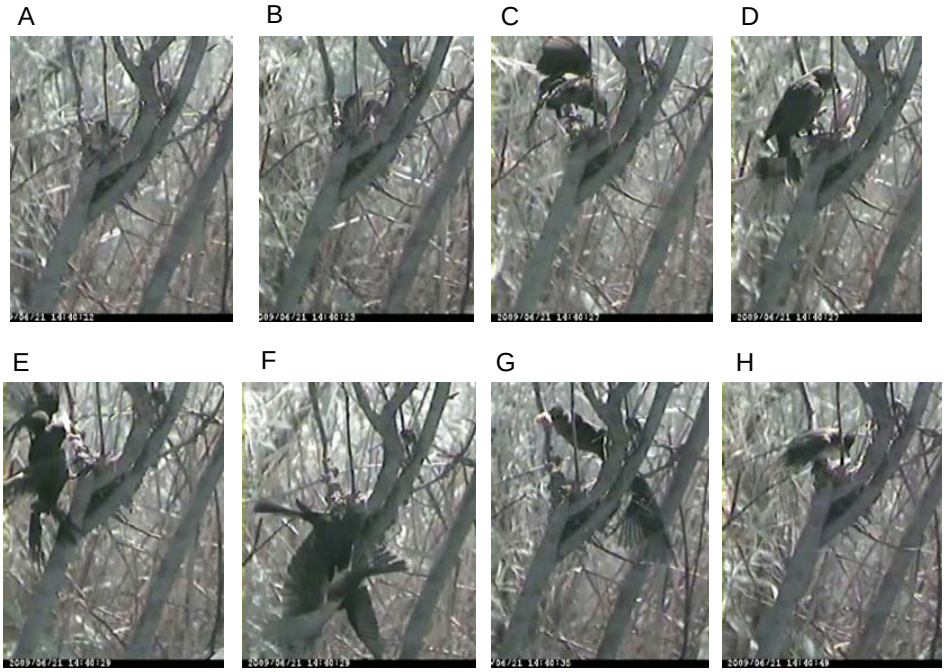

Figure 3.5. Southwestern Willow Flycatcher brooding two flycatcher nestlings and a cowbird nestling at Mesquite, Nevada on 21 June 2009 (A). The flycatcher looked up (B) then vacated the nest and a female cowbird appeared (C) with a flycatcher attacking it (D and E) even pulling the cowbird off the nest (F). The cowbird returned to snatch a nestling (G) 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 21 June 2009. The cowbird pecked and then flung one nesting 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.

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;* white-footed mice, *Peromyscus* spp.; and woodrats, *Neotoma* spp.) and 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 artificial nest success at those sites in 2008 (correlation coefficient = -0.44, Fig 3.7). However, when the artificial nest success was compared to nest success of Willow Flycatchers across both 2008 and 2009, there was a strong positive correlation (correlation coefficient = 0.68; Fig. 3.8).

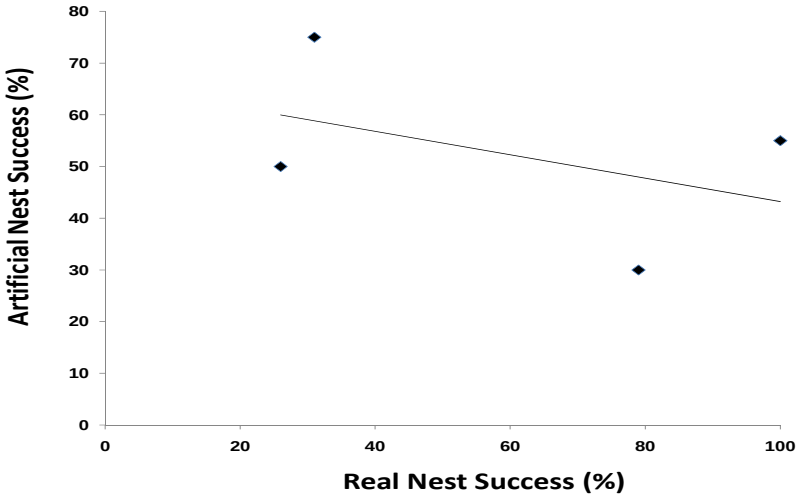

Figure 3.7. Percentage of all real nests escaping predation and parasitism versus percentage of artificial nests surviving at Bill Williams, Topock, Mesquite, and Pahranagat in 2008.

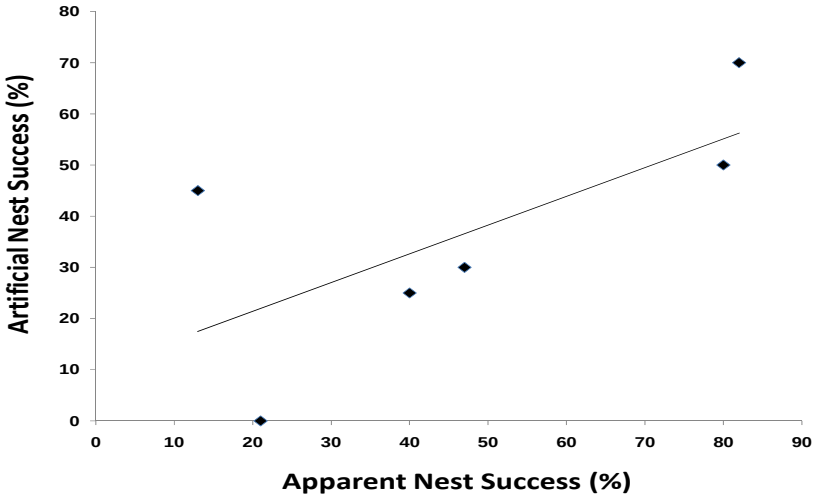

Figure 3.8. Apparent nest success for Willow Flycatchers as determined by SWCA at each site in 2008 and 2009 versus artificial nest success at Bill Williams, Topock, Mesquite, and Pahranagat in 2008 and Pahranagat and Mesquite in 2009.

Discussion:

The nest predators we documented attacking real nests at Pahranagat and Mesquite in 2009 have all been implicated as nest predators in other studies. Female Brown-headed Cowbirds have been documented attacking nestlings of other host species (e.g., 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 (e.g., 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) and

accipiters (Ellis et al McCallum and Hannon 2001), and Red-shouldered Hawks were documented taking Spotted Towhee (*Pipilo maculates*) nestlings in California (Small 2005)). This species was unexpected as it does not normally occur at our Pahranagat study site and may have represented a wayward migrating or dispersing individual. This finding underscores the broad diversity of nest predators that could potentially influence nest success.

Artificial nests attracted a similar suite of 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 Pahranagat, the same site where we documented wrens attacking eggs in a Willow Flycatcher nest. We documented several potential nest predators at artificial nests that we did not detect at real nests in this study, including Western Screech Owls, Greater Roadrunner, Bullock's Oriole and rodents in the genera *Peromyscus* and *Neotoma*. All of these, or at least congeners of these, have been documented to be nest predators in previous studies (e.g., Baltimore Orioles (*Icterus galbula*) Sealy 1994, Zeger et al. 2000), Western Screech Owls (Ellis et al. 2008), Common Roadrunner (Stake et al. 2004), *Peromyscus* (e.g. Guillory 1987). 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. Artificial nest results must be viewed with caution because animals can visit artificial nests without the intent or potential to actually attack real eggs or nestlings. Rodents, for example may be attracted to artificial nests due to unique odors emitted by artificial eggs. However, the overlap in species detected at real and artificial nests we documented, and the fact that all of these species have been reported as predators of real nests in the literature, suggests that artificial nests may be an effective means to assess the potential nest predator community at sites along the Lower Colorado River.

We are less confident that artificial nests reflect the level at which real nests will be lost to predation at a site due to differences in the correlation between real and artificial nest loss. 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 (e.g. 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 strong positive correlation between artificial nest success and apparent 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 Pahranagat 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. Of these, cowbirds have traditionally been targeted for

management through trapping, shooting and/or removal or addling of eggs. Alternatively, reducing density of cover between the ground and the lower canopy layers could potentially reduce predation by chats and wrens by reducing habitat for these two species. 2) Overlap between the species documented visiting artificial nests and species preying on real nests suggests that artificial nests may be a relatively efficient way to assess the suite of potential nest predators at proposed restoration sites or at sites of management interest. However, we stress that artificial nest surveys should be interpreted with caution until the role of specific species visiting artificial nests can be confirmed as nest predators.

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 three of 62 studies reviewed in Conway and Martin (2000) recorded maximum temperatures greater than 30°C (87°F). 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. 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 from the nest. Video camera support arms were camouflaged with a cloth cover. Still cameras were not camouflaged in any way. Video cameras were programmed to record 1 frame/s from dawn until dusk, while still cameras were set to take 1 frame/min. 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, MA) 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.

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 two-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 MANOVA in SPSS version 12 to test for differences using mean number of bouts/each two hour block, mean brooding bout length during each two hour block and total time away from nest in each two 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 Pahranagat, 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 Pahranagat. 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.

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 Pahranagat in 2009 (Fig. 4.1). Ambient temperatures never reached above 35°C at Pahranagat during the periods we monitored, but we had several observation periods at temperatures over 40°C at Mesquite.

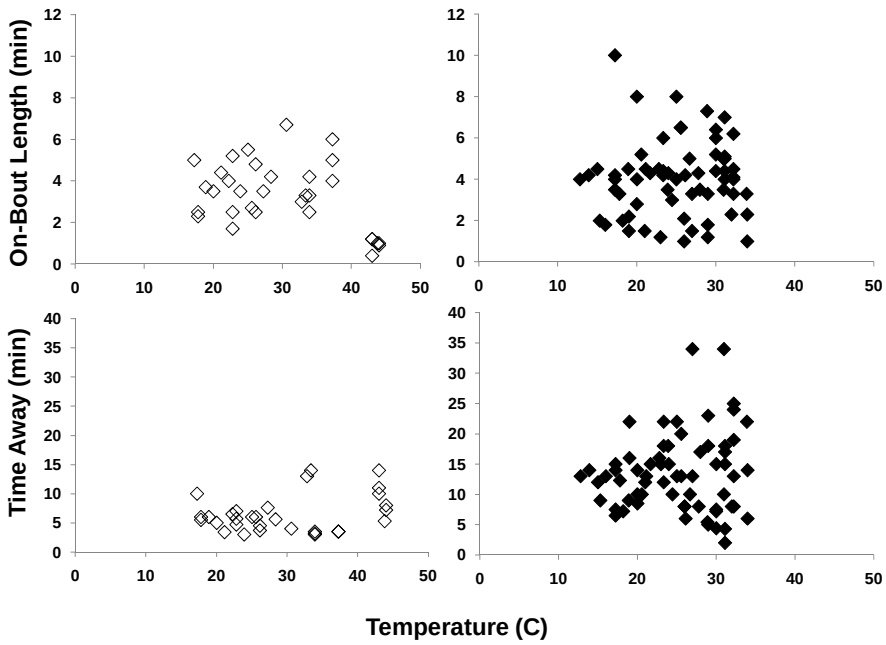

Figure 4.1. Ambient temperature within 2-3 m of the nest versus mean brooding bout length (on-bout length) and total time away from nest during the two-hour period (time away) for two Yellow Warblers and two Southwestern Willow Flycatchers at Mesquite, NV (open diamonds) and four Southwestern Willow Flycatchers Pahranagat, NV (closed diamonds) in 2009.

Across the four species we monitored in both years, a consistent behavioral shift from brooding to shading the eggs occurred between 29°C and 31°C (Fig. 4.2). 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.

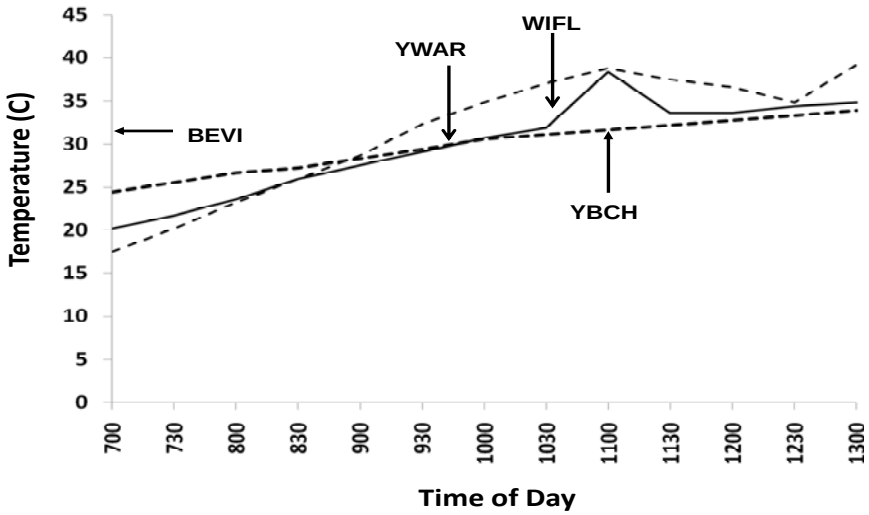

Figure 4.2. Temperature within 2–3 m of nests versus time of day for a Yellow Warbler (YWAR) at Mesquite, NV in June 2009, a Yellow-breasted Chat (YBCH) at Bill Williams River NWR, AZ in July 2008, and a Willow Flycatcher (WIFL) at Mesquite, NV in July 2009. Arrows indicate when parent birds shifted from brooding eggs to covering or shading eggs. Bell's Vireos (BEVI) observed at Bill Williams River NWR in 2008 showed a similar response, shifting to shading eggs at 30°C based on 2-hr nest watches made across several days.

Brooding behavior differed between Mesquite and Pahranagat (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 test 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 two-hour periods ($F = 8.8$, $p = 0.01$; Fig. 4.3).

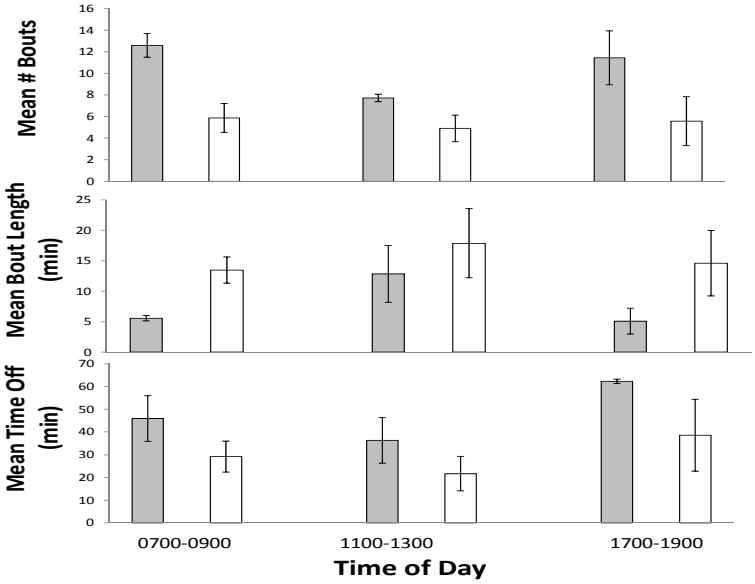

Figure 4.3. Mean (± SD) number of brooding bouts, bout length and time off nest during 2-hour blocks representing morning, mid-day and evening for four birds at Mesquite, NV (two Yellow Warblers and two Willow Flycatchers, gray bars) versus four Willow Flycatchers at Pahranagat NWR, NV (open bars).

Differences in nest attendance behavior between Mesquite and Pahranagat may have been driven by differences in ambient temperatures at the two sites, as Mesquite nests experienced overall higher ambient temperatures than those at Pahranagat. However, when we compared two Willow Flycatcher nests at the same stage in the nesting cycle and on the same day in June, we found the same differences in nest behavior (more frequent but shorter brooding bouts and longer total time away from nest at Mesquite) that we documented overall, even though ambient temperatures at the two nests were strikingly similar on that day (Fig 4.4).

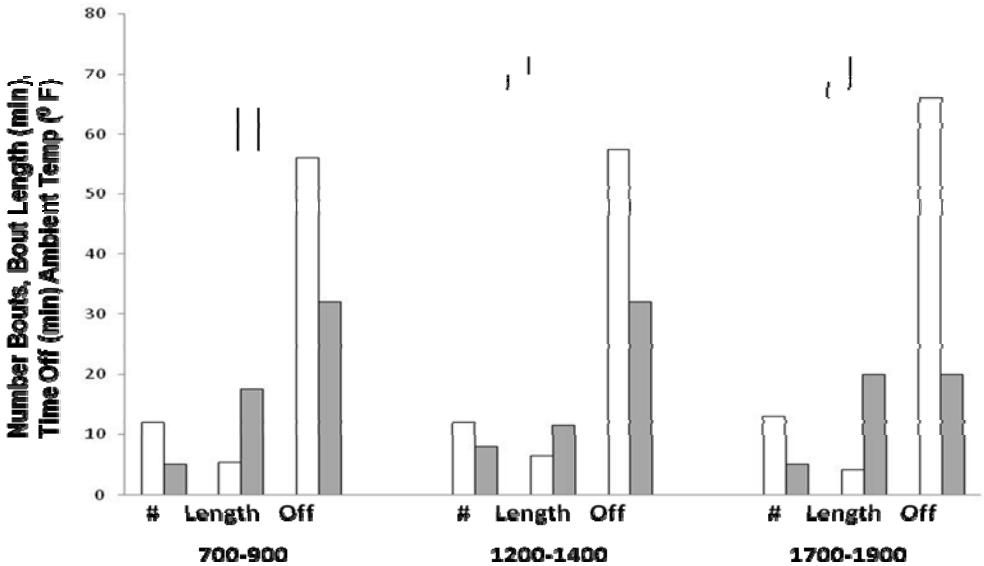

Figure 4.4. Number of brooding bouts (#), mean bout length (Length), and total time off nest (Off) during three 2-hr blocks (morning, 0700-0900 hrs; mid-day, 1100-1300 hrs; and evening, 1700-1900 hrs) for one Willow Flycatcher at Mesquite, NV (open bars) and one at Pahranagat NWR, NV (shaded bars) on 16 June 2009. Paired line above bars represent temperature ranges recorded within 2–3 meters of the nest at each site (left = Mesq, R = Pahr) during each 2-hr block.

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 temperature 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 relationship between on- bout duration and off-bout durations at temperatures lower than 24°C in our data from Willow Flycatchers at Pahranagat 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 Pahranagat 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 Pahranagat and had significantly shorter bout lengths and nests remained untended for longer periods of time. Birds at Pahranagat 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 Pahranagat, 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 Pahranagat. We found no indication 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 Pahranagat in recent years. If the latter is an important driver, then we would predict nest attentiveness should change at Pahranagat 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.

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